1. **Purpose**

This SOP covers the precautions and safe handling procedures for the use of Carbon Monoxide, an Acutely Toxic Gas (ATG).

For a list of ATGs covered by this SOP and their use(s), see the “List of Chemicals”. Procedures described in Section 12 apply to all materials covered in this SOP.

*If you have questions concerning the applicability of any recommendation or requirement listed in this procedure, contact the Principal Investigator/Laboratory Supervisor or the campus Chemical Hygiene Officer at ucbcho@berkeley.edu.*

2. **Acutely Toxic Gases Information**

Before working with any Acutely Toxic Gases (ATGs), review the UC-Berkeley EH&S publication *Toxic Gas Program on the EH&S website*. If you have questions about Toxic Gas Program requirements, contact EH&S at 642-3073.

Rev. Date: 2021-06-29
3. Potential Hazards/Toxicity

Toxic gases are gases that may cause significant acute health effects at low concentrations. Health effects may include severe skin or eye irritation, pulmonary edema, neurotoxicity, or other potentially fatal conditions.

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) designates ATGs by one or more of the following H codes:

- **H280** Contains gas under pressure; may explode if heated
- **H330** Fatal if inhaled
- **H331** Toxic if inhaled
- **H332** Harmful if inhaled
- **H333** May be harmful if inhaled

ATGs may also have other hazardous properties in addition to acute toxicity (e.g. corrosivity, pyrophoricity). Safe use requires assessing all potential hazards.

It is the Principal Investigator’s responsibility to ensure activity-specific laboratory procedures and/or processes are taken into account when using this Chemical Class SOP.

Please, review the SDS of any chemical before use (see Section 11 – SDS Location). The following information is not intended to replace the SDS.

**Specific Hazards/Toxicity for Carbon Monoxide**

- **H220** - extremely flammable gas
- **H280** - contains gas under pressure; may explode if heated
- **H331** - toxic if inhaled
- **H360** - may damage fertility or the unborn child
- **H372** - causes damage to organs (central nervous system) through prolonged or repeated exposure

It is a colorless, odorless, poisonous and extremely flammable gas. Carbon Monoxide is a chemical asphyxiant and may be fatal if inhaled. Exposure to Carbon Monoxide can cause nausea, dizziness, headaches, and collapse. Carbon Monoxide poses a serious fire hazard when it is accidentally released. Flame or high temperature impinging on a localized area of the cylinder of Carbon Monoxide can cause the cylinder to explode without activating the cylinder’s relief devices. Provide adequate fire protection during emergency response situations.

The most significant route of over-exposure for Carbon Monoxide is by inhalation.

**INHALATION:** Carbon monoxide is classified as a chemical asphyxiant, producing a toxic action by combining with the hemoglobin of the blood and replacing the available oxygen. Through this replacement, the body is deprived of the required oxygen, and asphyxiation occurs. Since the affinity of carbon monoxide for hemoglobin is about 200-300 times that of oxygen, only a small amount of Carbon Monoxide will cause a toxic reaction to occur. Carbon Monoxide exposures in excess of 50 ppm will produce symptoms of poisoning if breathed for a sufficiently long time. Other effects of exposure can be summarized as follows:
CONCENTRATION OF GAS OBSERVED EFFECT

All exposure levels: Over-exposure to Carbon Monoxide can be indicated by the lips and fingernails turning bright red.

200 ppm: Slight symptoms (headache, discomfort) after several hours of exposure.

400 ppm: Headache and discomfort experienced within 2-3 hours of exposure.

1,000 -2000 ppm: Within 30 minutes, slight palpitations of the heart occur. Within 1.5 hours, there is a tendency to stagger. Within 2 hours, there is mental confusion, headache, and nausea.

2000-2500 ppm: Unconsciousness within 30 minutes.

>2500 ppm: Potential for collapse and death before warning symptoms are produced.

NOTE: At high altitudes, individuals may be more susceptible to Carbon Monoxide over-exposures. Development of symptoms may also occur more rapidly if individuals are doing physically demanding tasks. Individuals who have heart conditions may experience a more rapid onset of symptoms. During recovery, victims can experience headaches, vision problems, and memory loss.

HEALTH EFFECTS OR RISKS FROM EXPOSURE:

Over-exposure to Carbon Monoxide may cause the following health effects:

**ACUTE**: Carbon Monoxide is a toxic gas. Symptoms of Carbon Monoxide poisoning can develop gradually, or can arise suddenly, depending on the concentration and duration of exposure. Lips and fingernails will turn bright red, which is a significant sign of Carbon Monoxide over-exposure. Other symptoms of over-exposure can include headache, shortness of breath, wheezing, dizziness, indigestion, and nausea. At high concentrations unconsciousness or death may occur. Symptoms can include blurred vision and memory loss.

**CHRONIC**: Clinical studies indicate that there is a relationship between exposure to Carbon Monoxide in specific occupations (i.e., fire-fighters, foundry workers) and an increased incidence of cardiovascular problems. Carbon Monoxide is a reproductive toxin. Refer to Section 11 of this MSDS for further information.

**TARGET ORGANS**: Respiratory system, circulatory system, cardiovascular system, reproductive system.

4. Engineering Controls

Use the engineering controls listed below unless other lab-specific information is included in the Protocol/Procedure section.

- Work with ATGs must be conducted in a fume hood unless other controls are designated in the lab-specific Protocol/Procedure section. Sash height must be kept low to avoid escaping fumes and provide a physical barrier.
- Indoor storage of all gas cylinders in this program must be in a mechanically ventilated, lockable area. Examples of mechanical ventilated areas include exhausted gas cabinets, fume hoods, and special fire code compliant gas storage rooms.
- All cylinders and gas cabinets must be clearly labeled with content and hazard information.
- All regulators, valves, piping, tubing and fittings must be chemically compatible with the gases being used. Regulators must be compatible with the size and type of gas cylinder being used and rated for full cylinder pressure. Consult your gas supplier for approved regulators, valves, piping, tubing, and fittings.
- Cylinders must be stored upright, with tank valves securely closed and valve protection cap in place, and firmly secured to prevent falling or being knocked over.
5. **Personal Protective Equipment**

At a minimum, the following PPE must be worn at all times.

**Eye and Face Protection**

A. ANSI Z87.1-compliant safety glasses with side shields, or chemical splash goggles.
   - Ordinary prescription glasses will NOT provide adequate protection unless they also meet ANSI standard and have compliant side shields.

B. If the potential for explosion/splashing exists, and adequate coverage is not provided by the hood sash, a face shield must be worn.

**Skin and Body Protection**

1. Gloves are required when handling hazardous chemicals.
   - Refer to specific chemical SDS for information on glove selection.
   - For additional information on glove selection, go to: http://ehs.berkeley.edu/hs/63-laboratory-safety/94-glove-selection-and-usage.html

2. Lab coats are required when handling hazardous chemicals in the lab. Select the type of lab coat according to the hazards at the specific workplace.

3. Long pants, closed-toe/closed-heel shoes, covered legs, and ankles.

**Respiratory Protection**

Respiratory protection is normally not required for UC Berkeley laboratory activities. Any lab personnel considering the use of a respirator must contact EH&S for a workplace assessment.

6. **First Aid Procedures and Medical Emergencies**

*In the event of an injury, notify your supervisor immediately and EH&S within 8 hours.*

⚠️ Go to the Occupational Health Facility (Tang Health Center, on campus); if after hours, go to the nearest emergency room (Alta Bates, 2450 Ashby Ave in Berkeley); or

⚠️ Call 911 (from a cell phone: 510-642-3333) if:
   - it is a life threatening emergency; or
   - you not are confident in your ability to fully assess the conditions of the environment and/or the condition of the contaminated/injured person, or you cannot be assured of your own safety; or
   - the contaminated/injured person is not breathing or is unconscious.
Please remember to provide a copy of the appropriate manufacturer SDS (if available) to the emergency responders or physician. At a minimum, be ready to provide the identity/name of any hazardous materials involved.

In case of skin contact
If skin contact occurs, and/or skin or clothing are on fire, immediately drench in the safety shower with copious amounts of water for no less than 15 minutes to remove any remaining contaminants. If possible to do so without further injury, remove any remaining jewelry or clothing.

In case of eye contact
Rinse thoroughly with plenty of water using an eyewash station for at least 15 minutes, occasionally lifting the upper and lower eyelids. Remove contact lenses if possible.

If inhaled
Move into fresh air.

7. Special Handling, Storage, and Disposal Requirements

Lab-specific information on handling and storage may be included in the Protocol/Procedure section.

Precautions for safe handling

- Do not drag, roll, slide or drop cylinders. A suitable hand truck, to which the cylinder is secured, must be used for cylinder movement.
- When transporting gases outside the lab, the protective cap must be in place and must cover the valve.
- Never attempt to lift a cylinder by its cap.
- Secure cylinders at all times while in use and during transport.
- Once cylinder has been connected to process, open valve slowly and carefully. If experiencing difficulty opening cylinder valve, discontinue use and contact supplier. Do not attempt to force freeing “frozen” or corroded valves.
- Regulators and valves must be kept free of moisture. Systems must be purged with dry inert gas (e.g. helium, nitrogen, argon, etc.) before the product is introduced and when system is out of service.

Conditions for safe storage

- It is essential that all ATGs be stored separately from all chemicals with which they may react. Ensure segregation of incompatible chemicals per guidance within EH&S guidelines. Also, follow any substance-specific storage guidance provided in Safety Data Sheet (SDS) documentation.
- All compressed gas cylinders must be stored upright with valve cover caps in place. Damage to a valve can cause the cylinder to become a dangerous projectile. Cylinders must be properly secured with two non-combustible restraints to prevent them from falling at all times.

Disposal

- All empty gas cylinders must be labeled as empty; however, empty cylinders may still contain some toxic gas, so must remain in exhausted enclosures or fire code compliant gas storage rooms. Depleted gas cylinders must be returnable to the vendor according to their guidelines.

8. Chemical Release
Chemical Release Dial 911

- Accidental Release – Help contaminated or injured persons. If conditions and time permit, close any open valve. Evacuate the release area. Avoid breathing vapors. Eliminate sources of ignition. Keep others from entering this area (e.g., use caution tape, barriers, etc.). Notify supervisor and EH&S immediately.
- Contact with body or clothes – Remove clothing and rinse body thoroughly in emergency shower for at least 15 minutes. Seek medical attention. Notify supervisor and EH&S immediately.
- Contact with Eyes – Immediately rinse eyeballs and inner surface of eyelid with water for 15 minutes using an eyewash station by forcibly holding the eye open. Seek medical attention. Notify supervisor and EH&S immediately.

9. Cleaning and Decontamination

Lab-specific information on decontamination may be included in the Protocol/Procedure section.

All lines or ducts carrying purged or exhausted emissions of gases must be connected to a mechanical exhaust system that discharges to a safe location (i.e., presents no potential for re-entrainment into any building supply air intake or occupied area). Construction of the exhaust ducts must be chemically resistant to degradation by the gas in use. Significant emissions of corrosive or toxic gases require an emission control device (e.g., scrubber, flare device, adsorbent) before the purged gas can be vented into the exhaust duct system. Refer to Toxic Gas Program.

10. Hazardous Waste Disposal

Label Waste
- All empty gas cylinders shall be labeled as empty

Dispose of Waste
- Depleted gas cylinders should be returnable to the vendor according to their guidelines.
- Contact EH&S at 642-3073 if you need assistance.

11. Safety Data Sheet (SDS) Location

SDS can be accessed online at http://ucsd.com
-Take **Ownership of Your Safety**-

Before starting any work, ask yourself:

1. What will I be doing?
2. Do I know what the hazards are?
3. Do I have everything I need to do the job safely?
4. Am I doing the job safely?
5. What can we do better?
# Acutely Toxic Gases

## Chemical Class Standard Operating Procedure

**Berkeley EH&S**

## 12. Protocol/Procedure – Acutely Toxic Gases (ATGs)

<table>
<thead>
<tr>
<th>Procedure/Use</th>
<th>Scale</th>
<th>Engineering Controls/Equipment</th>
<th>PPE (eye, face, gloves, clothing)</th>
<th>Procedure Steps and Precautions</th>
</tr>
</thead>
</table>
| 1. Use for STM/ncAFM tip preparation. | Up to a lecture bottle. | Conduct all operations in the designated space in Hildebrand Hall D61. Use only the permanently installed and approved equipment and lines. Set up a CO monitor whenever the lecture bottle is in use. Use with adequate ventilation. Provide natural or explosion-proof ventilation adequate to ensure Carbon Monoxide does not reach its lower flammability limit of 12.5%. Open flames and possible sparking and static electricity must be avoided. | **Eye protection**: Wear ANSI Approved tight-fitting safety goggles or safety glasses with side shields.  
**Face protection**: Face shields are to be used when there is no protection from the hood sash.  
**Hand protection**: Confirm the compatibility of the gloves you use with the specific ATG. General guidance (unless otherwise specified in the specific SDS): at a minimum, 8 mil minimum nitrile gloves must be used to prevent incidental contact. For gas release or for potential contact with larger quantities, use double nitrile or heavier gauge nitrile or neoprene gloves. Gloves must be inspected prior to use. Remove gloves immediately upon contamination. Wash and dry hands after use.  
**Clothing**: Wear lab coat; full length pants or equivalent; and close-toed, close-heeled shoes. | The deposition of carbon monoxide utilizes a leak valve that connects the UHV chamber and a small carbon monoxide cylinder. The UHV system should have good ventilation during the deposition process: the turbo pump and the roughing pump on the system should be turned on, and the roughing pump should be connected to the building ventilation system.  
Be aware of any signs of dizziness or fatigue; exposures to fatal concentrations of Carbon Monoxide could occur without any significant warning symptoms. Non-sparking tools should be used. Do not attempt to repair, adjust, or in any other way modify the cylinders containing Carbon Monoxide. Make sure the Carbon Monoxide detector works normally. |

**Notes**

Any deviation from this SOP requires approval from PI.
13 - Documentation of Training (signature of all users is required)

- Prior to conducting any work with ATGs, designated personnel must provide training to his/her laboratory personnel specific to the hazards involved in working with this substance, work area decontamination, and emergency procedures.

- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the relevant SDSs provided by the manufacturer.

I have read and understand the content of this SOP:

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Identifier</th>
<th>Date</th>
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Rev. Date: 2021-06-29
## Appendix – List of Acutely Toxic Gases (non-exhaustive list)

<table>
<thead>
<tr>
<th>Chemical Name/Formula</th>
<th>CAS#</th>
<th>Chemical Name/Formula</th>
<th>CAS#</th>
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<tbody>
<tr>
<td>Ammonia NH₃</td>
<td>7664-41-7</td>
<td>Arsenic pentafluoride AsF₅</td>
<td>7784-36-3</td>
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<td>Arsine AsH₃</td>
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<td>Boron trichloride BCl₃</td>
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<td>Boron trifluoride BF₃</td>
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<td>Carbon monoxide CO</td>
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<td>Cyanogen C₂N₂</td>
<td>460-19-5</td>
<td>Cyanogen chloride NCl₂</td>
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<td>Fluorine F₂</td>
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<td>Germane GeH₄</td>
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<td>Hexaethyltetraphosphinate C₁₂H₂O₃P₄</td>
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<td>Hydrogen bromide HBr</td>
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<td>Hydrogen Chloride HCl</td>
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<td>Hydrogen fluoride HF</td>
<td>7664-39-3</td>
<td>Hydrogen sulfide H₂S</td>
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<td>Hydrogen selenide H₂Se</td>
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<td>Selenium hexafluoride SeF₆</td>
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<td>Sulfur tetrafluoride SF₄</td>
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<td>Trimethylsilyldiazomethane (CH₃)₃SiCHN₂</td>
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Acutely Toxic Gases
Chemical Class Standard Operating Procedure
Berkeley EH&S

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<tr>
<th>Chemical(s)</th>
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<tbody>
<tr>
<td>Carbon monoxide</td>
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