**Potentially Explosive Compounds**

**STANDARD OPERATING PROCEDURE (SOP)**

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

**All personnel subject to these SOP requirements must review a completed SOP and sign the associated training record. Completed SOPs must be kept in the laboratory’s safety binder or be otherwise readily accessible to laboratory personnel. Electronic access is acceptable. SOPs must be reviewed, and revised where needed, as described in the** [**SJSU Chemical Hygiene Plan**](https://www.sjsu.edu/fdo/departments/ehs/lab/Chemical_Hygiene_Plan.pdf)**. Note that not all hazardous chemicals are appropriately addressed in a single Hazard Class SOP, and some chemicals are subject to several Hazard Class SOPs.**

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| Date SOP Written:  |  |  | Approval Date: |  |
| SOP Prepared by: | **REQUIRED - Insert Preparer's Name** |
| SOP Reviewed and Approved by (name/signature): | **REQUIRED - Insert Approver's Name & Signature** |
| Department:  | **REQUIRED - Insert Department** |
| Principal Investigator/Laboratory Supervisor:  | **REQUIRED - Insert Name** | Phone:  | **REQUIRED - Insert Phone#** |
| Emergency Contact(s):  | **REQUIRED - Insert Name** | Phone:  | **REQUIRED - Insert Phone#** |
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| Location(s) covered by SOP: | Building: | **REQUIRED - Insert Name** |  Phone: | **REQUIRED - Insert Phone#** |
| Room #(s):  | **REQUIRED - Insert Number** |

1. **HAZARD OVERVIEW**

This document applies to the use and handling of Potentially Explosive Compounds (PECs) in research for their chemical or physical properties rather than their explosive properties. PECs are a broad class of materials which can be defined as “Any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation, or other suitable initiation, undergoes rapid chemical change evolving large volumes of highly heated vapors or gases—typically H2O, N2 or CO2—that exert pressure on the surrounding medium,” which can lead to catastrophic container/vessel failure.

Source: *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*, Section 4.D.3.1 Explosive Hazards. National Academies Press: Washington DC, 2011.

Materials of each detonation or decomposition type have their own specific handling requirements which **MUST** be addressed by the user prior to use. Additionally, many PECs do not carry the relevant GHS codes for explosion hazards, and the lack thereof does not imply that a material is not a PEC. The Safety Data Sheet (SDS) for many PECs note the conditions under which they become explosive. This information is generally located in sections 2.3, 7.2, or 10 of the GHS-compliant SDS. *Bretherick’s Handbook of Reactive Chemical Hazards* (physical copy available at SJSU library) is an excellent resource for identifying PECs and the conditions under which they become explosive.

Note that this SOP does not cover time-sensitive, peroxide-forming compounds. For more information on these materials, refer to the [SJSU Chemical Hygiene Plan](https://www.sjsu.edu/fdo/departments/ehs/lab/Chemical_Hygiene_Plan.pdf).

1. **HAZARDOUS CHEMICAL(S)/CLASS OF HAZARDOUS CHEMICAL(S)**

Before using any PEC, it is essential to understand the potential triggers which lead to explosion or violent decomposition (this can be shock, friction, light, pressure, static electricity, heat, or moisture). Find lists of representative PECs below. **Note: These lists are not comprehensive!**

Also note that PECs present additional hazards due to byproducts of explosions such as shrapnel, burns, and fires. Furthermore, the PECs discussed here may also be covered by other SOPs such as Pyrophoric Materials, Corrosive Materials, Acutely Toxic Solids and Liquids, etc.

The table below summarizes some of the more common functional groups found in PECs (replicated from UC Berkeley’s PEC SOP written by Professor Richmond Sarpong).

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| **Atom grouping within a Molecule** | **Example of functional Group** |
| **Structure** | **Name** |
| **C-C and C-N triple bonds and their metal salts** |  | Acetylenic; cyano |
| **Adjacent N-O atoms- many combinations** | R3C-NO2; R3C-O-N=O | Aryl nitro, alkyl nitro; alkyl nitrite |
| **Adjacent and consecutive N atom pairs, triplets and higher** | R2C=N2; R3C-N3 | Diazo; azide |
| **Adjacent O-O pairs** | -C-O-O-H; C-O-O-C | Peroxyacids; peroxyesters; peroxides |
| **Adjacent C atoms bridged by O or N and many ring combinations of 4 or fewer atoms** |  cid:DCB7D089-5872-4A5D-9A37-ED71F5B91E3D | Epoxides; azetidines |
| **O-X atomic pairs** | -O-X; ClO3 | Hypohalites; chlorates; oximes |
| **Many N-Metal atomic pairs** | =N-M | N-metal salts |

PECs are an extremely nebulous, poorly-defined group of materials. The following list provides a general description of some of the triggers that may cause PECs to explode or violently decompose:

1. **Shock/impact-sensitive materials:** PECs may explode when subjected to a sudden compression in the form of a shock or impact. This shock/impact may come from dropping or roughly placing a container on a hard surface, grinding in a mortar, or scraping with a spatula.
	* Examples of shock/impact sensitive PECs include picric acid, organic peroxides, heavy metal azides/acetylides/fulminates, nitrogen triiodide, nitrate esters, nitro compounds, metal perchlorates, and many others.
2. **Friction-sensitive materials:** PECs may explode when exposed to varying levels of friction. This friction may come from the motion of a stir bar, sweeping with a brush or dry tissue, grinding in a mortar, scraping with a spatula, seating a ground glass joint, or rotating a threaded connection.
	* Examples of friction sensitive materials include picric acid, organic peroxides, azide compounds, alkali fulminates, and many others.
3. **Heat sensitive materials**: Most PECs will decompose violently or explosively at elevated temperatures. Consider all sources of heat before performing a reaction involving a heat sensitive material, and ensure the reaction temperature remains as low as is practical.
4. **Moisture sensitive materials:** PECs may explode on contact with water, and should be kept in strictly anhydrous conditions.
	* Examples include the reduction of ruthenium salts with sodium borohydride, which results in solid products that detonate on contact with water. Other PECs (such as heavy metal acetylides) may violently decompose on contact with water, generating heat and releasing flammable or explosive gases.
5. **Pressure sensitive materials:** PECs may become unstable above certain absolute pressures. All work with pressure sensitive materials must be controlled by pressure regulators, and suitable relief valves should be used to prevent over-pressurization.
	* Acetylene is a notable example that may undergo explosive polymerization/decomposition above 29 psi (15 psig) when initiated by heat or shock.
6. **Light sensitive materials:** These exceptionally sensitive PECs may explode on exposure to sufficiently bright light.
	* Examples of light sensitive materials include hydrogen/chlorine mixtures, nitrogen trihalides, silver nitride, and several heavy metal azides, acetylides, and fulminates.
7. **Materials sensitive to static electricity:** PECs may explode when exposed to electrostatic discharge. Care should be taken to prevent the build-up of static electricity when working with PECs, either through the use of anti-static tools or suitable grounding. Please note: if a material can become explosive, it can likely be initiated by static electricity.
	* Examples of materials sensitive to static electricity include lead azide, lead styphnate, hydrazine, and many others.

**REQUIRED:** List (or attach) the chemical(s) in your inventory and describe important properties (e.g. conditions under which the PEC becomes explosive). Also list the signs/symptoms of exposure. The chemical’s Safety Data Sheet (SDS), [PubChem](https://pubchem.ncbi.nlm.nih.gov/)’s Laboratory Chemical Safety Sheet (LCSS), and *Bretherick’s Handbook of Reactive Chemical Hazards* are excellent sources for this information.

1. **ENGINEERING/VENTILATION CONTROLS**

Work with PECs must be carried out in a glovebox or properly functioning certified chemical fume hood with the sash closed as much as possible. If use in a fume hood or glovebox is not possible contact EH&S for advice at ehs@sjsu.edu.

The use of a blast shield may be necessary in certain cases (e.g. a reaction containing or generating PECs is to be left stirring unattended overnight). ANY laboratory with PECs in their inventory should have access to such equipment. The blast shield should be affixed to the work surface. Lastly, storage of PECs may require dedicated refrigeration or blast cage reinforced desiccators.

**REQUIRED:** Describe the lab-specific engineering or ventilation controls and equipment safety features (if applicable) that will be used to reduce the risk of chemical exposures, explosions, or injuries from working with Potentially Explosive Compounds.

**INSERT IF APPLICABLE:** Describe materials, activities, or reactions that require the use of a properly affixed blast shield.

1. **ADMINISTRATIVE CONTROLS**

The following elements are required:

1. Complete laboratory safety training prior to working in the laboratory;
2. Complete laboratory-specific safety orientation and training on laboratory-specific safety equipment, procedures, and techniques to be used, including the location of laboratory safety equipment (emergency eyewash, safety shower, fire extinguisher);
3. Demonstrate competency to perform the procedures described in this SOP to the Principal Investigator (PI) or trainer;
4. Be familiar with the location and content of any Safety Data Sheets (SDSs) for the chemicals used (online SDSs are available from [MSDS online](https://msdsmanagement.msdsonline.com/8511b604-100d-449a-9a6b-366eff19da04/ebinder/?nas=True));
5. Inspect all equipment and experimental setups prior to use;
6. Follow best practices for the movement, handling, and storage of hazardous chemicals (see Chapters 5 and 6 of [Prudent Practices in the Laboratory](http://ucanr.edu/sites/ucehs/files/133892.pdf) for more detail). An appropriate spill cleanup kit must be located in the laboratory. Chemical and hazardous waste storage must follow an appropriate segregation scheme and include appropriate labeling. Hazardous chemical waste must be properly labelled, stored in closed containers, in secondary containment, and in a designated location;
7. Do not deviate from the instructions described in this SOP without prior discussion and approval from the PI; and
8. Notify the PI of any accidents, incidents, near-misses, or unexpected outcomes involving the Potentially Explosive Compounds (PECs) described in this SOP.

**The following are also required for use of PECs:**

1. Understand and describe the conditions under which the PECs listed in your chemical inventory become explosive;
2. Understand and describe known incompatibilities with PECs used in your laboratory. At a minimum, consult *Bretherick’s Handbook of Reactive Chemical Hazards* (physical copy available at SJSU library). Even extremely small quantities of unintentional side products can have disastrous effects;
3. All personnel sharing or using any space where PECs are used or stored shall be trained on this SOP;
4. Amounts of PECs stored in laboratories shall be minimized;
5. Waste containing PECs should be disposed promptly and the quantity kept to a minimum;
6. Always run reactions involving PECs on a small scale. Each lab shall define a safe working limit for each PEC used in the laboratory. Contact ehs@sjsu.edu for advice;
7. Before scaling up reaction quantities or changing reaction conditions (e.g. change in temperature, pressure, concentration, etc.) contact ehs@sjsu.edu for a hazard assessment; and

**REQUIRED:** Insert the laboratory-specific restrictions on maximum quantities to be used or stored, including any special handling or storage requirements.

**INSERT IF APPLICABLE:** Describe any additional administrative controls (e.g. restrictions on working alone/procedure/work equipment/work locations/unattended operations).

1. **PERSONAL PROTECTIVE EQUIPMENT (PPE)**

At a minimum, long pants (covered legs) and closed toe/closed heel shoes (covered feet) are required to enter a laboratory or technical area where hazardous chemicals are used or stored.

In addition to the minimum attire required upon entering a laboratory, the following PPE is required for work with Potentially Explosive Compounds:

1. **Eye Protection** (must be ANSI Z87.1-compliant)**:**
2. At a minimum safety glasses are necessary.
3. Splash goggles may be substituted for safety glasses, and are required for processes where splashes are foreseeable or when generating aerosols.
4. Ordinary prescription glasses are not acceptable eye protection and cannot be used in lieu of proper safety eyewear.
5. Depending on the hazard assessment, a face shield may be required and be worn over safety eyewear.
6. **Body Protection**: At a minimum a chemically-compatible laboratory coat that fully extends to the wrist is necessary. A chemically-compatible lab coat may be substituted for other types of body protection (e.g. apron, disposable sleeves, etc.) so long as the substituted protection provides similar or better protection to the researcher.
7. If a risk of fire exists, a flame-resistant laboratory coat that is NFPA 2112-compliant should be worn.
8. For chemicals that are corrosive and/or toxic by skin contact/absorption additional protective clothing (e.g. face shield, chemically-resistant apron, disposable sleeves, etc.) are required where splashes or skin contact is foreseeable.
9. **Hand Protection**: Hand protection is needed for the activities described in this SOP. Define the type of glove to be used based on:
10. The chemical(s) being used;
11. The anticipated chemical contact (e.g. incidental, immersion, etc.);
12. The manufacturers’ permeation/compatibility data; and
13. Whether a combination of different gloves is needed for a specific procedural step/task;

Note: Cotton or other static-reducing over gloves should be considered when working with static-sensitive PECs.

**REQUIRED:** Insert lab-specific descriptions of PPE and hygiene practices used with Potentially Explosive Compounds, including any specialized PPE needed for a procedural step or specific task.

1. **SPILL AND EMERGENCY PROCEDURES**

Do not attempt to clean up a chemical spill unless you have been trained and feel comfortable doing so. This is especially critical with spills containing PECs. Contact the College Safety Team or Environmental Health & Safety (EH&S), for help with cleaning up a small chemical spill. For a large spill of PECs, confine the spill within the fume hood or room, evacuate everyone from the lab, and call 911 (or 408-924-2222 from a non-campus phone).

Before you begin work with known PECs, you **MUST** develop a spill plan for each specific chemical or chemical class used. This ensures that those containing or cleaning up the spill know how to accomplish the task safely.

In case of a spill of a known PEC, the chemical-specific procedures described herein **MUST** be followed. For example, NEVER clean up a sodium azide spill by sweeping the material into a metal dustpan. This compound is both shock sensitive and subject to formation of metal azides (which are more sensitive than the sodium salt itself) upon exposure to metal.

**REQUIRED:** Descriptions of all spill cleanup procedures for the PECs used or described in this SOP.

1. **WASTE MANAGEMENT AND DECONTAMINATION**

**Waste Management:**

Hazardous waste must be managed as outlined in [SJSU’s Chemical Hygiene Plan](https://www.sjsu.edu/fdo/departments/ehs/lab/Chemical_Hygiene_Plan.pdf), and must be [properly labeled](http://www.science.sjsu.edu/safety/HazWasteForm.pdf).

**NEVER** combine a PEC waste stream with other materials with potential incompatibilities (e.g. never place acids or bases in a waste container which also contains acrolein or other highly polymerizable materials).

Minimize waste containing PECs and dispose promptly.

**REQUIRED:** Insert description(s) of laboratory-specific information on the waste streams generated, storage location, and any special handling/storage requirements.

**Decontamination:**

Decontamination procedures vary depending on the material being handled. All surfaces and equipment should cleaned after work with PECs to prevent hazardous material accumulation.

Carefully inspect work areas to make sure no hazardous materials remain. Clean contaminated work areas with an appropriate cleaning agent, and dispose of cleaning materials properly. Be sure all ignition sources are secured before beginning clean up with flammable liquids.

**REQUIRED:** Insert description(s) of decontamination procedures for equipment, glassware, and/or controlled areas (e.g. gloveboxes, restricted access hoods, or designated portions of the laboratory).

Upon completion of work with Potentially Explosive Compounds and/or decontamination of equipment, remove gloves and/or PPE to wash hands and arms with soap and water. Additionally, upon leaving a designated PEC work area remove all PPE worn and wash hands and forearms as needed. Contaminated clothing or PPE should not be worn outside the lab. Soiled lab coats should be sent for professional laundering. Grossly contaminated clothing/PPE and disposable gloves must disposed of as hazardous waste.

1. **DESIGNATED AREA**

The area where PECs are used (and stored) must be clearly marked with a hazard sign such as “Potentially Explosive Compounds in Use.” Only label the appropriate cabinet, shelving, or secondary containment and the specific area of immediate use. DO NOT post PEC hazard labels on exterior doors or walls, or in any area viewable by and/or accessible to the public.

**REQUIRED**: Insert description(s) of the designated area(s) for Potentially Explosive Compounds in your laboratory. The entire laboratory, a portion of the laboratory, a fume hood, etc. can be designated.

1. **DETAILED PROTOCOL**

Detailed here are general handling guidelines for PECs:

1. Handle all PECs with care. Place containers gently on counters, and clamp reaction vessels to prevent inadvertent shocks.
2. If a free-flowing PEC has aggregated, **DO NOT** scrape or chip at the material to dislodge it. Contact EH&S for disposal.
3. Avoid using a mortar and pestle as it can initiate an explosion.
4. Ensure all glassware to be used is free of defects (e.g. star cracks). A polariscope can be used to check for cracks that cannot be seen with the naked eye.
5. When placing PECs into laboratory glassware with ground glass joints, ensure none of the material remains on the joint before assembly.
6. Use of metal or ceramic tools (e.g. spatulas) is discouraged. Some PECs will react with metal surfaces, and ceramics can create sufficient friction or pressure to initiate a reaction. Plastic tools are generally preferred, though the generation of static electricity must be taken into account.
7. Consider any sources of heat that may change the temperature of a reaction (e.g. heat of mixing/reaction, mechanical heating from stirring, loss of cooling, etc.), as this may alter reaction rates or initiate an explosion.

**REQUIRED:** Insert or attach the lab-specific protocol for the process, hazardous chemical(s), or hazard class described in this SOP. Include any relevant resources such as journal articles, patents, etc. as desired.

**TEMPLATE REVISION HISTORY**

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| --- | --- | --- | --- |
| **Version** | **Date Implemented** | **Author** | **Revision Notes:** |
| **1.0** | **6/17/2021** | **Alexi Ball-Jones** | **New template** |
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**LAB-SPECIFIC REVISION HISTORY**

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| **Version** | **Date Approved** | **Author** | **Revision Notes:** |
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**Documentation of Standard Operating Procedure Training**

*(Signature of all users is required)*

* Prior to using **Potentially Explosive Compounds (PECs)**, laboratory personnel must be trained on the hazards described in this SOP, how to protect themselves from these hazards, and emergency procedures.
* Ready access to this SOP and to a Safety Data Sheet for each hazardous material described in the SOP must be made available.
* The Principal Investigator (PI), or the Laboratory Supervisor if the activity does not involve a PI, must ensure that their laboratory personnel have attended appropriate laboratory safety training or refresher training within the last three years.
* Training must be repeated following **any** revision to the content of this SOP. Training must be documented. This training sheet is provided as one option; other forms of training documentation (including electronic) are acceptable but records must be accessible and immediately available upon request.

**Designated Trainer:** *(signature is required)*

I have read and acknowledge the contents, requirements, and responsibilities outlined in this SOP:

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| **Name** | **Signature** | **Trainer Initials** | **Date** |
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