Explosive and Highly Reactive Chemicals

Introduction

Several laboratory chemicals become explosive or highly reactive when exposed to certain environmental conditions (e.g., heat, fire, water, air, etc.). Others become explosive or reactive when they contact incompatible materials, polymerize vigorously, are allowed to dry out, decompose, or encounter sources of friction or mechanical shock. Due to the high hazards associated with such compounds, appropriate procedures, control measures, personal protective equipment and training are imperative to ensure safe use. Planning is imperative to avoid serious accidents. Failure to comply with safety measures can lead to explosions, fires, property damage, and serious injuries.

Classes of Highly Reactive or Explosive Chemicals

The Occupational Safety and Health Administration (OSHA) classifies many chemicals as highly reactive or explosive. A table of the hazard classes, pictograms, definitions, and examples of each class is listed below.

Hazard Class	Pictogram(s)	Definition	Examples
Explosives		An explosive chemical is a solid or liquid chemical which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings.	▪ Benzoyl peroxide Dinitrophenol ▪ Lead azide ▪ Nitroglycerin Nitrocellulose ▪ Picric acid
Chemicals which, in contact with water, emit flammable gases		Chemicals which, in contact with water, emit flammable gases are solid or liquid chemicals which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.	▪ Alkali metals ▪ Calcium carbide ▪ Metal alkyls ▪ Grignard reagents ▪ Sodium hydride ▪ Zinc powders

Organic peroxides		Organic peroxide means a liquid or solid organic chemical which contains the bivalent -0-0- structure and as such is considered a derivative of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals.	▪ Acetaldehyde ▪ Diethyl ether ▪ Isopropyl ether ▪ Potassium metal ▪ Tetrahydrofuran
Pyrophoric Liquids		Pyrophoric liquid means a liquid which, even in small quantities, is liable to ignite within five minutes after coming into contact with air.	▪ tert-Butyllithium ▪ Diethylzinc ▪ Grignard reagents ▪ Tributylphosphine ▪ Trimethylaluminum
Pyrophoric Solids		Pyrophoric solid means a solid which, even in small quantities, is liable to ignite within five minutes after coming into contact with air.	▪ Alkali metals ▪ Finely divided metals ▪ Metal hydrides ▪ White Phosphorus
Self-Heating		A self-heating chemical is a solid or liquid chemical, other than a pyrophoric liquid or solid, which, by reaction with air and without energy supply, is liable to self-heat; this chemical differs from a pyrophoric liquid or solid in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days).	▪ Lithium tert-butoxide ▪ Potassium sulfide anhydrous ▪ Sodium dithionite ▪ Thiourea dioxide ▪ Titanium disulfide
Self-Reactive		Self-reactive chemicals are thermally unstable liquid or solid chemicals liable to undergo a strongly exothermic decomposition even without participation of oxygen (air).	▪ 2,2'Azobisisobutyronitrile ▪ 3-azidosulfonylbenzoic acid

Standard Operating Procedures

Due to the inherent risks involved with the use of explosive or highly reactive chemicals, lab personnel must take measures to identify hazards, assess risks, and control hazards prior to engaging in active experimentation. Conducting "dry runs" of high hazard experiments is recommended to reinforce proper techniques, safety measures, and emergency procedures. The guidelines listed below must be followed when handling high hazard chemicals.

Administrative Controls

- Safety training must be provided by the principal investigator or other qualified personnel to all researchers working with explosive or highly reactive chemicals. **Documentation** of the training is recommended.
- Read the safety data sheet (SDS) for each chemical prior to use.
- Eliminate, substitute with a less hazardous chemical, or reduce the quantity of high hazard chemicals being used, if possible.
- Develop a standard operating procedure to communicate the hazards and safe work practices.
- Use the minimum quantity of chemical(s) needed to achieve the desired outcome.
- Do not work alone with explosive or highly reactive chemicals.
- Never deviate from standard operating procedures (e.g., scale up reactions) unless previously discussed and agreed upon with the principal investigator or other qualified supervisor.
- Verify the proper equipment and safeguards for an experiment by calculating an estimate of the heat and pressure that may be generated.
- Alert other laboratory personnel on what experiment is being conducted, what the potential hazards are, and when the experiment will be run.
- Restrict access to areas where high-scale reactions are taking place. Post a warning sign when an experiment is in progress.

Work Practice Controls

- Assemble equipment to enable the immediate removal of any heat source, cooling of the reaction vessel, or cessation of reagent additions in case of a runaway reaction.
- Label all secondary containers holding explosive or highly reactive materials with the chemical name(s) and hazard class(es).
- Use non-sparking plastic devices when stirring, cutting, scraping, or agitating explosive or highly reactive compounds. Do not use metal or wooden devices.
- Ensure safety devices (e.g., high temperature controls, water overflow devices, etc.) are used to help identify and mitigate potential incidents.

- Ensure heating baths consist of nonflammable materials.
- Inspect chemicals known to become explosive when dry regularly (e.g., picric acid). Contact EHS if dry, shock sensitive chemicals are discovered.
- Label chemicals known to become explosive after a period of time (e.g. **peroxide forming chemicals**) with the date the bottle arrived in the lab and the date the bottle was first opened. Dispose of expired peroxide-forming chemicals through EHS.
- Keep all sources of ignition away from explosive or highly reactive chemicals.
- Ensure a properly functioning eyewash station, safety shower, and other emergency equipment are readily available in the work area where explosive or highly reactive materials are in use.

Engineering Controls

- Perform work involving explosive or highly reactive chemicals in a fume hood, glove box, or with another form of ventilation. Fume hood sashes only provide protection against chemical splashes, fires, and minor explosions. In some cases, acrylic sliding shields may need to be installed in hoods or glove boxes to help protect workers from glass fragments resulting from laboratory-scale explosions.
- Use properly rated safety shields, barricades, and guards, if necessary, to protect personnel and equipment from injury or damage. Barriers must surround the entire hazardous area.
- Separate reactions as far as possible from one another and use appropriate shielding if more than one hazardous reaction must be performed simultaneously.
- Use adequate grounding to prevent static sparks from acting as ignition sources. An antistatic gun or antistatic ionizer is recommended.
- Consider using remote control equipment (e.g., mechanical arms, stopcock turners, labjack turners, remote cable controllers, and closed-circuit television monitors) to minimize exposure.
- Evaluate whether an armored laboratory chemical hood or barricade made with thick (1.0 in.) poly (vinyl butyral) resin shielding and heavy metal walls is necessary for work with certain explosive chemicals.

Personal Protective Equipment

- Wear personal protective equipment indicated in safety data sheet (SDS) or the workplace hazard assessment form.
- Wear ANSI Z87.1 certified splash goggles, at a minimum, for eye protection. Full length face shields that protect the face and throat are recommended if a risk of splashing, spraying, or explosion exists.

- Wear chemical-resistant gloves as indicated in the safety data sheet when handling high hazard chemicals. Heavy duty leather or other protective gloves may be required if lab personnel need to reach behind a shielded area while an experiment is in progress.
- Wear flame-resistant lab coats. Lab coats must be buttoned, fit properly, and cover as much skin as possible.
- Wear wool or other heavy, tight weave fabric shirts, long pants, and other clothing underneath fire-resistant lab coats and other personal protective equipment. Synthetic clothing (e.g., polyester, nylon, acetate, rayon, acrylic, etc.) should be avoided.
- Wear closed toed footwear that covers the entire foot.
- Additional personal protective equipment may be necessary based on the chemicals in use and the risks involved.

Storage

- Follow the manufacturer storage requirements (i.e., a flammable refrigerator, a flammable liquid storage cabinet, etc.) for explosive and highly reactive chemicals.
- Store in a designated storage area or cabinet with limited access.
- Store away from incompatible materials.
- Keep away from ignition sources such as open flames, hot surfaces, sparks, electrical sources, and direct sunlight.
- Store in chemically compatible secondary containers.
- Never store unlabeled chemicals.

Additional Resources

- **Occupational Safety and Health Administration- Chemical Reactivity Hazards**
- **Occupational Safety and Health Administration- Physical Hazard Criteria**
- **Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards**