3. STANDARD OPERATING PROCEDURES

3.1. General Laboratory Safety Procedures

DO

- Know the potential hazards of the materials used in the laboratory. Review the Safety Data Sheet (SDS) and container label prior to using a chemical.
- Know the location of safety equipment such as telephones, emergency call numbers, emergency showers, eyewashes, fire extinguishers, fire alarms, first aid kits, and spill kits which can be found on all campuses (IUPUI does not provide laboratory spill kits).
- Review your laboratory’s emergency procedures with your Principal Investigator, Lab Supervisor, or Lab Manager to ensure that necessary supplies and equipment are available for responding to laboratory accidents.
- Practice good housekeeping to minimize unsafe work conditions such as obstructed exits and safety equipment, cluttered benches and hoods, and accumulated chemical waste.
- Wear the appropriate personal protective apparel for the chemicals you are working with. This includes eye protection, lab coat, gloves, and appropriate foot protection (no sandals or open toed shoes). Gloves must be made of a material known to be resistant to permeation by the chemical in use.
- Shoes must cover the entire foot. Open toed shoes and sandals are inappropriate footwear in laboratories. Fabric and athletic shoes offer little or no protection from chemical spills. Leather shoes with slip-resistant soles are recommended.
- Street clothing is to be chosen so as to minimize exposed skin below the neck. Long pants and shirts with sleeves are required. Avoid rolled up sleeves. Shorts (including cargo shorts), capris, miniskirts, tank tops, sleeveless shirts and midriff-length shirts are inappropriate clothing in laboratories. Synthetic fabrics must be avoided in high-hazard areas where flammable liquids and reactive chemicals are utilized.
- Contact lenses are not recommended but are permitted. Appropriate safety eyewear is still required for those that use contact lenses. Inform the lab supervisor of the use of contact lenses.
- Wash skin promptly if contacted by any chemical, regardless of corrosivity or toxicity.
- Label all new chemical containers with the “date received” and “date opened.”
- Label and store chemicals properly. All chemical containers must be labeled to identify the container contents (no abbreviations or formulas) and should identify hazard information. Chemicals must be stored by hazard groups and chemical compatibilities.
- Use break-resistant bottle carriers when transporting chemicals in glass containers that are greater than 500 milliliters. Use lab carts for multiple containers. Do not use unstable carts.
- Use fume hoods when processes or experiments may result in the release of toxic or flammable vapors, fumes, or dusts.
- Restrain and confine long hair and loose clothing. Pony tails and scarves used to control hair must not present a loose tail that could catch fire or get caught in moving parts of machinery.
DON’T

- Eat, drink, chew gum, or apply cosmetics in rooms or laboratories where chemicals are used or stored.
- Store food in laboratory refrigerators, ice chests, cold rooms, or ovens.
- Drink water from laboratory water sources.
- Use laboratory glassware to prepare or consume food.
- Smell chemicals, taste chemicals, or pipette by mouth.
- Work alone in the laboratory without prior approval from the Principal Investigator, Lab Manager, or Lab Supervisor. Avoid chemical work or hazardous activities at night or during off-hours. Have a partner for assistance (use the “buddy-system”) at night or during off-hours.
- Leave potentially hazardous experiments or operations unattended without prior approval from the Principal Investigator, Lab Manager, or Lab Supervisor. In such instances, the lights in the laboratory should be left on and emergency phone numbers posted at the laboratory entrance.
3.2. Procedures for Proper Labeling, Storage, and Management of Chemicals

Proper chemical labeling and storage is essential for a safe laboratory work environment. Inappropriate storage of incompatible or unknown chemicals can lead to spontaneous fire and explosions with the associated release of toxic gases. To minimize these hazards, chemicals in the laboratory must be segregated properly. The storage procedures listed below are not intended to be all-inclusive but should serve instead to supplement more specific procedures and recommendations obtained from container labels, Safety Data Sheets (SDSs), and other chemical reference material. For more information about chemical storage contact the University Environmental Health and Safety for your respective campus. (see Laboratory Safety Contacts).

3.2.1. Labeling

- Manufacturer chemical labels must never be removed or defaced until the chemical is completely used.
- All chemical and waste containers must be clearly labeled with the full chemical name(s) (no abbreviations or formulas) and must contain appropriate hazard warning information.
- Small containers that are difficult to label such as 1-10 ml vials and test tubes can be numbered, lettered, or coded as long as an associated log is available that identifies the chemical constituents. Groups of small containers can be labeled as a group and stored together.
- Unattended beakers, flasks, and other laboratory equipment containing chemicals used during an experiment must be labeled with the full chemical name(s).
- All chemicals should be labeled with the “date received” and “date opened.”
- All laboratory chemical waste containers must be labeled with the name of the chemicals contained.
- All full waste containers must be disposed of promptly. Waste containers must NOT be filled to more than 90% of their capacity).
- All chemical storage areas such as cabinets, shelves and refrigerators should be labeled to identify the hazardous nature of the chemicals stored within the area (e.g., flammables, corrosives, oxidizers, water reactives, toxics, carcinogens, and reproductive toxins). All signs should be legible and conspicuously placed.

3.2.2. Safety Data Sheets

Safety Data Sheets (SDS) for all laboratory chemicals are required to be maintained in the laboratory or on-line. Safety Data Sheets are available from manufacturer’s web sites and through the MSDSOnline® service at the IUEHS website, https://msdsmanagement.msdsonline.com/6df89148-4e9b-4af6-9ba8-da0d494c926a/ebinder/?nas=True

- The SDS for the exact chemical or mixture provided by the manufacturer of the product must be available. The chemical identity and manufacturer found on the label must match the chemical identity and manufacturer found on the SDS.
- All personnel must know how to access the SDS whether they are maintained on paper or electronically.
- All personnel must know how to read and understand an SDS.

Additional guidance on how to read, understand, maintain and (if necessary) prepare a Safety Data Sheet is available from EHS for your respective campus.
### 3.2.3. Storage

**HAZARD GROUPS**

- * Flammable/Combustible Liquids
- * Flammable Solids
- * Inorganic Acids
- * Organic Acids
- * Oxidizing Acids (Nitric, etc.)
- * Caustics (Bases)
- * Oxidizers
- * Water Reactives
- * Air Reactives
- * Unstable (shock-sensitive, explosive)
- * Carcinogens & Reproductive Toxins
- * Toxins, Poisons
- * Non-Toxics
- * Gases:
  - Toxic Gases
  - Flammable Gases
  - Oxidizing Gases
  - Corrosive Gases
  - Inert Gases

- A defined storage place should be provided for each chemical and the chemical should be returned to that location after each use.
- Chemical containers must be in good condition before they are stored. Containers must be managed to prevent leaks.
- Maximum quantities of chemicals that can be in storage and use in laboratories are found in the Uniform Building Code\(^1\), the Uniform Fire Code\(^2\), the International Building Code\(^3\) and International Fire Code\(^4\). The tables maximum allowable quantities are found in Appendix B. These codes place specific quantity limits on storage of chemicals in all hazard classes and some are very low, such as those for highly toxic gases and organic peroxides.
- Chemicals (including waste) must be separated and stored according to their hazard group and specific chemical incompatibilities. Chemicals within the same hazard group can be incompatible, therefore, it is important to review the chemical label and Safety Data Sheet (SDS) to determine the specific storage requirements and possible incompatibilities. Appendix B contains a partial list of incompatible chemicals.
- Special attention should be given to the storage of chemicals that can be classified into two or more hazard groups. For example, acetic acid and acetic anhydride are both corrosive and flammable. In addition, nitric and perchloric acids are both corrosive and strong oxidizers. Separate organic acids from oxidizing acids using secondary tubs or trays in the corrosives cabinet. Refer to the Safety Data Sheet (SDS) for proper storage procedures.
- Chemicals should be separated by distance. Physical barriers such as storage cabinets and secondary containers should be used to prohibit contact of incompatible chemicals in the event that they are accidentally released or spilled.
- Secondary containers are highly recommended for the storage of liquid chemicals. Secondary containers must be made of a material that is compatible with the chemical(s) it will hold and must be large enough to contain the contents of the largest container.
- Liquids should not be stored above dry chemicals unless they are stored in secondary containers.
- Storage of chemicals within hoods and on bench tops should be avoided.
- Stored chemicals should not be exposed to heat or direct sunlight.
- Storage shelves and cabinets should be secure to prevent tipping. Shelving should contain a front-edge lip or doors to prevent containers from falling.
- Flammable and corrosive storage cabinets should be used when possible.
- Flammable liquids in quantities exceeding a total of 10 gallons in each laboratory must be stored in an approved flammable storage cabinet.
- Only explosion-proof or laboratory-safe refrigerators may be used to store flammable liquids.
- Liquid chemicals should be stored below eye level to avoid accidental spills.
- Chemicals must not be stored in areas where they can be accidentally broken and spilled such as on the floor or on the edge of a bench top.
- Chemicals must not be stored in areas where they obstruct aisles, exits, and emergency equipment.

### 3.2.4. Chemical Inventory Management

All reportable chemicals must be inventoried. A list of reportable chemicals can be found at [IUEHS](#). In addition to reportable chemicals, all chemicals should be inventoried. Inventories provide a method for tracking chemicals for ordering and re-ordering, waste disposal, complying with the maximum allowable quantity limits in accordance with the International Building and Fire Codes (found in Appendix B), hazard communication, community right-to-know requirements, and tracking dangerous or time-sensitive chemicals for safety and security reasons.

Indiana University provides a chemical inventory system for this purpose. Environmental Health and Safety Assistant (EHSA) is available through the IUEHS websites: [www.ehs.iu.edu](http://www.ehs.iu.edu) (IUB and Regional Campuses) or [www.ehs.iupui.edu](http://www.ehs.iupui.edu) (IUPUI and Columbus Campuses).

Inventories should contain all pertinent information including the following data:

- Chemical name (synonym or trade name found on the Safety Data Sheet), if mixture list composition and percent of components.
- Chemical Abstract Service (CAS) number.
- Manufacturer.
- Product number.
- Physical state.
- Hazard class.
- Container size.
- Units of measure.
- Quantity or number of containers.
- Principal Investigator, Lab Manager, Lab Supervisor, or Chemical Hygiene Officer.
- Owner or researcher.
- Location (e.g., building, room number, cabinet).
- Receiving date.
- Opened container date.
- Expiration date.

Other information such as cost can be recorded as necessary for accounting purposes. Expiration dates are of particular importance for time-sensitive chemicals that can become dangerous with age. Several noteworthy time-sensitive laboratory chemicals include:

- Chemicals that form peroxides.
- Picric acid and other multi-nitro aromatics.
- Chloroform.
- Anhydrous hydrogen fluoride and hydrogen bromide.
- Liquid hydrogen cyanide.
- Formic acid.
- Alkali metals (such as potassium, sodium, and lithium).

Use the following guidelines to manage laboratory chemicals including time-sensitive materials:

3.2.4.1. **Acquisition control**
- Do not hoard chemicals
- Do not over-purchase quantities
- Use just-in-time purchasing whenever possible
- Dispose of unused portions

3.2.4.2. **Research the literature and Safety Data Sheet (SDS) information**
- Define storage conditions
- Consider refrigeration requirements or other storage options
- Consider chemical incompatibilities

3.2.4.3. **Define “unsafe” conditions such as:**
- Temperature or humidity extremes
- Peroxide concentrations greater than 100 ppm
- Dry picric acid
- Expiration dates

3.2.4.4. **Track Laboratory Chemicals**
- Maintain a chemical inventory and check expiration dates regularly
- Define inspection interval for each chemical
- Log the date of inspection and re-inspect without fail

3.2.4.5. **Manage Expired or “Unsafe” Chemicals**
- Never place chemicals where they will become lost or forgotten.
- Do NOT touch lost time-sensitive chemicals. Call IUEHS for your respective campus immediately (see Laboratory Safety Contacts).

References:

3.3. Chemical Fume Hoods – Procedures for Proper and Safe Use

Chemical fume hoods are one of the most important items of safety equipment present within the laboratory. Chemical fume hoods serve to control the accumulation of toxic, flammable, and offensive vapors by preventing their escape into the laboratory atmosphere. In addition, fume hoods provide physical isolation and containment of chemicals and their reactions and thus serve as a protective barrier (with the sash closed) between laboratory personnel and the chemical or chemical process within the hood.

- A chemical fume hood must be used for any chemical procedures that have the potential of creating:
  1. Airborne chemical concentrations that might approach Permissible Exposure Limits (PELs) for an Occupational Safety and Health Administration (OSHA) regulated substance. These substances include carcinogens, mutagens, teratogens, and other toxics. PELs are found in 1910.1450, Appendix A. The OSHA Select Carcinogens and examples of reproductive toxins are found in Appendix B of this document.
  2. Flammable/combustible vapors approaching one tenth the lower explosive limit (LEL). The LEL is the minimum concentration (percent by volume) of the fuel (vapor) in air at which a flame is propagated when an ignition source is present.
  3. Explosion or fire hazards.
  4. Odors that are annoying to personnel within the laboratory or adjacent laboratory/office units.

- Vertical fume hood sashes can be used in three positions: 1) closed, 2) the operating height (or half open), and 3) the set-up position (or fully open).

- Hoods must be closed when unattended.

- The sash opening must be positioned no higher than the operating height (or half open) when the hood is being used with chemicals present or when chemical manipulations are performed. Place the sash in front of the face to protect the persons breathing zone near the nose and mouth from chemical contaminants released within the fume hood. When working with hazardous chemicals, the hood sash should always be positioned so that it acts as a protective barrier between laboratory personnel and the chemicals.

- The set-up position (fully open) is only used to place equipment in the hood when no chemicals are present. Do not fully open the sash when chemicals are present.

- Sliding horizontal sash panels are used with one panel placed in front of the face and arms reaching around the sides to perform manipulations. Do not slide the panels laterally exposing the face to the interior of the hood with chemicals present.

- Hood baffles or slots should be positioned properly if available. The top baffle/slot should be opened when chemicals with a vapor density of less than 1 (lighter than air) are used. The bottom baffle/slot (if available) should be opened when chemicals with vapor densities greater than 1 (heavier than air) are used.

- Chemicals and equipment (apparatus, instruments, etc.) should be placed at least 6 inches (15 cm) from the front edge of the hood.

- Equipment should be placed in the center of the working surface in the hood. Do not place materials at the front of the working surface because it will block the slot under the air foil sill at the front. Do not place materials at the back of the working surface because it will block airflow to the lower slot under the baffle in the back. Separate and elevate equipment by using blocks or lab jacks to ensure that air can flow easily around and under the equipment.

- Chemical fume hoods must be kept clean and free from unnecessary items and debris at all times. Solid material (paper, tissue, aluminum foil, etc.) must be kept from obstructing the rear baffles and from entering the exhaust ducts of the hood.
• Minimize the amount of bottles, beakers and equipment used and stored inside the hood because these items interfere with the airflow across the work surface of the hood.

• Chemicals should not be stored in a hood because they will likely become involved if there is an accidental spill, fire or explosion in the hood, thus creating a more serious problem. Fume hoods are not flammable cabinets and do not offer fire protection for materials stored inside.

• Sliding horizontal sash windows must not be removed from the hood sash.

• Laboratory personnel must not extend their head inside the hood when operations are in progress.

• The hood must not be used for waste disposal (evaporation).

• Hoods should be monitored daily by the user to ensure that air is moving into the hood. A small piece of thread, yarn, or small piece of Kimwipe® can be taped to the hood sash as a visual indicator that the hood is pulling air. Any hoods that are not working properly must be taken out of service and reported to Facility Services/Physical Plant (FS/PP) and University Environmental Health and Safety for your respective campus (see Laboratory Safety Contacts). IUEHS is responsible for evaluating chemical fume hoods annually.

• Perchloric acid digestions and other procedures using perchloric acid at elevated temperatures must not be performed in standard chemical fume hoods. Specially designed perchloric acid fume hoods must be utilized for this purpose. Call IUEHS for your respective campus for more information.
3.4. Corrosive Chemicals – Procedures for Safe Handling and Storage

Corrosives (liquids, solids, and gases) are chemicals that cause visible destruction or irreversible alterations to living tissue by chemical action at the site of contact. Corrosive effects can occur not only to the skin and eyes, but also to the respiratory tract through inhalation and to the gastrointestinal tract through ingestion. Corrosive liquids have a high potential to cause external injury to the body, while corrosive gases are readily absorbed into the body through skin contact and inhalation. Corrosive solids and their dusts can damage tissue by dissolving rapidly in moisture on the skin or within the respiratory tract when inhaled. In order to minimize these potential hazards, precautionary procedures must be observed when handling corrosives.

3.4.1. Handling

- Appropriate personal protective equipment (e.g., gloves, fire-resistant or all cotton lab coat, and safety goggles) must be worn when working with corrosive chemicals. A face shield, rubber apron, and rubber booties may also be appropriate depending on the work performed.
- Appropriate protective gloves that are resistant to permeation or penetration from corrosive chemicals must be selected and tested for the absence of pin holes prior to use.
- Eyewashes and safety showers must be readily available in areas where corrosive chemicals are used and stored. In the event of skin or eye contact with a corrosive chemical, the affected area should be immediately flushed with water for 15 minutes. Contaminated clothing should be removed and medical attention sought.
- Corrosive chemicals should be handled in a fume hood to ensure that any possible hazardous or noxious fumes generated are adequately vented.
- When mixing concentrated acids with water, add the acid slowly to the water. Allow the acid to run down the side of a container and mix slowly to avoid violent reactions and splattering. Never add water to acid.
- Appropriate spill clean-up material should be available in areas where corrosive chemicals are used and stored.
- Protective carriers shall be used when transporting corrosive chemicals.

3.4.2. Storage

- Containers and equipment used for storage and processing of corrosive material must be corrosion resistant.
- Corrosive chemicals must be stored below eye level, preferably near the floor to minimize the danger of their falling from cabinets or shelves.
- Acids and caustics (i.e. bases) must be stored separately from each other. Secondary containers or trays must be used to separate acids and bases or other incompatible corrosives within a corrosive cabinet.
- Oxidizing acids must be separated from organic acids and flammable/combustible materials (oxidizing acids are particularly reactive with organics and flammable/combustible materials).
- Acids must be segregated from active metals (e.g., sodium, potassium, and magnesium) and from chemicals that can generate toxic gases (e.g., sodium cyanide and iron sulfide).
- Corrosive gas cylinders must be returned for disposal every two years.
3.5. Flammable and Combustible Liquids – Procedures for Safe Handling and Storage

Chemicals which exist at ambient temperatures in a liquid form with sufficient vapor pressure to ignite in the presence of an ignition source are called flammable or combustible liquids (note that the flammable/combustible liquid itself does not burn; it is the vapor from the liquid that burns). According to the National Fire Protection Association (NFPA) classification system, “flammables” generate sufficient vapor at temperatures below 100 °F (37.8 °C), whereas “combustibles” generate sufficient vapor at temperatures at or above 100 °F. Invisible vapor trails from these liquids can reach remote ignition sources causing flashback fires. In addition, these liquids become increasingly hazardous at elevated temperatures due to more rapid vaporization. For these reasons, precautionary measures must be observed when handling and storing flammables and combustibles.

3.5.1. Classification

<table>
<thead>
<tr>
<th>NFPA Classification</th>
<th>Flash Point(^1)</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammable Liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class IA</td>
<td>&lt;73° F (22.8 °C)</td>
<td>&lt;100° F (37.8° C)</td>
</tr>
<tr>
<td>Class IB</td>
<td>&lt;73° F</td>
<td>≥100° F</td>
</tr>
<tr>
<td>Class IC</td>
<td>≥73° F and &lt;100 °F</td>
<td>NA</td>
</tr>
<tr>
<td>Combustible Liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>≥100° F and &lt;140° F (60°C)</td>
<td>NA</td>
</tr>
<tr>
<td>Class IIIA</td>
<td>≥140° F and &lt;200° F (93°C)</td>
<td>NA</td>
</tr>
</tbody>
</table>

\(^1\) The minimum temperature at which liquid gives off enough vapor in sufficient concentration to form an ignitable mixture in air near the surface of a liquid.

3.5.2. Handling

- Appropriate personal protective equipment (e.g., gloves, fire-resistant or all cotton lab coat, and safety goggles) must be worn when working with flammable/combustible liquids.
- Flammable/combustible liquids must never be heated using open flames. Preferred heat sources include steam baths, water baths, oil baths, hot air baths, and heating mantels.
- Ignition sources must be eliminated in areas where flammable vapors may be present.
- Flammable/combustible liquids should only be dispensed under a fume hood. Ventilation is one of the most effective ways to prevent the formation and concentration of flammable vapors.
- When pouring from conductive containers with a capacity of 1 gallon (3.8 liters) or greater, make sure both containers involved are electrically interconnected by bonding to each other and to a ground. The friction of flowing liquid may be sufficient to generate static electricity, which in turn may discharge, causing a spark and ignition.
- Flammable/combustible liquids in containers with a volume greater than 1 gallon (3.8 liters) should be transferred to smaller containers that can be easily manipulated by one person.
- Appropriate fire extinguishers must be available in areas where flammables are used.
3.5.3. **Storage**

- Flammable/combustible liquid in quantities exceeding a total of 10 gallons (38 liters) within a laboratory must be stored in approved flammable storage cabinets or safety cans.
- Flammable/combustible liquid stored outside of flammable storage cabinets in the laboratory should be kept to the minimum necessary for the work being done.
- Containers with a volume greater than 5 gallons (19 liters) shall not be stored in the laboratory without prior approval of IUEHS for the respective campus.
- Flammable/combustible liquid stored in glass containers shall not exceed 1 gallon (3.8 liters).
- Flammable storage cabinets and safety cans must not be altered or modified.
- Safety cans with damaged screens (spark arrestors) or faulty springs (that do not close tightly) do not meet the required specifications of a safety can and must be taken out of service immediately and repaired or replaced.
- Flammable liquids must only be stored in explosion-proof or laboratory-safe refrigeration equipment.
- Flammable/combustible liquid containers, filled or empty, must not be stored in hallways or obstructing exits.
- Bulk waste flammable/combustible liquids should be stored in safety cans.
- Flammables and combustibles must not be stored near oxidizers, corrosives, combustible material, or near heat sources. Make sure all chemicals stored near flammables and combustibles are compatible.
3.6. Oxidizing Agents – Procedures for Safe Handling and Storage

Oxidizing agents are chemicals that bring about an oxidation reaction. The oxidizing agent may 1) provide oxygen to the substance being oxidized (in which case the agent has to be oxygen or contain oxygen) or 2) receive electrons being transferred from the substance undergoing oxidation (chlorine is a good oxidizing agent for electron-transfer purposes, even though it does not contain oxygen). The intensity of the oxidation reaction depends on the oxidizing-reducing potential of the material involved. Fire or explosion is possible when strong oxidizing agents come into contact with easily oxidizable compounds, such as metals, metal hydrides or organics. Because oxidizing agents possess varying degrees of instability, they can be explosively unpredictable.

3.6.1. Examples of Oxidizing Agents

<table>
<thead>
<tr>
<th>Gases</th>
<th>Fluorine, Chlorine, Ozone, Nitrous Oxide, Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquids</td>
<td>Hydrogen Peroxide, Nitric Acid, Perchloric Acid, Bromine, Sulfuric Acid</td>
</tr>
<tr>
<td>Solids</td>
<td>Nitrites, Nitrates, Perchlorates, Peroxides, Chromates, Dichromates, Picrates, Permanganates, Hypochlorites, Bromates, Iodates, Chlorites, Chlorates, Persulfates</td>
</tr>
</tbody>
</table>

3.6.2. Handling

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire resistant or all cotton lab coat) must be worn when working with oxidizers.
- If a reaction is potentially explosive or if the reaction is unknown, use a fume hood (with the sash down as a protective barrier), safety shield, or other methods for isolating the material or the process.
- Oxidizers can react violently when in contact with incompatible materials. For this reason, know the reactivity of the material involved in an experimental process. Assure that no extraneous material is in the area where it can become involved in a reaction.
- The quantity of oxidizer used should be the minimum necessary for the procedure. Do not leave excessive amounts of an oxidizer in the vicinity of the process.
- Perchloric acid digestions and other procedures using perchloric acid at elevated temperatures must not be performed in a standard chemical fume hood. A specially designed Perchloric Acid Fume Hood must be utilized for this purpose. Contact IUEHS for your respective campus (see Laboratory Safety Contacts) for more information.

3.6.3. Storage

- Oxidizers should be stored in a cool, dry place.
- Oxidizers must be segregated from organic material, flammables, combustibles and strong reducing agents such as zinc, alkaline metals, and formic acid.
- Oxidizing acids such as perchloric acid and nitric acid must be stored separately in compatible secondary containers away from other acids.

For the purpose of storage, the Uniform and International Building Code and the National Fire Protection Association classify oxidizers based on the increase in the burning rate of the combustible material with which it comes into contact. See Appendix B of this document for the definitions and a list of examples. Contact IUEHS for your respective campus (see Laboratory Safety Contacts) for more information.
3.7. Reactive Chemicals – Procedures for Safe Handling and Storage

Reactives are substances that have the potential to vigorously polymerize, decompose, condense, or become self-reactive due to shock, pressure, temperature, light, or contact with another material. All reactive hazards involve the release of energy in a quantity or at a rate too great to be dissipated by the immediate environment of the reaction system so that destructive effects occur. Reactive chemicals include: 1) explosives, 2) organic peroxides, 3) water-reactives and 4) pyrophorics. Effective control is essential to minimize the occurrence of reactive chemical hazards.

3.7.1. Explosives

A chemical that causes sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden adverse conditions. Heat, light, mechanical shock, detonation, and certain catalysts can initiate explosive reactions. Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, or ozonide are sensitive to shock and heat and can explode violently.

- Appropriate personal protective equipment (e.g., face shield, safety goggles, leather outer gloves, chemical resistant gloves, fire-resistant or all cotton lab coat) must be worn when working with explosives.
- Before working with explosives, understand their chemical properties, know the products of side reactions, know the incompatibility of certain chemicals, and monitor environmental catalysts such as temperature changes.
- Containers should be dated upon receipt and when opened. Expired explosives should be disposed of through IUEHS for your respective campus promptly.
- Explosives should be kept to the minimum necessary for the procedure.
- If there is a chance of explosion, use protective barriers (e.g., fume hood sash and safety shield) or other methods for isolating the material or process.
- Explosives should be stored in a cool, dry, and protected area. Segregate from other material that could create a serious risk to life or property should an accident occur.

3.7.2. Organic Peroxides

These chemicals contain an -O-O- structure bonded to organic groups. These compounds can be considered as structural derivatives of hydrogen peroxide, H-O-O-H, in which one or both of the hydrogen atoms have been replaced by an organic group. Generally, organic peroxides are low-powered explosives that are sensitive to shock, sparks, and heat due to the weak -O-O- bond which can be cleaved easily. Some organic compounds such as ethers, tetrahydrofuran, and p-dioxane can react with oxygen from the air forming unstable peroxides. Peroxide formation can occur under normal storage conditions, when compounds become concentrated by evaporation, or when mixed with other compounds. These accumulated peroxides can violently explode when exposed to shock, friction, or heat.

- Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with organic peroxides or peroxide-forming compounds.
- Containers must be labeled with the receiving and opening dates. Unopened material should be discarded within 1 year and opened material should be disposed of through IUEHS for the respective campus within 6 months.
- Containers should be airtight, and stored in a cool, dry place away from direct sunlight and segregated from incompatible chemicals.
- Peroxide-formers, liquid peroxides, or solutions should not be refrigerated below the temperature at which the peroxide freezes or precipitates. Peroxides in these forms are extra sensitive to shock (never store diethyl ether in a refrigerator or freezer).
• Unused peroxides should never be returned to the stock container.
• Metal spatulas should not be used with peroxide-formers. Only ceramic or plastic spatulas should be used. Contamination by metal can cause explosive decomposition.
• Friction, grinding, and all forms of impact, especially with solid organic peroxides should be avoided. Never use glass containers with screw cap lids or glass stoppers. Instead, use plastic bottles and sealers.
• Containers with obvious crystal formation around the lid or viscous liquid at the bottom of the container must NOT be opened or moved. Call IUEHS for your respective campus (see Laboratory Safety Contacts) for guidance and disposal.
• Organic peroxides produce vapors during decomposition. This can result in pressure build-up. The rapid increase in pressure may cause explosive rupture of containers, vessels or other equipment.
• Ignition sources must be avoided.
• Organic Peroxides have a Self-Accelerating Decomposition Temperature (SADT). Never store organic peroxides where they may be exposed to temperatures above the SADT. At or above this temperature an irreversible runaway reaction will take place. The recommended storage temperature is printed on the product label and Safety Data Sheet.

For more information on organic peroxide-forming compounds please refer to SOP 3.17, Peroxide-Forming Chemicals and Other Time-Sensitive Materials, Procedures for Safe Handling and Management and Appendix B of this document, for a list of chemicals that can form peroxides upon aging.

3.7.3. Water-Reactives
A chemical that reacts with water or moisture in the air (humidity) releasing heat or flammable, toxic gas. Examples include alkali metals, alkaline earth metals, carbides, hydrides, inorganic chlorides, nitrides, peroxides, and phosphides.

• Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with water-reactives.
• Water-reactives should be stored under mineral oil in a cool, dry place and isolated from other chemicals.
• Water-reactives must not be stored near water, alcohols, and other compounds containing acidic OH.

In case of fire, keep water away. Appropriate fire extinguishers should be available in areas where water-reactives are used (use a Type “D” fire extinguisher to extinguish active metal fires).

3.7.4. Pyrophorics
A chemical that ignites spontaneously in air below 130° F (54° C). Often the flame is invisible. Examples of pyrophoric materials include silane, silicon tetrachloride, white and yellow phosphorus, sodium, tetraethyl lead, potassium, nickel carbonyl, and cesium.

• Appropriate personal protective equipment (e.g., safety goggles, gloves, fire-resistant or all cotton lab coat) must be worn when working with pyrophorics.
• Pyrophorics must be used and stored in inert environments.
• Appropriate fire extinguishers should be available in areas where pyrophorics are used.
3.7.5. Synthesis

Synthesis of any reactive or energetic (explosive) compound is subject to the following requirements:

- The principal investigator’s written prior approval of the procedure is required. (use Chemical Reaction Hazard Assessment Form, Appendix A, Form LCS-7).
- The procedure must be documented in writing with specific step by step instructions.
- The principal investigator is required to provide documented procedure-specific training and documented daily supervision of the research.
- A written hazard analysis of the procedure is required prior to start up and whenever a change to the procedure is made. Worst case scenarios must be considered (Appendix A, Form LCS-7).
- Appropriate hazard controls, as determined by the hazard analysis, must be in place prior to the experiment.
- The synthesized quantity is limited to 100 milligrams. Synthesis of more than 100 mg of reactive or energetic compounds is prohibited.
3.8. Particularly Hazardous Substances - Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) Laboratory Standard requires that special handling procedures be employed for certain chemicals identified as “particularly hazardous substances.” Particularly hazardous substances include chemicals that are “select carcinogens, reproductive toxins, and chemicals that have a high degree of acute toxicity.” In addition, many chemicals used (including novel chemicals that are synthesized) in research laboratories have not been tested explicitly for carcinogenic or toxic properties and should therefore be handled as “particularly hazardous substances” since their hazards are unknown.

3.8.1. Carcinogen

A substance that either causes cancer in humans or, because it causes cancer in animals, is considered capable of causing cancer in humans. OSHA defines those substances that are known to pose the greatest carcinogenic hazards as “select carcinogens” (see Appendix B). These materials include substances that:

- OSHA regulates as a carcinogen; or
- The National Toxicology Program (NTP) lists as “known to be a carcinogen” or “reasonably anticipated to be a carcinogen” in their Annual Report on Carcinogens; or
- The International Agency for Research on Cancer (IARC) lists under Group 1 (“carcinogenic to humans”), Group 2A (“probably carcinogenic to humans”), or Group 2B (“possibly carcinogenic to humans”).

3.8.2. Reproductive Toxin

A substance that causes chromosomal damage or genetic alterations (mutagens) or substances that cause lethal or physical malformations or defects in a developing fetus or embryo (teratogens).

Additional information and guidance can be found in SOP 3.21, Reproductive Toxins, Mutagens, Teratogens, and Embryotoxins – Procedures for Safe Handling and Storage.

3.8.3. Chemicals with a High Degree of Acute Toxicity

Acute toxicity is the ability of a chemical to cause a harmful effect rapidly after a single short term exposure. Acutely toxic chemicals can cause local toxic effects, systemic effects, or both. OSHA’s “chemicals with a high degree of acute toxicity” includes both “highly toxic” and “toxic” chemicals that “may be fatal or cause damage to target organs as a result of a single exposure or exposures of short duration” (i.e., acutely toxic effects) as defined in 29 CFR 1910.1200, Appendix A (Mandatory). Combining the definitions from 29 CFR 1910.1200, Appendix A, yields the following table:

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>Highly Toxic</th>
<th>Toxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral LD$_{50}$ (albino rats)</td>
<td>≤ 50 mg/kg</td>
<td>&gt;50-500 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD$_{50}$ (albino rabbits, 24 hour)</td>
<td>≤ 200 mg/kg</td>
<td>&gt;200-1000 mg/kg</td>
</tr>
<tr>
<td>Inhalation LC$_{50}$ (albino rats, one hour) as vapor</td>
<td>≤ 200 ppm</td>
<td>&gt;200-2000 ppm</td>
</tr>
<tr>
<td>Inhalation LC$_{50}$ (albino rats, one hour) as dust, mist, or fumes</td>
<td>or ≤ 2 mg/liter</td>
<td>or &gt;2-20 mg/liter</td>
</tr>
</tbody>
</table>

Note: The lethal dose (LD$_{50}$) is the dose (in mg/kg of body weight) and the lethal concentration (LC$_{50}$) is the concentration in air (in ppm) at which 50% of the test subjects expire.

In general, “chemicals with a high degree of acute toxicity” include 1) “highly toxic” chemicals that have an Oral LD$_{50}$ of ≤50 mg/kg (rats), Skin Contact LD$_{50}$ of ≤200 mg/kg (rabbits), Inhalation LC$_{50}$ of ≤200 pm (rats for 1 hour) and 2) “toxic” chemicals with acutely toxic effects or those that have an Inhalation LC$_{50}$ of ≤2000 ppm (rats for 1 hour).
Comparing the former OSHA definition to the Globally Harmonized System (GHS) of chemical classification and labeling, the GHS acute toxicity ratings of 1 and 2 account for the old OSHA “highly toxic” categories and the “toxic” inhalation category. Therefore, the GHS acute toxicity ratings of 1 and 2 can be used as to determine the laboratory chemicals that are considered “chemicals with a high degree of acute toxicity” and as such, “particularly hazardous substances.”

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>GHS Acute Toxicity Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Oral LD₅₀</td>
<td>0-≤5 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD₅₀</td>
<td>0-≤50 mg/kg</td>
</tr>
<tr>
<td>Inhalation (gas) LC₅₀</td>
<td>0-≤100 ppm</td>
</tr>
<tr>
<td>Inhalation (vapors) LC₅₀</td>
<td>0-≤0.5 mg/l</td>
</tr>
<tr>
<td>Inhalation (dust &amp; mist) LC₅₀</td>
<td>0-≤0.05 mg/l</td>
</tr>
</tbody>
</table>

Using the National Fire Protection Association’s (NFPA) 704 health hazard classifications, the NFPA health hazard ratings of 3 and 4 accounts for all the OSHA “highly toxic” categories and the “toxic” inhalation category. Therefore, the NFPA health hazard ratings of 3 and 4 can be used as practical guide to determine the laboratory chemicals that are considered “chemicals with a high degree of acute toxicity” and as such, “particularly hazardous substances.”

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>NFPA 704 Health Hazard Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Oral LD₅₀</td>
<td>0-5 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD₅₀</td>
<td>0-40 mg/kg</td>
</tr>
<tr>
<td>Inhalation LC₅₀</td>
<td>0-1000 ppm</td>
</tr>
</tbody>
</table>

3.8.4. Handling

- Designated areas (e.g., fume hoods, glove boxes, lab benches, outside rooms) for material use must be established and the areas identified by signs or postings.
- Containment devices such as fume hoods (if necessary) and personal protective equipment (e.g., gloves, lab coat, and eye protection) must be used when handling these hazardous substances.
- Procedures for the safe use of the material and waste removal must be established prior to use.
- Decontamination procedures must be developed in advance and strictly followed.
- Only laboratory personnel trained to work with these substances can perform the work, and always within the designated area. Prior approval is required by the Principal Investigator, Lab Manager or Lab Supervisor (see Section 2.1.1 Prior Approval of Hazardous Operations).
- Only the minimum quantity of the material should be used.

3.8.5. Storage

- These materials must be stored in areas designated for “particularly hazardous substances.”
- Storage areas should be clearly marked with the appropriate hazard warning signs.
- All containers of these materials (even if the material is in very small quantities such as 0.1%) must be clearly labeled with the chemical name or mixture components and should be labeled with the appropriate hazard warning information.
- Chemical storage areas should be secure to avoid spills or broken containers.
- Storage areas or laboratory rooms must be locked when laboratory personnel are away or not present.
3.9. Compressed Gases – Procedures for Safe Handling and Storage

In general, a compressed gas is any material contained under pressure that is dissolved or liquefied by compression or refrigeration. Compressed gas cylinders must be handled as high-energy sources and therefore as potential explosives and projectiles. Prudent safety practices must be followed when handling compressed gases because they expose workers to both chemical and physical hazards.

This section provides general standard operating procedures for use of compressed gases in laboratories. For further information refer to the IU Compressed Gas Cylinder Safety Program.

3.9.1. Handling

- Safety glasses with side shields (or safety goggles) and other appropriate personal protective equipment must be worn when working with compressed gases.
- Cylinders must be marked with a label that clearly identifies the contents.
- All cylinders must be checked for damage prior to use. Do not repair damaged cylinders or valves. Damaged or defective cylinders, valves, etc., must be taken out of use immediately and returned to the manufacturer/distributor for repair.
- All gas cylinders (full or empty) must be rigidly secured to a substantial structure at 2/3 height. Only two cylinders per restraint are allowed in the laboratory and only soldered link chains or belts with buckles are acceptable. Cylinder stands are also acceptable but not preferred.
- Handcarts shall be used when moving gas cylinders. Cylinders must be chained to the carts.
- All cylinders must be fitted with safety valve covers before they are moved.
- Only three-wheeled or four-wheeled carts should be used to move cylinders.
- A pressure-regulating device shall be used at all times to control the flow of gas from the cylinder.
- The main cylinder valve shall be the only means by which gas flow is to be shut off. The correct position for the main valve is all the way on or all the way off.
- Cylinder valves must never be lubricated, modified, forced, or tampered. Regulator fittings must not be sealed with Teflon tape, grease or pipe sealant. Never grease any oxygen fittings (use PTFE Teflon tape only).
- After connecting a cylinder, check for leaks at connections. Periodically check for leaks while the cylinder is in use.
- Regulators and valves must be tightened firmly with the proper size wrench. Do not use adjustable wrenches or pliers because they may damage the nuts.
- Cylinders must not be placed near heat or where they can become part of an electrical circuit.
- Cylinders must not be exposed to temperatures above 50o C (122o F). Some rupture devices on cylinders will release at about 65o C (149o F). Some small cylinders, such as lecture bottles, are not fitted with rupture devices and may explode if exposed to high temperatures.
- Rapid release of a compressed gas must be avoided because it will cause an unsecured gas hose to whip dangerously and also may build up enough static charge to ignite a flammable gas.
- Appropriate regulators must be used on each gas cylinder. Threads and the configuration of valve outlets are different for each family of gases to avoid improper use. Use the Compressed Gas Association (CGA) numbered fittings appropriate for the gas in use. Consult manufacturer’s catalogs for the appropriate equipment. Adaptors and homemade modifications are prohibited.
- Cylinders must never be bled completely empty. Leave a slight pressure to keep contaminants out.
3.9.2. Storage

- When not in use, cylinders must be stored with their main valve closed and the valve safety cap in place.
- Cylinders with less than 1.3 gallons water volume may be stored on their side. All cylinders must be secured. Dissolved gases such as acetylene (which is dissolved in acetone) must be stored upright (see Special Precautions). The pressure relief device on cylinders of gases that are liquid under pressure (such as some flammable gases) must be in contact with the gas phase.
- Cylinders awaiting use and empty cylinders must be stored according to their hazard classes.
- Cylinders must not be located where objects may strike or fall on them.
- Cylinders must not be stored in damp areas or near salt, corrosive chemicals, chemical vapors, heat, or direct sunlight. Cylinders stored outside must be protected from the weather.
- Corrosive gas cylinders must be returned for disposal every two years.

3.9.3. Special Precautions

3.9.3.1. Flammable Gases

- No more than two cylinders can be manifolded together; however several instruments or outlets are permitted for a single cylinder.
- Valves on flammable gas cylinders must be shut off when the laboratory is unattended and no experimental process is in progress.
- Flammable gas cylinders must be grounded. (Do not ground to an electrical outlet.)
- Flames involving a highly flammable gas must not be extinguished until the source of the gas has been safely shut off; otherwise it can reignite causing an explosion.

3.9.3.2. Acetylene Gas Cylinders

- Acetylene cylinders must always be stored upright. They contain acetone, which can discharge instead of or along with acetylene. Do not use an acetylene cylinder that has been stored or handled in a non-upright position until it has remained in an upright position for at least 30 minutes.
- The outlet line of an acetylene cylinder must be protected by a flame arrester.
- Compatible tubing must be used to transport gaseous acetylene. Some tubing like copper forms explosive acetylides.

3.9.3.3. Lecture Bottles

- All lecture bottles must be marked with a label that clearly identifies the contents.
- Lecture bottles must be stored according to their hazard classes.
- Lecture bottles which contain toxic gases must be stored in a ventilated cabinet.
- Lecture bottles must be secured in storage and when in use, secured to a fixed frame or structure.
- Lecture bottles must not be stored near corrosives, heat, direct sunlight, or in damp areas.
- To avoid costly disposal fees, lecture bottles should only be purchased from suppliers that will accept returned bottles (full or empty). Contact the supplier before purchasing lecture bottles to ensure that they have a return policy.
- Lecture bottles should be dated upon initial use. It is advised that bottles be sent back to the supplier after one year to avoid accumulation of old bottles.
3.10. Cryogenic Liquids – Procedures for Safe Handling and Storage

Cryogenic liquids are liquefied gases having boiling points of less than -73.3°C (-100°F). The primary hazards of cryogenic liquids include both physical hazards such as fire, explosion, and pressure buildup and health hazards such as severe frostbite and asphyxiation. Potential fire or explosion hazards exist because cryogenic liquids are capable, under the right conditions, of condensing oxygen from the atmosphere. This oxygen-rich environment in combination with flammable/combustible materials and an ignition source are particularly hazardous. Pressure is also a hazard because of the large volume expansion ratio from liquid to gas that a cryogen exhibits as it warms and the liquid evaporates. This expansion ratio also makes cryogenic liquids more prone to splash and therefore skin and eye contact is more likely to occur. Contact with living tissue can cause frostbite or thermal burns, and prolonged contact can cause blood clots that have very serious consequences. All laboratory personnel should follow prudent safety practices when handling and storing cryogenic liquids.

3.10.1. Properties of Common Cryogenic Liquids

<table>
<thead>
<tr>
<th>Gas</th>
<th>Boiling Point °F (°C)</th>
<th>Liquid to Gas Volume Expansion Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td>-452 (-268.9)</td>
<td>1-757</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>-423 (-252.7)</td>
<td>1-851</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>-321 (-195.8)</td>
<td>1-696</td>
</tr>
<tr>
<td>Fluorine</td>
<td>-307 (-187.0)</td>
<td>1-888</td>
</tr>
<tr>
<td>Argon</td>
<td>-303 (-185.7)</td>
<td>1-847</td>
</tr>
<tr>
<td>Oxygen</td>
<td>-297 (-183.0)</td>
<td>1-860</td>
</tr>
<tr>
<td>Methane</td>
<td>-256 (-161.4)</td>
<td>1-578</td>
</tr>
</tbody>
</table>

Note: Absolute zero = - 459.67 °F (- 273.15 °C)

3.10.2. Handling

- Appropriate personal protective equipment must be worn when handling cryogenic liquids. This includes special cryogen gloves, safety goggles, full face shield, impervious apron or coat, long pants, and high topped shoes. Gloves must be impervious and sufficiently large to be readily removed should a cryogen be spilled. Watches, rings, and other jewelry should NOT be worn.
- Unprotected body parts must not come in contact with vessels or pipes that contain cryogenic liquids because extremely cold material may bond firmly to the skin and tear flesh if separation is attempted.
- Objects that are in contact with cryogenic liquid must be handled with tongs or proper gloves.
- All precautions should be taken to keep liquid oxygen from organic materials; spills on oxidizable surfaces can be hazardous.
- All equipment should be kept clean, especially when working with liquid or gaseous oxygen.
- Work areas must be well ventilated.
- Transfers or pouring of cryogenic liquid should be done very slowly to minimize boiling and splashing.
- Cryogenic liquids and dry ice used as refrigerant baths should be open to the atmosphere. They must never be in a closed system where they may develop uncontrolled or dangerously high pressure.
- Liquid hydrogen must not be transferred in an air atmosphere because oxygen from the air can condense in the liquid hydrogen presenting a possible explosion risk.
3.10.3. Storage

- Cryogenic liquids must be handled and stored in containers that are designed for the pressure and temperature to which they may be subjected. The most common container for cryogenic liquids is a double-walled, evacuated container known as a Dewar flask.

- Containers and systems containing cryogenic liquids should have pressure-relief mechanisms.

- Coolers and Styrofoam boxes may be used for storage of small amounts of solid carbon dioxide (dry ice) only. Do not use coolers and Styrofoam boxes as the primary container for the transportation and storage of liquid cryogens.

- Cylinders and other pressure vessels such as Dewar flasks used for the storage of cryogenic liquids should not be filled more than 80% of capacity to protect against possible thermal expansion of the contents and bursting of the vessel by hydrostatic pressure. If the possibility exists that the temperature of the cylinder may increase to above 30°C (86°F), a lower percentage (e.g., 60 percent capacity) should be the limit.

- Dewar flasks should be shielded with tape or wire mesh to minimize flying glass and fragments should an implosion occur.

- Dewar flasks must be labeled with the full cryogenic liquid name and should be labeled with hazard warning information.

- Work and storage areas must be well ventilated.

- Evaporation of the liquid cryogens will displace oxygen in the room and may present an asphyxiating hazard. Air contains about 21% oxygen and breathing air with less than 19.5% is considered a dangerous oxygen deficient atmosphere. Concentrations of 18% can cause dizziness and result in unconsciousness and death.

- Note: The cloud that appears when liquid nitrogen is exposed to air is condensed moisture in the atmosphere. Gaseous nitrogen is invisible.

- Do not store cryogenic Dewar's in walk-in refrigerators. Typical walk-in refrigerators only receive fresh air when the door is opened. Evaporating liquid cryogens could displace enough air to create an oxygen deficient atmosphere.
3.11. Electrical Safety Procedures

Serious injury or death by electrocution is possible when appropriate attention is not given to the engineering and maintenance of electrical equipment and personal work practices around such equipment. In addition, equipment malfunctions can lead to electrical fires. By taking reasonable precautions, electrical hazards in the laboratory can be dramatically minimized.

- Laboratory personnel should know the location of electrical shut-off switches and/or circuit breakers in or near the laboratory so that power can be quickly terminated in the event of a fire or accident.
- Electrical panels and switches must never be obstructed and should be clearly labeled to indicate what equipment or power source they control.
- All electrical equipment should be periodically inspected to ensure that cords and plugs are in good condition. Frayed wires and wires with eroded or cracked insulation must be repaired immediately, especially on electrical equipment located in wet areas such as cold rooms or near cooling baths. Insulation on wires can easily be eroded by corrosive chemicals and organic solvents.
- All electrical outlets should have a grounding connection requiring a three-pronged plug.
- All electrical equipment should have three-pronged, grounded connectors. The only exception to this rule are instruments entirely encased in plastic (such as electric pipetters and some types of microscopes) and Glas-Col heating mantels. If equipment does not have a three-pronged plug, replace the plug and cord to ground the equipment.
- Face plates must not be removed from electrical outlets.
- Electrical wires must not be used as supports.
- Extension cords should be avoided. If used, they should have three-pronged, grounded connectors, positioned or secured as not to create a tripping hazard, and ONLY for temporary use.
- All shocks should be reported to the principal investigator or supervisor. All faulty electrical equipment must be immediately removed from service until repaired.
- Electrical outlets, wiring, and equipment within a laboratory or building should only be repaired by Facility Services/Physical Plant (FS/PP) for your respective campus or other professional electricians.
- Electrical appliances must only be repaired by authorized electricians or the manufacturer. Unauthorized modifications of electrical appliances is prohibited.
- Proper grounding and bonding of flammable liquid containers should be practiced to avoid the build-up of excess static electricity. Sparks generated from static electricity are good ignition sources.
- Experimental electrical equipment in laboratories must be shielded, insulated, or have appropriate fail-safe devices when energized or in use. Personnel must be proficient in use of the equipment and safety precautions. Personnel should be trained in first aid and CPR in case of electrical shock.

3.12.1. Definitions

Sharps - The term "sharps" refers to “any item having corners, edges, or projections capable of cutting or piercing the skin.”

Puncture Proof – Commercial sharps containers intended for the disposal of broken glass, syringe needles, scalpels, etc.

Puncture Resistant – Re-used containers that, when carefully used, will resist puncture by the disposed item.

Examples of “sharps” include:

- Needles
- Syringes
- Lancets
- Scalpel blades
- Exacto knives
- Broken glass
- Razor blades
- Glass Pasteur pipettes
- Microtome blades
- Any other sharp lab waste

3.12.2. Handling

- Glassware and sharps should be handled and stored carefully to avoid damage.
- Reusable syringes that are not biologically contaminated must be capped and put away after use. Cap syringes using the one-handed method of picking up the cap with the needle then carefully securing the cap onto the syringe. Retractable syringes are preferred. A disposable syringe should be used for biological materials and should be placed in a sharps container without recapping.
- Chipped, broken, or star-cracked glassware should be discarded or repaired. Damaged glassware should never be used unless it has been repaired.
- Because of the potential for catastrophic breakage resulting in sharp projectiles, only thick-walled, pressure-resistant glassware may be utilized under positive pressure or a vacuum.
- Use appropriate hand protection when inserting glass tubing into a rubber stopper or when placing rubber tubing on glass hose connections. Use of plastic or metal connectors should be considered.
- Use appropriate hand protection when picking up broken glass or other sharp objects. Small pieces should be swept up using a brush and dustpan.
- See SOP 3.14 Glass Apparatus and Plasticware Assembly for detailed instructions.

3.12.3. Disposal

Sharps waste is categorized by the type of contamination present. Specific disposal methods are dictated by category, but all categories require packaging in puncture-resistant cardboard or plastic containers in order to minimize the risk of injuries.

3.12.3.1. Uncontaminated Sharps

- Uncontaminated metal or glass sharps should be collected in puncture-proof containers, labeled, sealed, and disposed according to your campus procedures found in the IU Waste Management Program.

Note: Disposable items such as pipette tips and wood swabs that are not sharps but may perforate the liners of the waste receptacles present a hazard to custodians. These may be placed in any puncture resistant container such as a non-breakable plastic jar, bottle, thick plastic bag or other type of container and placed in the waste receptacle. Custodial services will remove this waste.
3.12.3.2. Chemically Contaminated Sharps

- Chemically contaminated metal or glass sharps that are grossly contaminated with hazardous chemicals, should be collected in puncture-proof containers, labeled, sealed, and disposed according to your campus procedures found in the IU Waste Management Program.

Note: Spill residue with broken glass, spill absorbents, etc., must be collected as “Hazardous Chemical Waste” and not placed into the broken glass receptacles (see SOP 3.13 Chemical Spill Response Procedures).

Caution: To avoid dumpster fires, boxes may only be used if the chemical contamination is compatible with the organic cellulose of the box material. Materials contaminated with oxidants should be placed in glass, metallic, or chemically resistant plastic containers.

3.12.3.3. Radioactive Sharps

Refer to the Radiation Safety Manual for disposal of materials with radioactive contamination.

3.12.3.4. Biohazardous items

Refer to the IU Biosafety Manual for disposal of materials with biohazardous contamination.
3.13. Chemical Spill Response Procedures

Despite the best efforts of researchers to practice safe science in the laboratory, accidents resulting in the release of chemicals will occur. For this reason, it is essential that laboratory personnel understand the spill response procedure for their campus which may include appropriate procedures and materials to adequately contain and cleanup a spill.

All chemical spills must be reported to your campus IUEHS representative (see Laboratory Safety Contacts). Environmental Health and Safety will respond to evaluate the release and determine the best course-of-action for the containment and cleanup of the spill.

Do not attempt to clean up spills involving chemicals that are flammable, toxic, corrosive or reactive as indicated on the label or Safety Data Sheet (SDS); or that cause eye or respiratory tract irritation; or chemicals that emit strong, or noxious odors or fumes.

Exceptions for in-house spill response include minor chemical spills, which meet all of the following criteria and mercury thermometer spills that are contained in your workspace and for which you have a mercury spill kit:

- Personnel directly involved in the spill that have immediate access to an SDS for the chemical, and the NFPA and/or HMIS ratings are a 0 or 1 for health and fire, and 0 for reactivity, and/or the GHS rating on the label or SDS is a 5 or 4 for health, fire and reactivity and;
- The amount spilled is 500 milliliters or less for liquids or 500 grams or less for solids and;
- The material does not emit strong odors, vapors, fumes or dust that are noxious or irritating to the eyes or respiratory system and;
- The material is not a known to be a carcinogen or strong mutagen, or dangerous for the environment. This information will also be in the SDS along with the HMIS or NFPA ratings and;
- The spill is contained on an impervious surface, and cannot migrate into the environment through drains, soil, ground water or surface water.

3.13.1. Procedures for Spills that Meet the Exception Criteria

The following procedures should be used as a guide to help laboratory personnel design an effective spill control plan for their laboratory (see Section 6.10 Spill Control Kit for information on spill kit contents).

If you have contacted IUEHS, the spill meets the above criteria, and the chemical does not pose an immediate risk to health or require respiratory protection:

- Notify other laboratory personnel of the accident.
- Isolate the area. Close laboratory doors and evacuate the immediate area if necessary.
- Remove all ignition sources and establish exhaust ventilation. Vent vapors to outside of building only (open windows and turn on fume hood).
- Choose appropriate personal protective equipment (e.g., goggles, face shield, impervious gloves, lab coat, apron or coveralls, and boots).
- Confine and contain the spill. Cover with appropriate absorbent material. Sweep solid material into a dust pan and place in a sealed plastic container. Decontaminate the area with soap and water after cleanup and place residue in a plastic bag or another sealed plastic container.
- Label the container.
- Contact IUEHS for your respective campus for disposal.

3.13.2. Procedures for Spills that DO NOT Meet the Exception Criteria

Laboratory personnel must not attempt to clean up a hazardous chemical spill of the type and quantity that poses an immediate risk to health, the environment, or those that require respiratory protection. The most senior staff member present at the time of the spill is responsible for ensuring the following procedures are followed and that the spill is reported to IUEHS and emergency responders as necessary.

Follow the chemical spill response (ESCAPE) procedure as follows:

1. **Exit the area** — Immediately after a hazardous chemical is spilled you must exit the area. If the spill occurred in a laboratory and access to the fume hood is not blocked by the spill and/or hazardous vapors are not present in the area then raise the sash on the fume hood and increase the airflow.

2. **Shut the doors and secure the area** — Shut the doors to the area where the spill is located and secure the area if possible. Most laboratories are under negative pressure which will pull air from the hallway into the lab, keeping potentially hazardous vapors from spreading into other areas.

3. **Call 911 from a campus phone or IUPD for your respective campus from a non-campus phone from a safe location and give the following information:**
   
   a. Building name
   b. Room number or location
   c. Type of incident
   d. Name of chemical spilled or description of odor if unsure of the chemical
   e. Estimate of the volume of chemical spilled

4. **Assess the situation** — Determine if the spill is Immediately Dangerous to Life or Health (IDLH). IDLH incidents are those that pose a significant and immediate threat to building occupants due to extreme toxicity, imminent explosion, or other life threatening conditions. These types of incidents are rare. If the spill does not pose a threat to the building occupants then remain outside the entrance to the laboratory until the spill response team arrives. If you determine that the situation is Immediately Dangerous to Life or Health, then proceed to the next step.

5. **Pull the fire alarm** — If the spill poses an immediate danger to the building occupants pull the fire alarm. Activating the fire alarm will evacuate the building occupants and in some locations will also notify the Fire Department. As a precaution dial 911 and give appropriate information to the dispatcher.

6. **Exit the building** — Once the fire alarm has been activated exit the building. Remain at a safe distance from the main entrance of the building. Give your information to the emergency response teams that will be arriving.
3.13.3. Procedures for Chemical Contamination to the Eyes or Body

In the event of chemical contamination to the eyes or body:

1. Remove any contaminated clothing immediately and flush all areas of bodily contact with copious amounts of water. This should take place while someone else makes the appropriate phone calls from a safe location.

2. Ensure that medical assistance is obtained for those injured or exposed (safety shower, medical attention, etc.). Continue to rinse body contact areas with copious amounts of water for at least 15 minutes unless directed otherwise by appropriate emergency medical personnel (Physician, Nurse, Paramedic or Emergency Medical Technician).

3. Visit the designated medical services provider for your campus or the emergency room for medical care and evaluation (see Section 5.0). If possible, take applicable Safety Data Sheets (SDS) with you.

Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use ultra violet (UV) or other light sources. The only soft glass provided in the laboratory should be reagent bottles, measuring equipment, stirring rods, and tubing.

Any glass equipment to be evacuated, such as suction flasks, must be specially designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or otherwise screened or contained in a metal jacket to prevent flying glass in the case of an implosion. Household Thermos bottles have thin walls and are not acceptable substitutes for laboratory Dewar flasks.

3.14.1. Preparation of Glass Tubing and Stoppers

To cut glass tubing:

If the tubing does not readily pull apart, the nick probably is too shallow or rounded. Make a fresh sharp file scratch in the same place and repeat the operation.

All glass tubing and rods, including stirring rods, should be fire polished before use. Unpolished cut glass has a razor-like edge, which not only can lacerate the skin, but will also cut into a stopper or rubber hose, making it difficult to insert the glass properly. After polishing or bending glass, allow ample time for it to cool before grasping it.

To drill a stopper:

- Use only a sharp borer one size smaller than that which will just slip over the glass tube.
- Lubricate rubber stoppers with water or glycerol.
- Bore the hole by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper.
- Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through.
- It is preferable to drill only part way through and then finish by drilling from the opposite side. Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if it is cracked, or if it leaks.
- Corks should have been previously softened by rolling and kneading. Rubber or cork stoppers should fit into a joint so that one-third to one-half of the stopper is inserted.

When available, glassware with ground joints is preferable. Glass stoppers and joints should be clean, dry and lightly lubricated.

3.14.2. Insertion of Glass Tubes or Rods into Stoppers or Flexible Tubing

To insert glass tubes into stoppers or flexible tubing:

- Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
- If not already fire polished, fire polish the end of the glass to be inserted; let it cool.
- Lubricate the glass. Water may be sufficient but glycerol is a better lubricant.
- Wear heavy gloves or wrap layers of cloth around the glass and protect the other hand by holding the hose or stopper with a layered cloth pad.
- Hold the glass rod or tube near the end to be inserted, not more than 5 cm (2 in) from the end.
- Insert the glass with a slight twisting motion, avoiding too much pressure and
torque.

- If necessary, use a cork borer as a sleeve for insertion of glass tubes.
- Substitute a piece of metal tubing for glass tubing if possible.
- Remove stuck tubes by slitting the hose or stopper with a sharp knife.

3.14.3. Apparatus Assembly

The following recommendations will help make apparatus assembly easier, safer, and avoid equipment failure during use:

- Keep your workspace free of clutter.
- Set up clean, dry apparatus, firmly clamped and well back from the edge of the lab bench or hood with due regard to the proximity of reagent bottles to burners and to other workers and their equipment. Choose sizes that can properly accommodate the operation to be performed, allowing 20% free space at the minimum.
- Use only equipment that is free from flaws such as cracks, chips, frayed wire, and obvious defects. Glassware can be examined in polarized light for stains. Even the smallest chip or crack renders glassware unusable; chipped or cracked ware should be repaired or discarded.
- A properly placed pan under a reaction vessel or container will act as a secondary containment to confine spilled liquids in the event of glass breakage.
- Addition and separatory funnels should be properly supported and oriented so that the stopcock will not be loosened by gravity. A retainer ring should be used on the stopcock plug. Glass stopcocks should be freshly lubricated. Teflon stopcocks should not need lubrication.
- Condensers must be properly supported with securely positioned clamps. The attached water hoses must be secured to the glass fittings with wire or appropriate hose clamps.
- Stirrer motors and vessels should be secured to maintain proper alignment. Magnetic stirring is preferable.
- Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side. There should be adequate provision for removing burners or baths quickly. Standards bearing heavy loads should be firmly attached to the bench top. Equipment racks should be securely anchored at the top and bottom.

3.14.4. Operational Precautions

The following precautions should be considered prior to assembly and during operation of the apparatus.

- When working with flammable gases or liquids, do not allow burners or other ignition sources in the vicinity. Use appropriate traps, condensers, or scrubbers to minimize release of vapors to the environment. If a hot plate is used, ensure that the temperatures of all exposed surfaces are less than the autoignition temperature of the chemicals likely to be released and that the temperature control device and the stirring or ventilating motors do not spark.
- Only non-sparking motors or pneumatic motors should be used in chemical laboratories.
- Whenever possible, use controlled electrical heaters or steam in place of gas burners.
- Inspect power cords for chemical or physical damage by unplugging the equipment then bending the cord to look for cracks in the insulation. Be sure to check carefully
and close to the point where the power cord enters the housing.

- Apparatus, equipment, or chemical bottles must not be placed on the floor.
- Never heat a closed container. Provide a vent as part of the apparatus for chemicals that are to be heated. Prior to heating a liquid, place boiling stones in unstirred vessels (except test tubes). If a burner is to be used, distribute the heat with a ceramic-centered wire gauze. Use a thermometer with its bulb in the boiling liquid if there is the possibility of a dangerous exothermic decomposition as in some distillations. This will provide a warning and may allow time to remove the heat and apply external cooling. The setup should allow for fast removal of heat.
- Whenever hazardous gases or fumes are likely to be evolved, an appropriate gas trap should be used and the operation confined to a fume hood.
- Fume hoods are recommended for all operations in which toxic or flammable vapors are evolved as in many distillations. Most vapors have a density greater than that of air and will settle on a bench top or floor where they may diffuse to a distant burner or ignition source. These vapors will roll out over astonishingly long distances and, if flammable, an ignition can cause a flash back to the source of the vapors. Once diluted with significant amounts of air, vapors move in air essentially as air itself.
- Use a hood when working with a system under reduced pressure (which may implode). Close the sash to provide a shield. If a hood is not available, use a standing shield. Shields that can be knocked over must be stabilized with weights or fasteners. Standing shields are preferably secured near the top. Proper eye and face protection must be worn even when using the shields or hood.
3.15. Solvent Stills – Procedures for Set-up, Use, and Neutralization

Although the procedures for purifying laboratory chemicals are inherently safe, care must be exercised if hazards are to be avoided. Solvent distillation equipment in which flammable liquids are purified by distillation with reactive metals or metal hydrides, such as sodium, potassium, calcium hydride and lithium aluminum hydride, are possibly the greatest danger in any organic chemistry laboratory. The potential fire and explosion hazards associated with the combination of air- and/or water-reactive metals with large amounts of organic solvents are great and the effects on personnel and equipment can be catastrophic. The chances of personnel escaping such an incident unharmed are very low. Consider using alternative solvent purification systems and methods before proceeding (see column purification method below for a procedure that avoids all heat and distillation).

3.15.1. Set-Up and Operation

1. Use proper personal protective equipment (e.g., gloves, safety glasses, and fire-resistant or all cotton lab coat) while operating a distillation unit.
2. Any solvent stills containing reactive metals should be located in a fume hood.
3. After set up and before start up get prior approval and a final equipment check from the principal investigator or an approved competent person.
4. The total volume of solvent used in these stills shall be kept to a minimum (BUT they should never be allowed to go “dry”). Their useful working volume is ¼ to ⅔ of filled capacity.
5. Stills should be operated under an inert gas atmosphere of nitrogen or argon.
6. Several types of drying agents can be used:
   a) Sodium, potassium or sodium-potassium alloys must never be used for solvents containing C-Cl or O-H bonds.
   b) Because of their pyrophoric nature (possible spontaneous ignition upon contact with air) the use of sodium/potassium alloys (NaK), which are liquids at ambient temperature should be avoided. Solvent flasks containing lithium aluminum hydride must never be heated. As a drying agent lithium aluminum hydride is therefore only suitable for non-reducible solvents that can be obtained pure by flask-to-flask vacuum-transfer at ambient temperature.
   c) The use of potassium alone is recommended for THF only – in these solvents the metal will melt providing a fresh & reactive surface. Be aware that it is much more reactive than sodium, especially when quenching a solvent still (see below).
   d) The use of sodium alone is recommended for diethyl ether and all other hydrocarbons such as toluene, benzene, pentane, hexane, heptane, etc.
   e) Calcium hydride is recommended for methylene chloride and other halogenated solvents.
   f) Magnesium/Iodine is recommended for methanol and ethanol.
   g) For all high boiling solvents the use of 4 Å molecular sieves (activated by heating under full dynamic vacuum overnight) is recommended.
7. Solvent stills should never be left running (i.e., being heated to reflux) while unattended – especially not overnight.
8. Stills must be deactivated and restarted with all fresh solvent and drying agents on a regular basis to avoid buildup of metal hydroxides and benzophenone “cakes” that would impair stirring necessary during deactivation. Record the date of maintenance activities at the still for reference.
9. To deactivate a solvent still containing reactive metals follow the procedure below for deactivation and neutralization.

3.15.2. Deactivation and Neutralization

Please read and follow these procedures carefully. This procedure can be dangerous and requires plenty of time to complete. Do not rush the process. Only properly trained persons are to perform this procedure.

1. Deactivation and neutralization must be performed immediately when there is no longer a need for the distillation process. Do not abandon distillation units for others to decommission. If an abandoned unit is discovered, do not touch it and contact IUEHS for your respective campus immediately (see pgs. ix-xi).

2. Notify other laboratory occupants and your supervisor of your intent to perform this procedure. Do not perform this procedure "after-hours".

3. Wear a lab coat, safety glasses, face shield, and appropriate gloves. Familiarize yourself with the location of the nearest emergency shower, fire blanket, and exit. Have a dry-chemical fire extinguisher available.

4. Inspect the still flask. The still flask should not be more than 1/5 full and the mixture must be stirring freely using a magnetic stir bar. If it is not, carefully attempt to break up any solid deposits in the flask using a large spatula. If this does not work, seek assistance from your supervisor.

5. In a fume hood cleared of all other reactions and equipment, set up a reaction apparatus as illustrated in the attached scheme. Securely clamp the still flask and all other parts of the apparatus to a sturdy lab-stand or support rod.

6. Make sure that there is an ample supply of nitrogen or argon that will last at least 24 hours with a slow rate of bubbling and establish that both nitrogen/argon and cooling water are flowing at a reasonable rate with the hose connections to the condenser secured by copper wire or similar.

7. If the solvent still contains sodium or potassium:
   a) With stirring, slowly add an equal volume of toluene or preferably xylene to the flask (see attached figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus. The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. observing the reaction.
   b) With stirring, add 1 ml of n-butanol or t-butanol and observe the reaction. In the presence of active metal hydrogen gas evolution will occur. Further 1 ml portions of the alcohol are added at such a rate that the heat evolved by neutralization does not cause the reaction mixture to come to reflux. This will take several hours, or even longer. The reactivity of the mixture can be monitored by briefly interrupting the nitrogen flow and monitoring the bubbler. As long as there is gas evolution from the apparatus, reactive metal is present.
   c) When no further reactivity is observed, procedure b) is repeated with ethanol. Again this may take several hours, or overnight, until all hydrogen evolution ceases.
   d) Add 50-100 ml methanol in 5 ml portions and monitor the reaction. Stir at least 1 h or until no further gas evolution is observed.
   e) Repeat procedure b) with water until no further gas evolution is observed.
   f) Dispose of the contents of the flask as organic chemical waste from your laboratory.

8. If the solvent still contains lithium aluminum hydride:
   a) With stirring, slowly add 1 ml portions of 95 % ethanol to the flask containing the hydride in solution (see attached figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus. The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. observing the reaction. When no more gas evolution is
observed slowly add a saturated solution of ammonium chloride.

b) Separate the organic and aqueous layers formed.

c) Dispose of the two components in the appropriate manner, i.e., the organic layer into the organic waste collection container, the aqueous layer into the aqueous waste collection container in your laboratory.

9. If the solvent still contains calcium hydride in dichloromethane (CH$_2$Cl$_2$):

a) With stirring, slowly add 1-2 ml portions of methanol to the flask (see figure) while maintaining a slight counter-flow of nitrogen or argon through the apparatus.

b) The counter-flow should be maintained during any additions to the flask throughout the entire procedure. Stir for 5-10 min. after each addition observing the reaction.

c) When no more gas evolution is observed slowly add excess water.

d) Separate the organic and aqueous layers formed.

e) Dispose of the two components in the appropriate manner, i.e., the organic layer into the halogenated organic waste collection container, the aqueous layer into the aqueous waste collection container in your laboratory.

3.15.3. Column Purification Systems

Commercially available column purification systems are a viable alternative for some distillation procedures. While the column method does not have the fire or explosion initiators that distillation units have, they do, however, have their own set of safety considerations that must be accounted for.

1. The quantities of solvents in the system tend to be larger so the units must be used in an appropriate location equipped with flammable liquid cabinets, fire doors, sprinklers, and the quantity limits imposed by the building codes must not be exceeded.

2. The columns are pressurized from 5-50 psi therefore; they must be secure and equipped with the appropriate valves and plumbing.

3. Peroxides may accumulate on the columns and must be changed in accordance with the manufacturer's recommendation.

4. Some solvents, including tetrahydrofuran and methylene chloride, are incompatible with the copper catalyst therefore; the column method may not be suitable for some applications.

3.16. Personal Protective Equipment – Procedures for Selection and Use

Personal protective equipment (PPE) is selected based on the potential hazard presented by the work. Scrutinize each laboratory procedure individually for potential hazards based on the chemicals to be used and the procedure to be performed. The hazard assessment is then used to determine the appropriate personal protective equipment.

Each laboratory group is responsible for assessing the potential hazards presented by their work. The IU Personal Protective Equipment Policy and the Laboratory Chemical Personal Protective Equipment guideline found in Appendix A can be used for this purpose. The potential hazards presented by typical laboratory procedures and the corresponding personal protective equipment are found on the form. The list does not include all laboratory procedures. Additional tasks and personal protective equipment should be added as necessary on the form.

A list of chemicals that require skin protection can be found in Appendix B. These chemicals have been identified by the Occupational Safety and Health Administration (OSHA) and/or the American Conference of Governmental Industrial Hygienists (ACGIH) as chemicals that present a significant risk of skin absorption and subsequent toxicity. Many chemicals not on the list also require the use of gloves and other personal protective equipment. Never underestimate the risk of exposure. Always practice good chemical hygiene and use personal protective equipment.

3.16.1. Hand Protection

No glove is resistant to all chemicals. Consult the glove manufacturer’s selection guides for chemical compatibility prior to use. Glove selection guides can also be found at the manufacturer’s web sites. For further information contact IUEHS for your respective campus.

3.16.1.1. Selection

When selecting and using gloves always:

- Consider chemical resistance, thickness, length, and dexterity requirements.
- Inspect all gloves before use for signs of swelling, cracking, discoloration, pinholes, etc.
- Consider double gloving (wearing one glove over another) as a precaution.
- Change gloves frequently or as often as needed if they become contaminated.
- Do not wear gloves into the hallways or other common areas.
- Do not touch doorknobs, phones, etc., when wearing gloves. (Remove them before touching anything to prevent leaving chemical residue on the item.)
- Remove gloves by pinching the material in the palm and turning them inside out as the glove is removed over the finger tips (thus keeping contamination on the inside of the removed glove.)
- Rinse thicker reusable gloves after every use.

3.16.1.2. Chemical Resistance

Chemical resistance is based on several characteristics of the glove material. When selecting the appropriate glove, the following properties must be considered:

- Degradation
- Breakthrough time
- Permeation rate

**Degradation** is the change in one or more of the physical properties of a glove caused by contact with a chemical. Degradation typically appears as hardening, stiffening, swelling, shrinking or cracking of the glove. Degradation ratings indicate
how well a glove will hold up when exposed to a chemical. When looking at a chemical compatibility chart, degradation is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended) or NT (not tested).

**Breakthrough time** is the elapsed time between the initial contact of the test chemical on the surface of the glove and the analytical detection of the chemical on the inside of the glove.

**Permeation rate** is the rate at which the test chemical passes through the glove material once breakthrough has occurred and equilibrium is reached. Permeation involves absorption of the chemical on the surface of the glove, diffusion through the glove, and desorption of the chemical on the inside of the glove. Resistance to permeation rate is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended), or NT (not tested). If chemical breakthrough does not occur, then permeation rate is not measured and is reported ND (none detected).

Manufacturers stress that permeation and degradation tests are done under laboratory test conditions, which can vary significantly from actual conditions in the work environment. Users may decide to conduct their own tests, particularly when working with highly toxic materials or chemicals for which no data can be found. This must always be done carefully in a fume hood with PPE and without touching the chemicals or contaminated materials with the hands (e.g., use forceps).

For mixtures, it is recommended that the glove material be selected based on the shortest breakthrough time.

The following table shows the typical glove materials and their general uses.

<table>
<thead>
<tr>
<th>Glove Material</th>
<th>General Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl</td>
<td>Offers the highest resistance to permeation by most gases and water vapor. Especially suitable for use with esters and ketones.</td>
</tr>
<tr>
<td>Neoprene</td>
<td>Provides moderate abrasion resistance but good tensile strength and heat resistance. Compatible with many acids, caustics and oils.</td>
</tr>
<tr>
<td>Nitrile</td>
<td>Excellent general duty glove. Provides protection from a wide variety of solvents, oils, petroleum products and some corrosives. Excellent resistance to cuts, snags, punctures and abrasions.</td>
</tr>
<tr>
<td>PVC</td>
<td>Provides excellent abrasion resistance and protection from most fats, acids, and petroleum hydrocarbons.</td>
</tr>
<tr>
<td>PVA</td>
<td>Highly impermeable to gases. Excellent protection from aromatic and chlorinated solvents. Cannot be used in water or water-based solutions.</td>
</tr>
<tr>
<td>Viton</td>
<td>Exceptional resistance to chlorinated and aromatic solvents. Good resistance to cuts and abrasions.</td>
</tr>
<tr>
<td>Silver Shield</td>
<td>Resists a wide variety of toxic and hazardous chemicals. Provides the highest level of overall chemical resistance.</td>
</tr>
<tr>
<td>Natural rubber</td>
<td>Provides flexibility and resistance to a wide variety of acids, caustics, salts, detergents and alcohols. (See Latex Gloves and Related Allergies below).</td>
</tr>
</tbody>
</table>
3.16.1.3. Latex Gloves and Related Allergies

Allergic reactions to natural rubber latex can sometimes occur. The term "latex" refers to natural rubber latex and includes products made from dry natural rubber. Natural rubber latex is found in many products including disposable gloves and other personal protective equipment.

Several chemicals are added to this fluid during the processing and manufacture of commercial latex. Some proteins in latex can cause a range of mild to severe allergic reactions. The chemicals added during processing may also cause skin rashes.

Latex exposure symptoms include skin rash and inflammation, respiratory irritation, asthma and shock. The amount of exposure needed to sensitize an individual to natural rubber latex is not known, but when exposures are reduced, sensitization decreases.

In addition to skin contact with the latex allergens, inhalation is another potential route of exposure. The proteins responsible for latex allergies have been shown to fasten to powder that is used on some latex gloves. Latex proteins may be released into the air along with the powders used to lubricate the interior of the glove.

The following actions are recommended to reduce exposure to latex:

- Whenever possible, substitute another glove material.
- If latex gloves must be used, choose reduced-protein, powder-free latex gloves.
- Wash hands with mild soap and water after removing latex gloves.

Once a worker becomes allergic to latex, special precautions are needed to prevent exposures during work. Certain medications may reduce the allergy symptoms, but complete latex avoidance is the most effective approach.

3.16.2. Protective Eyewear

Protective eyewear is *required* whenever there is a reasonable probability that the eyes could be exposed to chemicals. The type of eyewear required depends on the hazard classification of the area and procedure to be performed. Please refer to the IU Eye and Face Protection Program for additional guidance.

3.16.2.1. Types of Protective Eyewear

3.16.2.1.1. Safety Glasses

Safety glasses have shatter resistant lenses made of materials like polycarbonate plastic with side shields attached to the temples that meet the specifications of the American National Standards Institute Standard Z87.1-1989. Safety glasses are designed to stop physical objects or harmful radiation such as laser light from entering the eyes and provide little or no protection from vapors or liquids.

3.16.2.1.2. Goggles

Properly vented safety goggles are the preferred eye protection to be worn when chemicals are handled in the laboratory. These should be worn over prescription glasses.

Goggles come in two types: vented and non-vented. Non-vented goggles are used to protect your eyes from vapors, mists, fumes, or other eye hazards that require complete eye coverage with no leaks or perforations.

Vented goggles are used where there are moderate quantities of liquids being used but no vapors or mists are involved. There are several types of vented goggles. The type of vented goggles made for laboratory use has a series of
buttons embedded into the plastic. These buttons house a baffle plate that allows air to pass but presents a physical barrier to liquids. Do not use the common vented goggle with simple holes drilled in the sides. This type of vented goggle will not stop liquids from coming in through the holes and is not suitable for laboratory work.

3.16.2.1.3. Face Shields

Face shields are designed to augment other types of eye protection and are not meant to be a stand-alone form of eye protection. Face shields are used to protect your entire face to catch any liquids that might splash onto the face.

3.16.2.2. Hazard Classifications

Areas and operations within research buildings can be classified into three types of hazardous areas based on the following definitions. It is important to recognize that the procedure is classified as well as the area. If a procedure creates a greater hazard than the laboratory classification would indicate, eye and face protection appropriate for the hazard shall be worn. It would be possible to have a Class 3 operation in a Class 2 area. Appropriate additional protection would be required.

3.16.2.2.1. Class 1 – Eye Protection Not Required

This classification includes laboratories that do not use chemicals, biological materials, or physically hazardous materials. Hazards requiring eye protection are seldom encountered in this area. These areas are exempt from the requirement that occupants and visitors must wear industrial safety glasses. Examples include computer or imaging laboratories and other areas such as:

- Offices including enclosed offices within laboratories or protected desk areas. To comply with this requirement there must be a line of sight barrier (for example an office partition) between personnel and any chemicals or any chemical process in the laboratory.
- Conference rooms
- Libraries and reading rooms
- Corridors, lobbies, elevators, and stairwells
- Locker and rest rooms
- Mail and copier rooms
- Computer and computer user rooms
- Lounges and break rooms

3.16.2.2.2. Class 2 – Eye Protection Required When Hazards Exist

This classification includes laboratories that use chemicals, biological materials, or physically hazardous materials on an occasional basis. Eye protection must be worn when the hazards exist. Safety eyewear such as industrial safety glasses with side shields are required for workers and visitors in these areas. Examples include laser laboratories and some research laboratories.

3.16.2.2.3. Class 3 – Eye Protection Required At All Times

Specific and predictable eye hazards exist in these areas such as laboratories that routinely use chemicals, biological materials, or machinery. Examples of eye protection required in these areas are acid splash goggles, face shields, welding helmets, and laser goggles. Industrial safety glasses alone may not provide adequate eye protection in these areas. Examples include chemistry teaching laboratories and organic chemistry laboratories.

Note: Contact lenses may complicate treatment in the event of an accident. They
may be allowed or prohibited based on the specific laboratory procedures and policy. The use of contact lenses is only allowed in conjunction with appropriate safety eyewear and the laboratory supervisor’s approval. Instructors or supervisors must be aware of those wearing contact lenses.

3.16.2.3. Exemption Procedure

Eye protection may need to be removed while viewing materials through a microscope or similar equipment. Eye protection must be replaced after operation is complete. Microscope and similar equipment must be located in an area where removal of eye protection does not place personnel at risk from other hazards in the area.

3.16.2.3.1. Local Safety Procedure Required

State if eye protection can be removed behind a line of sight barrier. Define the line of sight barrier. Any approved exemptions must be identified on the Personal Protective Equipment Hazard Assessment Form LCS-4 in Appendix A.

3.16.3. Protective Clothing

Protective clothing in the form of lab coats, aprons, and closed-toed shoes are required whenever the possibility of chemical contamination to the body exists. Protective clothing that resists physical and chemical hazards should be worn over street clothes.

Lab coats and aprons should be left in the laboratory and not taken home. This prevents the worker from carrying incidental contamination out of the laboratory and presenting a chemical hazard to co-workers, friends, or family.

Disposable outer garments such as Tyvek suits, aprons, and lab coats may be useful when cleaning and decontamination of reusable clothing is difficult.

Shorts, loose clothing (including ties), or torn clothing are inappropriate for work with hazardous chemicals.

3.16.3.1. Lab Coats

Lab coats are appropriate for minor chemical splashes and spills. They must be worn buttoned with the sleeves covering the arms. Do not roll up the sleeves.

3.16.3.2. Aprons

Rubber or plastic aprons are appropriate for handling corrosives or irritating liquids.

3.16.4. Footwear

Close-toed shoes must be worn at all times where chemicals are stored or used. Perforated shoes, sandals or cloth sneakers must not be worn in laboratories. They offer no barrier between the laboratory worker and chemicals or broken glass. Leather shoes are preferable but tend to absorb chemicals and may have to be discarded if contaminated with a hazardous material.

Chemical resistant overshoes, boots, or disposable shoe coverings (“booties”), may be used to avoid possible exposure to corrosive chemicals or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup).

Although generally not required in most laboratories, composite-toed safety shoes may be necessary when there is a risk of heavy objects falling or rolling onto the feet, such as in bottle-washing operations, animal care facilities, or if large quantities of liquids are stored and moved in drums.

Please refer to the IU Foot Protection Program for additional guidance.
3.16.5. Respiratory Protection

Respiratory protection is typically provided by using adequate engineering controls such as chemical fume hoods, canopy hoods, snorkel hoods, glove boxes, and appropriately equipped biological safety cabinets. It should be noted that not all biological safety cabinets provide protection from toxic chemical vapors and fumes. These devices should be carefully selected and used only for their intended purpose.

A respirator may only be used when engineering controls, such as general ventilation or a fume hood, are not feasible or do not reduce the exposure of a chemical to acceptable levels. Respirators can only be used in accordance with the Indiana University Respiratory Protection Program. Contact IUEHS for your respective campus for more information or to obtain a respirator and arrange the required respirator fit test and medical examination.

3.16.6. Head Protection

Head protection may be necessary in industrial type laboratories where overhead hazards exist or fluids may splash onto the head. Appropriate head protection in the form of hard hats or fluid barrier hats should be used in these cases. Hooded disposable coveralls may also be used if necessary.
3.17. Peroxide-Forming Chemicals and Other Time-Sensitive Materials – Procedures for Safe Handling and Management

Some laboratory chemicals, known as time-sensitive chemicals, can become dangerous with age. This can be due to chemical reactions, over-pressurization of containers, toxicity, and other hazardous properties. For this reason handling and management of time-sensitive chemicals are of particular importance. These chemicals include the following:

- Chemicals that form peroxides upon aging;
- Picric acid and other multi-nitro aromatics;
- Chloroform;
- Anhydrous hydrogen fluoride and hydrogen bromide;
- Liquid hydrogen cyanide;
- Formic acid;
- Alkali metals (such as potassium, sodium and lithium).

Other relevant sections of this plan include; SOP 3.2, Procedures for Proper Labeling, Storage, and Management of Chemicals; SOP 3.7, Reactive Chemicals; and the table of Peroxide-Forming Chemicals in Appendix B.

3.17.1. Peroxide-Forming Chemicals

The peroxide-forming chemicals include common organic solvents and can react with atmospheric oxygen to undergo autoxidation or peroxidation, producing unstable and dangerous organic peroxides and hydroperoxides.

Formation of peroxides is accelerated by light and heat. Substances which have undergone peroxidation are sensitive to thermal or mechanical shock and may explode violently. All laboratory workers must learn to recognize and safely handle peroxidizable compounds. Peroxide-forming substances include aldehydes, ethers (especially cyclic ether), compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidene compounds. A list of these chemicals can be found in Appendix B.

3.17.1.1. Safe Handling and Usage

- Labels on peroxide-forming substances must contain the date the container was received and the date it was first opened.
- Include a notice such as Warning Peroxide-Former on the container.
- Check for the presence of peroxides while in storage based on the suggested shelf-life using peroxide test strips (see test methods below).
- If peroxides are found at a concentration <100 ppm, the material must be treated (to remove peroxides) or stabilized (to prevent further peroxide formation) and turned in to IUEHS for your respective campus for disposal. The date of treatment or stabilization must be written on the label. If >100 ppm peroxides are found contact IUEHS for your respective campus (see pgs. ix-xi). See disposal instructions below.
- The date and results of any testing must be placed on the container label.
- Never use a metal spatula with peroxides. Contamination by metals or disturbance of the crystals can lead to explosive decompositions.
- Store peroxides and peroxide-forming compounds according to the manufacturer’s recommendations, away from light and heat.
- If storing peroxide formers in a refrigerator, the refrigerators must be designed for the storage of flammable substances. Do not use domestic refrigerators to store flammable liquids.
- Do not open or test the contents of the container if 1) crystals are visibly present on or in the container or lid, 2) if a precipitate has formed or an oily viscous layer is present, or 3) if the container has been opened but not tested and is more than two years old. Call the University Environmental Health and Safety (IUEHS) at your respective campus for assistance.

### 3.17.1.2. Disposal

- Dispose of Class A (see table in Appendix B) peroxidizable solvents within one year of purchase if unopened or 6 months of the opening. See IU Waste Management Program for disposal.

- If the container has a manufacturer’s expiration date on the label, turn the material in to IUEHS for your respective campus for disposal on or before the expiration date.

- If the peroxide-forming substance is greater than 1 year old and less than 2 years old, test for peroxide formation using peroxide test strips (see test methods below). If the peroxide concentration is less than 100 ppm add 1 tsp. of hydroquinone per pint of solvent to prevent further peroxide formation and contact IUEHS for your respective campus for disposal. If the concentration is greater than 100 ppm contact IUEHS for your respective campus for assistance. If the peroxide former is expired or over 2 years old it must be properly disposed of through IUEHS.

- If the peroxide-forming substance is greater than 2 years old and less than 5 years old do not open the container to check for peroxide concentration. Contact IUEHS for your respective campus for assistance.

- If the container is greater than 5 years old, do not move the container at all. Contact IUEHS for your respective campus for assistance.

- Additional information can be found in the IU Waste Management Program.

### 3.17.1.3. Testing

The following test procedures may be used on most organic solvents. However, there is not a suitable, simple test procedure for detection of peroxides in substances such as alkali metals, alkali metal alkoxides, amides, or organometallics. Do not test or treat any peroxide-forming chemicals if you are unsure of the age, if there are visible crystals, or if a precipitate or oily viscous layer is present.

**Peroxide Test Strips:**

The use of peroxide test strips is perhaps the most convenient method to test for the presence of peroxides. Test strips are commercially available from several vendors including:

- Gallade Chemical - Cat. No. 10081, [www.galladechem.com](http://www.galladechem.com), (888) 830-9092

Follow the manufacturer's instructions for using the strips to ensure adequate colorimetric detection. IUEHS recommends disposal of any chemicals that test positive for peroxides because the positive test indicates they are aging and beginning to form peroxides. Concentrations at or above 100 ppm must be turned in to IUEHS for your respective campus for disposal.

**3.17.1.3.1. Iodide Test**

Add 0.5-1.0 ml of the solvent to be tested to an equal volume of glacial acetic acid to which has been added about 0.1 g of sodium iodide or potassium iodide crystals. A yellow color indicates a low concentration of peroxide in the sample; a brown color indicates a high concentration. A blank determination should be made.
Always prepare the iodide/acetic acid mixture at the time of the test because air oxidation slowly turns the blank to a brown color.

### 3.17.1.3.2. Ferrous Thiocyanate Test

A drop of the solvent to be tested is mixed with a drop of sodium ferrothiocyanate reagent which is prepared by dissolving 9 g of FeSO$_4$·7H$_2$O in 50 ml of 18% hydrochloric acid. Add 0.5-1.0 g granulated zinc followed by 5 g sodium thiocyanate. When the transient red color fades, add 12 g more of sodium thiocyanate and decant the liquid from the unused zinc into a clean stoppered bottle. Pink or red coloration indicates the presence of peroxides.

### 3.17.1.4. Treatment

Useable chemicals may be treated prior to use. Chemicals intended for IUEHS disposal do not need to be treated. Any of the following procedures may be used to remove the peroxides. One of the above test procedures should be employed following treatment to ensure that peroxides have been removed. **Do not test or treat any peroxide-forming chemicals if you are unsure of the age, if there are visible crystals, or if a precipitate or oily viscous layer is present.**

#### 3.17.1.4.1. Method 1 - Activated Alumina

Peroxides can be removed by passing the solvent through a short column of activated alumina. This method is effective for both water-insoluble and water-soluble solvents (except low molecular weight alcohols). Since this method does not destroy peroxides the alumina should be flushed with a dilute acid solution of potassium iodide or ferrous sulfate following treatment to remove peroxides from the alumina.

#### 3.17.1.4.2. Method 2 - Ferrous Salt

Peroxide impurities in water-soluble solvents are easily removed by gently shaking with a concentrated solution of a ferrous salt. A frequently used ferrous salt solution can be prepared either from 60 g of ferrous sulfate + 6 ml concentrated sulfuric acid + 110 ml water; or from 100 g of ferrous sulfate + 42 ml of concentrated hydrochloric acid + 85 ml of water.

### 3.17.2. Picric Acid and Other Multi-Nitro Aromatics

Picric acid (C$_6$H$_3$N$_3$O$_7$ and other multi-nitro aromatics) can be extremely dangerous if allowed to dry. Picric acid with a moisture content of greater than 30% is considered a flammable solid by the Department of Transportation (DOT). Picric acid with a moisture content of less than 30% is considered a Class 1.1D explosive by DOT and is very shock sensitive. **DO NOT OPEN OR MOVE** a container of dry picric acid.

### 3.17.3. Chloroform

Chloroform (CHCl$_3$) reacts with air to form phosgene gas (CCl$_2$O) which has a very low IDLH (Immediately Dangerous to Life or Health) value of 2 parts per million. Always open chloroform in a fume hood.

### 3.17.4. Formic acid

Formic acid (90-100% CH$_2$O$_2$) decomposes to form carbon monoxide and water (CO + H$_2$O). Pressure greater than 100 psi can develop with prolonged storage of 1 year or greater which is sufficient to break a sealed glass container. Vent containers frequently and read the product literature. Some have pressure relief caps and some Safety Data Sheets may recommend refrigeration.
3.17.5. Anhydrous Hydrogen Fluoride, Hydrogen Bromide, and Other Corrosive Gases

Anhydrous hydrogen fluoride and hydrogen bromide are in a liquid phase above 15 psi. Stored in carbon steel cylinders (lecture bottles) they can react with the steel to form iron fluoride and hydrogen gas. Lecture bottles have a typical working pressure of 1800 psi and these chemicals have a 2 year shelf life. Several anhydrous hydrogen fluoride cylinders have failed (at interior pressures greater than 2,400 psi) after 14-24 years of storage although there have been no reported problems with hydrogen bromide.

Other corrosive gases such as hydrogen chloride and hydrogen sulfide must be returned for disposal every two years.

3.17.6. Liquid Hydrogen Cyanide

Liquid hydrogen cyanide (CHN) is a liquid that boils at 26° C and is stored in low pressure cylinders. With no stabilizer (e.g. 1% sulfuric acid) present polymerization can occur along with the production of ammonia which also helps catalyze the process. A crust can form on the liquid that, when jarred, can break off and fall into the liquid causing rapid exothermic polymerization and rupture of the cylinder causing fragmentation and release of this acutely toxic gas.

3.17.7. Alkali Metals

The alkali metals (such as potassium, sodium lithium and sodium-potassium alloys) can react with dissolved oxygen when stored under mineral oil to form oxides and superoxides that can catch fire upon cutting. The oxidation forms a yellow or orange crust or coating. Lithium stored under nitrogen can form nitrides and the formation of the nitride is autocatalytic and can eventually autoignite.
3.18. Nanotechnology Safety Procedures

Nanomaterials are defined as ultrafine particles with a dimension of one to 100 nanometers in diameter. One nanometer is one-billionth of a meter.

Low-solubility ultrafine particles are more toxic than larger particles on a mass-for-mass basis. In addition to the hazardous properties of the chemical constituents, their smaller dimensions, larger surface area, and ability to penetrate cell membranes more easily than larger particles add to the hazardous properties of these materials.

Because of their small particle size, they can be deposited deep into the lungs and, once in the bloodstream, may be able to cross the blood-brain barrier. Exposure to these materials during synthesizing processes and use may occur through inhalation, ingestion, and contact with the skin or eyes.

Other hazards to consider are catalytic effects and fire or explosion. Particles in the nanometer size range are currently being evaluated for toxicity and critical exposure levels based on mass, surface area, and the number of particles per unit volume. Until these factors are determined, workers should implement stringent controls on exposure when working with them.

The following guidelines, modified from the American Chemical Society, are provided to educate and protect those working with nanomaterials.

3.18.1. Lab Safety Guidelines for Handling Nanomaterials

- Use good general laboratory safety practices as found in the Laboratory Safety and Chemical Hygiene Plan.
- Wear gloves, lab coats, safety glasses, face shields, and closed-toed shoes. Be sure to consider the hazards of precursor materials in evaluating process hazards. OSHA's "Particularly Hazardous Substances" (such as cadmium) must be handled in a containment such as a fume hood or a glove box.
- Avoid skin contact with nanoparticles or nanoparticle-containing solutions by using appropriate personal protective equipment. Do not handle nanoparticles with your bare skin.
- If it is necessary to handle nanoparticle powders outside of a HEPA-filtered powered-exhaust laminar flow hood, wear appropriate respiratory protection. The appropriate respirator must be selected based on professional consultation with IUEHS from your respective campus. Refer to the IU Respiratory Protection Program for additional information.
- Use fume exhaust hoods to expel fumes from tube furnaces or chemical reaction vessels.
- Dispose of and transport waste nanoparticles according to the hazardous chemical waste guidelines.
- Vacuum cleaners used to clean up nanoparticles must be factory tested, HEPA-filtered units.
- Equipment previously used to manufacture or handle nanoparticles should be evaluated for potential contamination prior to disposal or reuse for another purpose.
- Lab equipment and exhaust systems should also be evaluated prior to removal, remodeling, or repair.
- Given the differing synthetic methods and experimental goals, no blanket recommendation can be made regarding aerosol emissions controls. This should be evaluated on a case by case basis.
- Consideration should be given to the high reactivity of some nanomaterials with regard to potential fire and explosion hazards.
3.19. **Hot Oil Bath and Other Heating Sources** – Procedures for Set-Up and Safe Operation

Personal injury or property damage can result from the use of hot oil or sand baths and other heating sources in the laboratory. Personal hazards include injury and burns from hot surfaces, liquids, vapors or flames. Contact burns may occur and range from minor to severe.

Use of these devices are frequently left unattended and must be monitored. Sources of ignition exist from electrical components, hot surfaces, hot liquids, or open flames. Uncontrolled fire or explosion may result in severe personal injury or injury to others and/or widespread property damage.

The following procedure applies to, but is not limited to, all of the following devices:

- Ovens
- Hot plates
- Heating mantles and tapes
- Oil baths
- Salt baths
- Sand baths
- Hot-air guns
- Microwave ovens

### 3.19.1. Administrative Controls and Set-Up

#### 3.19.1.1. Unattended Operations

- All unattended operations must have prior approval from the Principal Investigator, Lab Manager, or Lab Supervisor.
- Provide for containment of materials in the event of spills or failures.
- Label all containers and process equipment with the name of the material and special hazards.
- Post the contact name and number of the person performing the experiment on the lab door
- Keep lab lights on.

#### 3.19.1.2. Ovens, Furnaces, Heating Mantles, and Other Devices

- Burners, induction heaters, ovens, furnaces, and other heat-producing equipment must be located a safe distance from areas where temperature-sensitive and flammable materials and compressed gases are handled.
- Drying ovens should only be used for their intended purpose and not overloaded with combustible materials.
- Always use the grounded three-prong plug on all electrical devices and when using variable transformers.
- Older models of Variacs will keep whatever is plugged into them electrically live even though the Variac is switched off. Touching this device and ground at the same time could complete a circuit with your body and lead to electrocution. Always disconnect a Variac from the outlet before working with the device plugged into it.
- Check all glassware before using to ensure it is free of cracks and other imperfections. Do not use if in doubt.
- Discard heating mantles if the ceramic is cracked or the fiberglass is brittle or damaged.
- Do not use any electrical equipment if the wire insulation is cracked, frayed or wires are exposed in any way.
3.19.1.3. Hot Oil and Sand Baths

- Do not leave an operating sand or oil bath unattended unless it is equipped with a high-temperature shutoff and with a warning label.
- Know the flash point of the material when using oil baths. Consult the chemical manufacturer’s technical information prior to use. NEVER heat a bath fluid above its flash point. Watch for smoking of the oil; oil that is smoking is too hot and may burst into flames at any moment. If an oil bath starts to produce smoke, turn off the heat immediately.
- Baths should be mounted on a laboratory jack that can be lowered easily without danger of the bath tipping over to cool the bath in an emergency. Equipment should be clamped high enough above a hot plate or oil bath that if the reaction begins to overheat, the heater can be lowered immediately and replaced with a cooling bath without having to readjust the clamps holding the equipment setup.
- Place equipment in a central location in the fume hood such that an uncontrolled fire does not melt the rubber seal surrounding the inspection ports located at the sides of the fume hood.
- When using hot oil or sand for heating, mount the baths in such a way that they cannot be overturned or that water cannot fall into an oil or sand bath causing hazardous splattering.
- Oil expands in volume when heated. Overfilling should be avoided.
- Secondary containment for oil baths must be used to contain any possible spills.
- All oil baths must be labeled with the name of the oil and its maximum safe working temperature:
  
  “Hot Mineral (Silicone) Oil”
  “Do not allow the temperature to exceed _____ deg C”

- Store the oil or sand for reuse in a covered secondary container that is labeled with the name and maximum safe working temperature.

3.19.2. Engineering Controls

Use non-mercury thermometers, thermocouples, or bimetallic temperature indicators. Do not use a sand or oil bath unless it is equipped with a thermometer (non-mercury) or other temperature-indicating device.

- Heating equipment with circulation fans shall be equipped with an interlock arranged to disconnect current to the heating elements if the fan fails.
- Heated Constant Temperature Baths: NEVER heat a bath fluid above its flash point.
- Electrically heated constant temperature baths shall be equipped with over-temperature shutoff switches in addition to normal temperature controls.

3.19.3. Personal Protective Equipment

- Appropriate gloves, safety glasses and lab coats must be worn when handling chemicals, containers, apparatus, and heating equipment.
3.19.4. Emergency Response

- Regardless of the method used to heat something, a stuck contact, an electrical short circuit, uncontrolled chemical reaction, or other malfunction can cause a reaction to heat to dangerously high temperatures. Do not leave experiments unattended without prior approval, implementing proper precautions, and using the proper fail-safe devices.
- Know where the emergency gas shut off is for your lab when using Bunsen burners.
- Know where the nearest fire alarm pull box is in relation to your lab.
- Know how to use a fire extinguisher. Activate the fire alarm FIRST and use only 1 fire extinguisher (if you have been trained and are comfortable in using the extinguisher) before evacuating the area.
3.20. **Chemical Allergens** – Procedures for Safe Handling and Storage

Allergens include a wide variety of substances that can produce skin and lung hypersensitivity. Examples include diazomethane, chromium, nickel bichromates, formaldehyde, isocyanates, and certain phenols. Many substances of unknown allergic activity can also produce responses.

- Conduct all aerosol-producing activities in a fume hood.
- Use appropriate personal protective equipment in the laboratory for handling these chemicals (e.g., lab coat, safety glasses, and gloves).
- Select suitable gloves based on the chemical resistance to prevent hand contact.
- Remove personnel from exposure if allergic reactions appear.
- Seek medical attention when appropriate. Refer to Section 5.0, Medical Consultations and Examinations.
3.21. Reproductive Toxins, Mutagens, Teratogens, and Embryotoxins – Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) establishes the safety standards for use of hazardous chemicals in the workplace including reproductive chemical toxins. The OSHA Laboratory Safety Standard recommends that the Chemical Hygiene Plan include standard operating procedures for handling and storage of reproductive toxins including mutagens, teratogens, and embryotoxins.

Traditional definitions of “reproductive toxins” typically involve any agent that can damage the sperm, egg, fertilization and related processes. Agents that may cause adverse reproductive effects include chemical, biological, and radiological agents. Reproductive and developmental toxicity may affect the ability to reproduce and the development of the fetus and child.

The most recent definition of reproductive toxins according to the Globally Harmonized System of Chemical Classification and Labelling includes chemicals that cause adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on development of the offspring including adverse effects on or via lactation. Some reproductive toxic effects cannot be clearly assigned to either impairment of sexual function and fertility or to developmental toxicity however chemicals with these effects are classified as reproductive toxicants also.

The male reproductive system can be affected resulting in reduced sperm count, changes in the shape and performance of the sperm, contaminants being carried by the sperm, decreases in sexual performance, or damage to the sperm chromosomes. Females may experience infertility, subfertility, changes in menstrual cycle, miscarriage or premature births, and changes in the pregnancy, fertilized egg and developing fetus. Birth defects, developmental disorders or childhood cancer may also result. Reproductive hazards may not affect every worker or every pregnancy.

The Center for Disease Control’s (CDC) National Institute for Occupational Safety and Health (NIOSH) Registry of Toxic Effects of Chemical Substances (RTECS) identifies seven major categories with sixty-five specific effects including paternal and maternal effects, fertility effects, effects on the embryo or fetus, developmental effects, tumorigenic effects and effects upon the newborn.

3.21.1. Definitions

**Reproductive Toxicity** - Adverse effects on the health of the reproductive organs, endocrine system, or gametes (egg or sperm) from exposure to an exogenous agent. This exposure may result in effects such as menstrual dysfunction, impaired fertility, feminization/masculinization, or inability to maintain a pregnancy.

**Developmental Toxicity** - Adverse effects on the developing organism that may occur anytime from conception to sexual maturity. These effects may include spontaneous abortion, structural or functional defects, low birth weight, or effects that may appear later in life.

**Mutagens** - Agents that cause change in the genetic material (DNA) of an organism and therefore increase the frequency of mutations above the natural background level. These mutations are passed along as the cell divides sometimes leading to defective cells or cancer. Because the mutations may cause cancer, mutagens are typically also carcinogens.

Not all mutations are caused by mutagens. Spontaneous mutations occur due to errors in DNA replication, repair, and recombination. Chemical mutagens include substances such as ethidium bromide used as a stain for DNA analysis. Because the molecule fits easily in between the strands of DNA it is a potent mutagen.

**Embryotoxins** - Embryotoxins are, by definition, toxic to embryos. Embryotoxins are agents that may kill, deform, retard the growth, or adversely affect the development of
specific functions in the unborn child and cause postnatal functional problems. Embryotoxins include mercury compounds, lead compounds and other heavy metals, and organic compounds such as formamide.

**Teratogens** - Agents that can disturb or cause a malformation in the development of an embryo or fetus. Teratogens may cause a birth defect in the child or cause termination of the pregnancy.

**Reproductive Toxin** - Any hazardous substance that damages reproductive organs and can cause sterility or birth defects. The OSHA definition of reproductive toxins are chemicals that cause “adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on development of the offspring.”

**Particularly Hazardous Substances** - Reproductive toxins are included in a category of chemicals identified by OSHA as “Particularly Hazardous Substances” and must be handled in accordance with SOP 3.8, Particularly Hazardous Substances.

Personnel may only handle “particularly hazardous substances” in a containment (i.e., fume hood or glove box) or a closed system (instrument plumbing, syringe, gavage, cannula, etc.). There must be an area designated for use by posting signs or barriers and there must be procedures for decontamination of the tools and area after use and provisions for waste removal.

### 3.21.2. General Procedures

The presence of any reproductive toxins in the lab does not mean that personnel have been exposed, nor are they likely to experience adverse effects. However, personnel must use proper precautions while handling these substances and those of childbearing age or known pregnancies may need to exercise extra precautions.

It is very important to recognize the potential risks and intervene early because short-term exposures during a critical period can result in long-term health effects. All personnel, both men and women, handling reproductive toxins must follow these general procedures:

- Minimize all chemical exposures.
- Review the chemicals in use to identify these chemicals.
- Read the Safety Data Sheet (SDS) and follow the recommended precautions.
- Review the use of these materials with the principal investigator, lab manager, or lab supervisor.
- Review the continuing use of these chemicals annually or when a procedural change is made.
- Label the containers with the chemical name and the hazard (e.g., reproductive toxin).
- Store in an adequately ventilated area in an unbreakable secondary container.
- Notify supervisors of all incidents of exposure or spills.
- Seek medical attention when appropriate. Refer to Section 5.0, Medical Consultations and Examinations.
- Have a designated area (signs or barriers) for their use.
- Handle these substances only in a closed system (glass apparatus, instrument plumbing, syringe, gavage, cannula, etc.) or in a containment (fume hood or glove box) whose satisfactory performance has been confirmed.
- Use appropriate protective apparel (especially gloves) to prevent skin contact.
- Follow procedures for decontamination of the tools and area after use.
- Follow procedures for waste removal.
3.21.3. Pregnant Individuals

Women expecting a child should follow the general guidelines above and implement the following administrative, engineering, and personal protective equipment hazard controls to help minimize or eliminate chemical exposure.

Individuals may contact IUEHS for their respective campus in confidence to receive safety information about reproductive or developmental hazards posed by potential exposures any time without declaring actual, suspected, or planned pregnancy.

3.21.3.1. Administrative Controls

- Consult your personal physician and inform them of the activities and chemicals used in the laboratory. Follow the instructions provided by the physician explicitly.
- Avoid handling reproductive toxins, mutagens, teratogens, embryotoxins, or carcinogens.
- Avoid all chemical exposure if possible. Many chemicals have not been tested to determine their reproductive or toxicological properties. Therefore, if the Safety Data Sheet (SDS) does not have sufficient information they too should be avoided.
- Minimize the amount of time spent in the lab.
- Use job rotation or transfers to reduce exposures.
- Use substitute personnel to perform specific chemical procedures.
- Substitute a less hazardous agent to eliminate exposure.
- Modify work practices or laboratory procedures to reduce exposure.
- Review the laboratory chemical inventory to identify these chemicals. Contact IUEHS for your respective campus for assistance.
- Read the Safety Data Sheet (SDS) and follow the recommendations provided.
- Review the use of these materials with the research supervisor.
- Label the containers with the chemical name and the hazard (e.g., reproductive toxin).
- Avoid touching work surfaces and equipment, handling waste, and practice good personal hygiene, washing hands after touching surfaces.
- All laboratory personnel practice good chemical hygiene and follow the standard operating procedures found in the Laboratory Safety and Chemical Hygiene Plan.
- All laboratory personnel practice good housekeeping and keep work surfaces clean.
- Be aware that the use of PPE, fume hoods, etc., will minimize the risk of exposure but does not completely eliminate the risk.
- Leave the area immediately in the event of an accident or spill.

3.21.3.2. Engineering Controls

- Ensure that all laboratory personnel perform all chemical manipulations in fume hood.
- Ensure that the fume hood is operating properly. Check the latest evaluation sticker. Monitor the velocity meter (if present) and/or tape a tell-tale indicator (tinsel, yarn, or light weight string or thread) to the sash that visually indicates air flow.
- Ensure that all personnel use fume hoods properly with the sash in the proper operating position, not fully open, and closed when not in use.
3.21.3.3. **Personal Protective Equipment**

- Ensure that all laboratory personnel use personal protective equipment (PPE), gloves, lab coat, and eye protection.
- Gloves must be removed and placed in a closed waste bag prior to exiting the lab.
- Lab coats should remain in the laboratory at the end of the day and not taken home.
3.22. **Chemicals with Moderate Chronic and High Chronic Toxicity** - Procedures for Safe Handling and Storage

The Occupational Safety and Health Administration (OSHA) Laboratory Standard recommends that the Chemical Hygiene Plan include standard operating procedures for handling and storage of 1) chemicals with moderate chronic or high acute toxicity and 2) chemicals with high chronic toxicity. Procedures for chemicals of high acute toxicity are found in [SOP 3.8, Particularly Hazardous Substances](#).

This procedure provides information for the handling chemicals with moderate chronic or high chronic toxicity. Chronically toxic chemicals may include reproductive toxins, those that cause chronic organ damage, other human carcinogens or substances with high carcinogenic potency in animals. Some of these, such as human carcinogens and reproductive toxins, may also be considered “particularly hazardous substances” and must be handled in accordance with [SOP 3.8](#).

### 3.22.1. Definitions

**Acute** – Sudden effects that occur rapidly as a result of a single exposure or several exposures over a short period of time.

**Chronic** - Gradual effects that occur as a result of frequent exposure over a long period of time.

**Toxicity** – The ability of a substance to damage an organism including a description of the effect and the conditions or concentration under which the effect takes place.

Using the National Fire Protection Associations (NFPA) health hazard classifications, chemicals with “high toxicity” can generally be identified as those having an NFPA health hazard rating of 3 and 4 and chemicals with “moderate toxicity” as those having an NFPA rating of 1 or 2. Chemicals of “low toxicity” can be identified as those having an NFPA health hazard rating of 0.

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>NFPA 704 Health Hazard Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Oral LD$_{50}$</td>
<td>0-5 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD$_{50}$</td>
<td>0-40 mg/kg</td>
</tr>
<tr>
<td>Inhalation LC$_{50}$</td>
<td>0-1000 ppm</td>
</tr>
</tbody>
</table>

Comparing the former OSHA definition to the Globally Harmonized System (GHS) of chemical classification and labeling, the GHS acute toxicity ratings of 1 and 2 account for the chemicals with “high acute toxicity”. Therefore, the GHS acute toxicity ratings of 3 and 4 can generally be used to identify chemicals that are considered “moderately toxic.” Those with toxicity ratings greater than those found under GHS category 4 (i.e. > 2000 mg/kg, etc.) as chemicals of “low toxicity.”

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>GHS Acute Toxicity Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Oral LD$_{50}$</td>
<td>0≤5 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD$_{50}$</td>
<td>0≤50 mg/kg</td>
</tr>
<tr>
<td>Inhalation (gas) LC$_{50}$</td>
<td>0≤100 ppm</td>
</tr>
<tr>
<td>Inhalation (vapors) LC$_{50}$</td>
<td>0≤0.5 mg/l</td>
</tr>
<tr>
<td>Inhalation (dust &amp; mist) LC$_{50}$</td>
<td>0≤0.05 mg/l</td>
</tr>
</tbody>
</table>
3.22.2. Procedures for Chemicals with Moderate Chronic Toxicity

- Minimize exposure to these toxic substances by any route using all reasonable precautions.
- Consult one of the standard compilations that list toxic properties of known substances and learn what is known about the substance that will be used. Follow the specific precautions and procedures for the chemical.
- Use and store these substances only in designated (restricted access) areas placarded with appropriate warning signs.
- Use a hood or other containment device for procedures which may result in the generation of aerosols or vapors; trap released vapors to prevent their discharge with fume hood exhaust.
- Avoid skin and eye contact by using gloves, safety glasses, and lab coats.
- Always wash hands and arms immediately after working with these materials.
- Maintain chemical inventories, amounts used, and the names of the personnel involved.
- Be prepared for accidents and spills. At least two people should be present at all times if compounds in use are highly toxic or of unknown toxicity.
- Store breakable containers in chemically resistant trays.
- Work and mount apparatus above trays or absorbent, plastic backed paper.
- If a major spill occurs outside the hood evacuate the area and call for assistance.
- Assure that cleanup personnel wear suitable protective apparel and equipment.
- Thoroughly decontaminate or dispose of contaminated clothing or shoes. If possible, chemically decontaminate by chemical conversion to a less toxic product.
- Store contaminated waste in closed, suitably labeled, impervious containers.

3.22.3. Procedures for Work with Chemicals of High Chronic Toxicity

The following supplemental procedures are provided, in addition to those mentioned above, for work with substances of known high chronic toxicity (in quantities above a few milligrams to a few grams, depending on the substance):

- **Access:** Conduct all transfers and work with these substances in a “controlled area”: a restricted access hood, glove box, or portion of a lab, designated for use of highly toxic substances, for which all people with access are aware of the substances being used and necessary precautions.
- **Approvals:** Prepare a plan for use and disposal of these materials and obtain the approval of the principle investigator, lab manager, or laboratory supervisor.
- **Decontamination:** Protect vacuum pumps against contamination using scrubbers or HEPA filters and vent them into the hood. Decontaminate vacuum pumps or other contaminated equipment, including glassware, in the hood before removing them from the controlled area. Decontaminate the controlled area before normal work is resumed there.
- **Exiting:** On leaving a controlled area, remove any protective apparel (placing it in an appropriate, labeled container) and thoroughly wash hands, forearms, face, and neck.
- **Housekeeping:** Use a wet mop or a vacuum cleaner equipped with a HEPA filter instead of dry sweeping if the toxic substance was a dry powder.
- **Medical surveillance:** If frequently using such a substance on a regular basis (e.g., 3 times per week), consult a qualified physician concerning desirability of
regular medical surveillance. See Section 5.0 for additional information.

- **Records:** Keep accurate records of the amounts of these substances stored and used, the dates of use, and names of users.

- **Signs and labels:** Assure that the controlled area is conspicuously marked with warning and restricted access signs and that all containers of these substances are appropriately labeled with identity and warning labels.

- **Spills:** Assure that contingency plans, equipment, and materials to minimize exposures of people and property in case of accident are available.

- **Storage:** Store containers of these chemicals only in a ventilated, limited access area in appropriately labeled, unbreakable, chemically resistant, secondary containers.

- **Glove boxes:** For a negative pressure glove box, ventilation rate must be at least 2 volume changes/hour and pressure at least 0.5 inches of water. For a positive pressure glove box, thoroughly check for leaks before each use. In either case, trap the exit gases or filter them through a HEPA filter and then release them into the hood.

- **Waste:** Use chemical decontamination whenever possible; ensure that containers of contaminated waste (including washings from contaminated flasks) are transferred from the controlled area in a secondary container.
3.23. **Animal Work with Chemicals of High Toxicity – Safety Procedures**

All researchers administering chemicals to animals must identify and understand the hazards of the chemicals used in their research, select the proper procedures, hazard controls, personal protective equipment, and provide protocol-specific training to protect those handling the chemicals. University Environmental Health and Safety (UEHHS) will provide the OSHA compliant laboratory chemical safety training.

The chemicals of concern include anesthetics, drugs, controlled substances, carcinogens, allergens, intoxicants, reproductive toxins, embryotoxins, chemical toxins, and novel substances such as synthesized experimental drugs, chemicals, or mixtures. Less hazardous substances such as saline solution and buffers are not chemicals of concern and should be handled using standard chemical handling procedures.

Principal investigators may use the “Principal Investigators Chemical Hazard Assessment for Animal Research” form in Appendix A to perform a chemical hazard assessment for the chemicals in use. Use the guidelines below to determine if the chemical is a “particularly hazardous substance” and follow the required procedures. UEHHS will perform a chemical hazard evaluation during the protocol safety review process and provide guidance on personal protective equipment, regulatory compliance and safety procedures based on the hazardous properties of the chemicals.

**Note:** Safety Data Sheets for all laboratory chemicals are required to be maintained in the laboratory or on-line. The pertinent information for chemical hazard analysis is found on the Safety Data Sheet (SDS) and in the Laboratory Safety and Chemical Hygiene Plan. The SDS for the exact chemical or mixture must be used and provided by the manufacturer of the product.

### 3.23.1. Particularly Hazardous Substances

If the chemical is a carcinogen, reproductive toxin, or a chemical with a high degree of acute toxicity the Occupational Safety and Health Administration (OSHA) defines it as a "particularly hazardous substance" (Laboratory Safety and Chemical Hygiene Plan, Section 3.8). In addition, novel chemicals including those synthesized in research laboratories, that have not been tested explicitly for carcinogenic or toxic properties must be handled as “particularly hazardous substances” until the hazards have been evaluated because their hazards are unknown.

#### 3.23.1.1. Carcinogen

A substance that either causes cancer in humans or, because it causes cancer in animals, is considered capable of causing cancer in humans. OSHA identifies those that pose the greatest carcinogenic hazards as "select carcinogens" and includes carcinogens identified by OSHA, the National Toxicology Program (NTP) or the International Agency for Research on Cancer (IARC). The list is provided in the Laboratory Safety and Chemical Hygiene Plan, Appendix B.

#### 3.23.1.2. Reproductive Toxin

A substance that cause chromosomal damage or genetic alterations (mutagens) or substances that cause lethal or physical malformations or defects in a developing fetus or embryo (teratogens) and is given on the Safety Data Sheet (SDS).

#### 3.23.1.3. Chemicals with a High Degree of Acute Toxicity

These chemicals include both “highly toxic” and “toxic” chemicals with acutely toxic effects and are based on the route of entry and lethal dose (LD50) or concentration (LC50) given on the Safety Data Sheet (SDS).
3.23.1.4. Chemicals with High Chronic Toxicity

These chemicals include both “highly toxic” and “toxic” chemicals under the OSHA Hazard Communication Standard prior to 2012 with chronic toxic effects. This group may include human carcinogens or reproductive toxins and therefore must be handled as “particularly hazardous substances” also.

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>Highly Toxic</th>
<th>Toxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral LD₅₀ (albino rats)</td>
<td>≤ 50 mg/kg</td>
<td>&gt;50-500 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD₅₀ (albino rabbits, 24 hour)</td>
<td>≤ 200 mg/kg</td>
<td>&gt;200-1000 mg/kg</td>
</tr>
<tr>
<td>Inhalation LC₅₀ (albino rats, 1-hour) as vapor</td>
<td>≤ 200 ppm</td>
<td>&gt;200-2000 ppm</td>
</tr>
<tr>
<td>Inhalation LC₅₀ (albino rats, 1-hour) as dust, mist, or fumes</td>
<td>or ≤ 2 mg/liter</td>
<td>or &gt;2-20 mg/liter</td>
</tr>
</tbody>
</table>

The current OSHA definition under to the Globally Harmonized System (GHS) of chemical classification and labeling would include GHS acute toxicity ratings of 1 or 2 to account for chemicals with “high acute toxicity”.

For practical purposes, these chemicals may also be identified using the National Fire Protection Associations (NFPA) health hazard classifications found on the bottle label and Safety Data Sheet (SDS). In general, a chemical with a 3 or 4 in the blue diamond of the NFPA label can be considered to be a “particularly hazardous substance” (excluding cryogenics and some corrosives).

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>NFPA 704 Health Hazard Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Oral LD₅₀</td>
<td>0-5 mg/kg</td>
</tr>
<tr>
<td>Skin Contact LD₅₀</td>
<td>0-40 mg/kg</td>
</tr>
<tr>
<td>Inhalation LC₅₀</td>
<td>0-1000 ppm</td>
</tr>
</tbody>
</table>

3.23.2. General Procedures

- **Access and facilities:** For large scale studies, special facilities with restricted access are preferable. IUEHS conducts annual chemical safety inspections of the facilities and evaluation of safety equipment. Animal facilities must be posted with a sign to indicate that particularly hazardous substances are used in the area and to provide safety instructions. The “Animal Facility Safety Information” sign found in Appendix A is an example that shows the chemicals present, personal protective equipment, and any other special requirements for entry.

- **Administration of the toxic substance:** When possible, administer the substance by injection or gavage instead of in the diet. If administration is in the diet, use a caging system under negative pressure or under laminar air flow directed toward HEPA filters.

- **Aerosol suppression:** Devise procedures, such as lightly spraying bedding with water, which minimize formation and dispersal of contaminated aerosols, including those from food, urine, and feces (e.g., use HEPA filtered vacuum equipment for cleaning, moisten contaminated bedding before removal from the cage, mix diets
in closed containers in a hood).

- **Personal protection:** When working in the animal room, wear plastic or rubber gloves, fully buttoned laboratory coat or jumpsuit and, if needed because of incomplete suppression of aerosols, other apparel and equipment (shoe and head coverings, respirator).

- **Waste disposal:** Package contaminated animal tissues and excreta appropriately for disposal by IUEHS or waste disposal vendor. See “Waste Disposal and Handling” below.

### 3.23.3. Chemical Handling

- These chemicals must be used in a designated area. This includes live animals and open cages with chemically contaminated bedding. Signs must be posted to designate that the entire laboratory or portion of the laboratory such as a specific fume hood, glove box, or adjacent room as the designated area for that chemical use. This may be accomplished by using the emergency door sign and identifying the chemical groups used in the laboratory (i.e., carcinogen, reproductive toxin, highly toxic or toxic chemical).

- The chemical must be handled in a containment (if decanted or exposed to the open air) or within a closed system. This includes live animals and open cages with chemically contaminated bedding. Containment devices include chemical fume hoods, glove boxes, or biosafety cabinets that are vented outside of the building. Closed systems include plumbing within instruments, cannulas, syringes, gavages, etc., as long as the chemical is not exposed to the atmosphere. If no containment is available then personal protective equipment assigned to the protocol during the safety review must be utilized by all personnel in the area.

- Only the minimum quantity of the material should be used.

- Appropriate personal protective equipment (e.g., gloves, lab coat, and eye protection) must be used when handling these hazardous substances.

- Procedures for waste removal must be established prior to use. Follow standard IUEHS chemical disposal procedures. Follow biological waste disposal guidelines below for animals and bedding.

- Decontamination procedures must be developed for the tools and area.

- The principal investigator listed on the protocol is responsible for establishing the experimental procedure, determining the hazard controls to be utilized, and providing protocol-specific training for the staff. Prior approval from the principal investigator or supervisor is required for the experiment to begin (see Laboratory Safety and Chemical Hygiene Plan Section 2.1.1 Prior Approval of Hazardous Operations).

- The University Environmental Health and Safety (IUEHS) will provide the OSHA compliant laboratory chemical safety training. All personnel that handle any chemicals in the laboratory must attend chemical safety training required by the OSHA Laboratory Standard from IUEHS. Only laboratory personnel that have received IUEHS laboratory chemical safety training and protocol specific training from the principal investigator may work with these substances, and only within the designated area. These chemicals may not be decanted or exposed to the atmosphere outside a containment or closed system.
3.23.4. Chemical Storage and Labeling

- Acutely toxic chemicals, carcinogens and reproductive toxins must be stored designated areas for “particularly hazardous substances.”
- Storage areas should be clearly marked with the appropriate hazard warning signs.
- All containers of these substances (even in small quantities such as 0.1%) must be clearly labeled with the chemical name or components of the mixture and should be labeled with hazard information.
- Chemical storage areas should be secure to avoid spills or broken containers.
- Storage areas or laboratory rooms must be locked when laboratory personnel are not present.
- For more information, refer to Section 3.2, Procedures for Proper Labeling, Storage, and Management of Chemicals.

3.23.5. Waste Disposal and Handling

- Waste handlers must wear standard personal protective equipment (PPE) required for laboratory work, lab coat or gown, safety glasses, gloves and closed toe shoes.
- Respiratory protection is not required if procedures do not produce aerosols or if a fume hood, ventilated cage dump station, or biosafety cabinet is utilized but may be used voluntarily to protect against fugitive dust emissions.
- All waste including biological tissues and fluid, chemicals, contaminated materials, sharps, and other items must be properly disposed as detailed in the IU Biosafety Manual.
- Empty containers, with the exception of acutely toxic waste, may be triple rinsed and disposed of as sanitary waste.
- Chemical waste and contaminated materials are disposed of in accordance with the IU Waste Management Program.
- All animal carcasses and tissues are disposed of as medical waste to prevent unacceptable conditions in the sanitary waste containers and to ensure that transgenic animals are disposed of as regulated medical waste.
- Animal use protocols are reviewed by the IUEHS staff to identify any rare or unusual circumstances that would affect waste disposal or occupational safety.
- Animal carcasses must be frozen for disposal. Place materials in a red biohazard bag with a biohazard symbol. Double bag if necessary to prevent perforations. Place the bag in a freezer and contact IUEHS for your respective campus for pickup (except for the IUPUI campus and IUSOM locations where the carcasses are picked up for disposal by an approved vendor).
- Animal bedding is sanitary waste and is disposed of with other sanitary waste from the facility.
- Even though animal bedding is not typically an EPA hazardous waste or biohazardous waste it must be handled carefully for occupational safety purposes. Animal bedding from chemically dosed animals may contain dosed uneaten food or water and shedding or excretions that contain very small amounts of hazardous chemicals or their metabolites.
  
a) If the bedding is known to contain small amounts of chemicals in dosed food or otherwise, the bedding must be handled using fully buttoned lab coats or gowns, gloves, safety glasses in a ventilated dump station, biosafety cabinet, fume hood or with respiratory protection.
  
b) If it is unknown or inconclusive that the bedding contains these hazardous substances then the bedding must be handled as if it does using fully
buttoned lab coats or gowns, gloves, safety glasses in a ventilated dump station, biosafety cabinet, fume hood or with respiratory protection.

c) If the researcher can demonstrate the bedding or excreta does not contain hazardous amounts of these substances then the waste handling requirements may be modified.

- Empty cage bedding from dosed animals into a waste bag using a ventilated dump station or within a chemical fume hood or biosafety cabinet. Place the cage within the bag. Remove the lid. Empty the cage into the bag and remove the cage from the bag. Close and secure the bag.
3.24. Chemical Transportation Procedures

Movement or transportation of chemicals used in laboratories can occur for many purposes and to various destinations. They include the transportation of chemicals:

- Between laboratories or within a building (intra-building).
- Between buildings or departments (inter-building).
- Between IU campuses and properties.
- Into the field for research.
- To and from other institutions or agencies.
- To commercial waste facilities.
- To and from manufacturers or commercial facilities.
- To and from other institutions or agencies.

The procedures and additional training requirements for transporting chemicals for these purposes can be found in the IU Hazardous Materials Transportation Program.
3.25. Laboratory Closeout Procedures

Proper transfer or disposal of hazardous materials is required whenever a Principal Investigator or researcher with assigned laboratory space leaves the University or transfers to a different laboratory.

Plan the transfer or disposal of hazardous materials carefully. Hazardous materials such as chemicals, microorganisms, tissues, and radioactive materials can injure faculty, students, staff, contractors and visitors if handled inappropriately.

Failure to adhere to these procedures and manage hazardous materials properly during the lab closure may result in sanctions such as the loss of laboratory privileges or the recovery of the cost of disposal of unknown, unlabeled, or poorly managed hazardous chemicals. Any charges for improperly managed waste or excessive cleanouts will be assessed to the responsible department.

The primary responsibility for the proper management of all hazardous materials used in laboratories lies with the principal investigator or researcher assigned to the space. If the principal investigator is not the responsible individual for purposes of these procedures, documentation identifying the responsible individual must be provided on the Laboratory Decommissioning/Closeout Checklist (Appendix A, Form LCS-8). The department or unit is responsible for ensuring that the principal investigator manages and disposes of these materials properly. University Environmental Health and Safety (IUEHS) provides guidance and disposal services for the principal investigator and department or unit. Refer to the IU Waste Management Program for disposal information.

3.25.1. Notification and Inspection Process

3.25.1.1. Notify

Use the Rese  Searcher Departure/Lab Closeout Notification to notify IUEHS for the respective campus at least 30 days in advance:

a) That your laboratory is relocating on-campus or off-campus, or
b) That your laboratory is closing down, or

c) That a researcher within your laboratory group is departing.

3.25.1.2. Complete Checklist

Print and complete the following checklist to ensure that you have completed all activities required to properly prepare for your departure or move located in Appendix A, Form LCS-8.

3.25.1.3. Schedule Lab Clearance Inspection

Once you have completed all items on the checklist, and all chemical transportation and waste removal has been arranged, sign the checklist, and submit the online Lab Clearance/Closeout Inspection Request to IUEHS.

Have the checklist ready to go over with the Laboratory Safety personnel who conduct your clearance inspection. Final clearance will not be given until all decontamination and hazardous material removal is complete.
3.25.2. General Closeout Guidelines

- Package and move items only during normal business hours (8:00 a.m. to 5:00 p.m., Monday through Friday) so IUEHS staff will be available to assist in case of a spill or accident.
- Never transport hazardous materials alone.
- Follow the IU Hazardous Materials Transportation Program for all chemical transportation.
- Wear appropriate personal protective equipment for the materials being handled.
- Review the location of safety glasses, eyewashes, fire extinguishers, and exits if the closeout involves moving to another campus lab.

3.25.3. Departing Student Researchers

- Turn in all waste bottles to IUEHS for disposal prior to departure. See the IU Waste Management Program.
- Dispose of all samples or identify, label, and transfer ownership.
- Turn in their unused chemicals to IUEHS, or
- Transfer the responsibility for the chemicals to someone remaining in the lab (i.e., identify/document who the new Responsible Individual is for the chemicals on the Laboratory Decommissioning/Closeout Checklist, Form LCS-8) and identify substances by chemical name in case of a need for future disposal.

3.25.4. Chemicals

- Determine if any chemicals are usable* and if you or anyone at IU would like to keep them. Document transfer of responsibility for any identified chemicals to a party willing to accept them using the checklist. If you are not going to keep them and a new user cannot be found, dispose of the materials through IUEHS by following the procedures in the IU Waste Management Program.

* Chemicals that cannot be considered usable and transferred to another user include the following:
  - Leaking containers
  - Handwritten labels (Chemicals in primary or secondary containers with handwritten labels can be retained, but cannot be transferred to another user.)
  - Deteriorating or illegible labels
  - Cracked or poorly sealing lids
  - Non-commercial mixtures/solutions
  - Expired chemicals
  - Compressed gases or pressurized liquids (unless specific approval has been given by IUEHS)
  - Mercury in any form
  - Samples (unless they have been identified and labeled with a full
proper chemical name – no abbreviations, acronyms, chemical structures, or reference numbers or initials)

- Waste containers

- Refer to the [IU Waste Management Program](https://www.iu.edu/noc) for waste disposal procedures. Do NOT evaporate chemicals, flush hazardous chemicals down the drain, or discard them in the trash.
- Characterize any "unknown" substances found in the lab according to standard procedures or knowledge of the substances. IUEHS can provide guidance upon request.
- Label all chemical containers with the proper chemical name. Abbreviations, chemical formulas or structures are not acceptable.
- Ensure that all containers are securely closed. Empty all beakers, flasks, evaporating dishes, etc. into appropriate containers with tight-fitting lids. Parafilm can be used to minimize odors as needed, but is not an acceptable lid.
- Remove all chemicals from refrigerators, freezers, fume hoods, bench tops, shelves and storage cabinets.
- Prepare all chemicals for disposal according to [IU Waste Management Program](https://www.iu.edu/noc). This process may take quite some time. Start at least one month before planned departure from the laboratory. Complete chemical waste removal before vacating the laboratory. At IUB and IUPUI allow two weeks for waste collection to occur after notifying IUEHS that the waste is properly prepared for pickup.
- Refer to the [IU Hazardous Materials Transportation Program](https://www.iu.edu/noc) for any chemicals being kept or transferred that need to be moved.
- Clean all areas of chemical use and storage, including benchtops, storage cabinets, fume hoods, incubators, refrigerators, freezers, etc. Soap and water, or surfactant-based cleaners are effective for most contamination.
- Collect broken glass, sharps, and other laboratory waste.

### 3.25.5. Shared Storage Areas

- Shared facilities include storage units such as stock rooms, walk-in refrigerators, constant temperature rooms, shared refrigerators, freezers, flammable liquids cabinets, waste collection areas, etc.
- They are of special concern if more than one person manages the area.
- Carefully inspect any shared facility in order to locate and appropriately dispose of the hazardous materials for which that researcher is responsible.

### 3.25.6. General Laboratory Cleaning

- Wash off fume hood surfaces and clean counter tops.
- Notify your department and IUEHS for the respective campus when laboratory clean-up is complete to arrange a closeout or clearance inspection.
3.25.7. Controlled Substances

- The U.S. Drug Enforcement Agency (DEA) issues controlled substance registrations to individual researchers. Refer to the IU Controlled Substances Program for additional information.
- Abandonment of a controlled substance is a violation of the DEA permit under which it was held.
- Permission to transfer a registration for a controlled substance to another individual must be approved and documented by the DEA.
- Relocation of controlled substance inventories to any new campus location or to a new research institution is prohibited unless the Indiana Board of Pharmacy and the US DEA are notified first. Contact IUEHS for more information.

3.25.8. Gas Cylinders

- Remove gas connections, replace cylinder caps, and return cylinders to suppliers or prepare them for transfer if you will be moving them to a new location within IU. Refer to the IU Compressed Gas Cylinder Safety Program for additional guidance on cylinder management and to the IU Hazardous Materials Transportation Program for information about cylinder transportation.
- If cylinders are non-returnable, please refer to the IU Waste Management Program for disposal guidance of waste compressed gases and pressurized liquids.
- Refer to SOP 3.9, Compressed Gases, for additional information.

3.25.9. Animal and Human Tissues

- Determine if any biological materials are usable and if you or anyone at IU would like to keep them. Document transfer of responsibility for any identified materials to a party willing to accept them using the checklist (Appendix A, Form LCS-8).
- Refer to the IU Biosafety Manual for disposal guidance for all biological waste materials that are not being kept or transferred.
- Refer to the IU Hazardous Materials Transportation Program for any biological materials being kept or transferred that need to be moved.
- If tissue was stored in a refrigerator or freezer - defrost, clean and disinfect the refrigerator and freezer after it has been emptied. Use an appropriate disinfectant.
- Questions or concerns regarding biological materials should be directed to IUEHS Biosafety for your respective campus.

3.25.10. Microorganisms and Cultures

- Notify IUEHS Biosafety for your respective campus of any transfer of NIH Risk Group 2 agents or higher
- Notify IUEHS Biosafety for your respective campus of the intent to transfer NIH Risk Group 2 agents or higher from the University. Because such transfers may fall under Department of Transportation (DOT) shipping regulations and/or require additional permits, they must be arranged well in advance.
• Refer to the IU Biosafety Manual for waste decontamination and disposal guidance.

3.25.11. Mixed Hazards

• Occasionally it is necessary to dispose of materials that may contain more than one hazard. Contact IUEHS for information on the disposal of any combination of chemically contaminated, biohazardous materials, and/or radioactive materials.

3.25.12. Sharps

• Refer to the IU Waste Management Program for guidance on sharps disposal based on the type of contamination on the sharps.

3.25.13. Radioactive Materials

• Contact the Radiation Safety Office to relocate any radioactive materials to another laboratory, to remove these materials from the University or the radioactive material inventory, for decontamination of the work area, and to conduct a final survey of the vacated area.
• Authorized radioactive materials use permit holders are responsible for notifying the Radiation Safety Officer for their authorized location of any changes that would affect their permit, such as departure from the University, change of personnel authorized as users of radioactivity under the permit, and changes in authorized inventory, including purchase, disposal, and transfers.
• Only Radiation Safety personnel can conduct a final radiation clearance on a radioactive materials use area and remove the radioactive materials door sign.

3.25.14. Equipment

• Alert IUEHS and/or Facilities Management if any exhaust or filtration equipment was used with heated perchloric acid digestion.
• Clean and disinfect laboratory equipment that is staying before departing. This includes refrigerators, freezers, drying ovens, incubators, centrifuges, etc. For equipment in which biohazardous material or microbial agents were used or stored, use an effective disinfectant. Cleaned equipment must be marked as clean.
• If moving biological safety cabinets, decontaminate before moving and recertify before use in the new location.
• Deface or cover hazard labels on equipment to be moved or discarded.
• Repair any damaged equipment (i.e. frayed wires, missing guards, etc.) that will remain in service. No damaged equipment should be moved. Use the laboratory downtime to accomplish previously undiscovered or neglected repairs.
• Contact Surplus Stores/Property on your respective campus to arrange disposal of equipment that can be effectively decontaminated and is functional. If equipment cannot be effectively decontaminated, contact IUEHS. All equipment disposed through Surplus must be decontaminated, marked as clean, and have all hazard
warning labels removed prior to transfer to Surplus.

- When discarding laboratory equipment, remove capacitors, transformers, mercury switches, mercury thermometers, radioactive sources, chemicals and biohazards before disposal. Contact IUEHS for your respective campus for any equipment that may contain asbestos or any of these materials.