**Standard Operating Procedure**

**Gases Under Pressure**

*Print a copy of this SOP and insert into your Safety on Site (SOS) Binder.*

|  |  |
| --- | --- |
| **Department:** |  |
| **Date SOP was written:** |  |
| **Date SOP was approved by PI/lab supervisor:** |  |
| **Principal Investigator:** |  |
| **Principal Investigator Signature:** |  |
| **Internal Lab Safety Coordinator/Lab Manager:** |  |
| **Lab Phone:** |  |
| **Office Phone:** |  |
| **Emergency Contact:** | *(Name and Phone Number)* |
| **Location(s) covered by this SOP:** | *(Building/Room Number)* |

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

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**Purpose**

The purpose of this standard operating procedure is to acquaint you with the proper and safe handling, use, storage and disposal of the subject chemicals.

**Subject Chemicals Used in this Laboratory**

Refer to the banded laboratory chemical inventory located in the SOS binder for a listing of all chemicals in this laboratory that this SOP applies to. In addition, the banded inventory includes chemical-specific notations that supplements the information provided in this SOP (e.g., special hazards, handling, PPE).

**Properties & Hazards**

Chemicals in this band present hazards based on the pressurized nature of their storage and use. All chemicals in this band are considered generally hazardous and the band is generally defined as follows:

* gases which are contained in a receptacle at a pressure of 29 p.s.i. (200 kPa) or more at 20 ºC
* gases which are liquefied or liquefied and refrigerated

The GHS and Cal/OSHA definition of the band is described in the table below:

|  |  |  |  |
| --- | --- | --- | --- |
| **UCI Hazard Level** | **GHS Category** | **GHS H-Code** | **Cal/OSHA Definitions** |
| Highly Hazardous | All chemicals in this band are considered generally hazardous. | | |
| Generally  Hazardous | Gases Under Pressure | H280, 281 | Compressed Gas |

In addition, UCI groups compressed gases by hazard class based on toxic, flammable, oxidizing and corrosive properties. Specifies storage and handling guidelines apply to each hazard class. The hazardous properties of gases are defined as follows:

* Toxic Gases
  + UCI: Gases are grouped into four classes based on the lethal concentration to 50% of test animals (rats) of each gas (LC50).
    - Class I, ≤ 200 ppm
    - Class II, >200 ppm , ≤ 2000 ppm
    - Class III, >2000 ppm, ≤ 5000 ppm
    - Class IV, > 5000 ppm
* Corrosive Gases
  + Are considered highly hazardous under the Corrosives & Irritants hazard band.
* Flammable Gases
  + Are considered highly hazardous under the Flammables hazard band.
* Oxidizing Gases
  + Are considered highly hazardous under the Oxidizers hazard band.

A listing of hazard classifications for various compressed gases is included in Appendix B.

**Administrative Controls**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

General practices:

1. Be sure to review the Safety Data Sheet (SDS) for all chemicals to be used in the experiment.
2. Never work alone. At least one other person must be present in the same laboratory when any work involving hazardous chemicals is being done.
3. Eliminate or substitute for a less hazardous material when possible.
4. Design your experiment to use the least amount of material possible to achieve the desired result.
5. Verify your experimental set-up and procedure prior to use. Be familiar with the Safety Data Sheets for all chemicals in use. Assess the hazards to ensure that appropriate controls are in place to minimize risk and address emergency shut-down procedures as appropriate.
6. Consult with the PI if the work involves procedure scale-up or other large quantities or there are any questions regarding appropriate safety procedures.

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| Band-specific practices:   1. Incorporated into the “Special Handling and Storage Requirements” section below. |

**Engineering Controls**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

General practices:

1. In general, it is preferable to perform all work with hazardous chemicals in a fume hood. Sash height should be kept as low as possible to avoid the escape of vapors, gases and particulates.
2. Supplemental equipment such as blast shields should be used when working with chemicals or processes that may result in explosions or pressure releases.
3. Consider the use of a glove box, toxic gas cabinet or other local exhaust in order to further contain hazards as appropriate.

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| Band-specific practices:   1. Various engineering controls are incorporated into the “Special Handling and Storage Requirements” section below. |

**Personal Protective Equipment (PPE)**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

**Respiratory Protection**

Respiratory protection is generally not required for lab research, provided the appropriate engineering controls are employed. Respirators should be used only under any of the following circumstances:

Lab personnel intending to use/wear a respirator mask must be trained and fit-tested by EH&S. This is a regulatory requirement. If you think that your process may require respirator use, contact EH&S for assistance (<http://www.ehs.uci.edu/programs/ih/respiratory.html>)

**Hand Protection**

Disposable nitrile gloves provide sufficient protection for most routine lab operations involving small quantities. They should be changed if liquid is splashed onto them. They are not appropriate for longer operations or operations using larger quantities.

For longer operations, or operations using larger quantities, use thicker gloves made from a material appropriate for the specific chemical in use (e.g., natural rubber, butyl, neoprene, nitrile, PVA). When working chemicals or processes that increase the risk of exposure to fire, use hand protection appropriate to both the risk of chemical exposure and the risk from fire. Gloves must be inspected prior to use for signs of wear or damage. Such gloves should be disposed of in accordance with appropriate laboratory disposal practices.

Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with any chemical residues on the surface. Wash and dry hands after use.

For additional information on selection of glove material, review the specific chemical Safety Data Sheet. Consult with your preferred glove manufacturer’s website to ensure that the gloves you plan on using are compatible with a specific chemical substance. Common manufacturer glove selection guidance can be found at::

<http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf>

<http://www.allsafetyproducts.biz/page/74172>

<http://www.showabestglove.com/site/default.aspx>

<http://www.mapa-pro.com/our-gloves/protections/chemical-protection/b/handled_product.html>

**Eye Protection**

Use safety glasses with side shields or tightly fitting safety goggles whenever working in the laboratory.

**Skin and Body Protection**

Long pants, closed toed-shoes, shirt and a lab coat must be worn whenever working in the laboratory. Flame resistant Nomex® lab coats should be used when working with chemicals or processes that increase the risk of fire. Fully extend sleeves to the wrists and keep buttoned at all times. Avoid wearing synthetic clothing when practicable.

**Hygiene Measures**

Wash hands immediately and thoroughly after handling chemicals. Any contaminated clothing should be disposed of or washed before reuse.

**Special Handling & Storage Requirements**

In addition to the practices described below, follow procedures as specified in the lab-specific section of this SOP.

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| Band-specific practices:  **Storage Areas**   1. Store full and empty cylinders separately to avoid confusion. Serious back flow can occur when an empty cylinder is attached to a pressurized system. 2. Select a cool, dry, and well-ventilated area.    1. Cool areas minimize pressure increases that can result from heat or direct sunlight.    2. Dryness deters rust and corrosion.    3. Ventilation is essential in case of leaks.    4. Never store compressed gas cylinders (with the exception of compressed air) in environmental rooms (i.e., refrigerated cold rooms or warm rooms). These rooms are not well ventilated and could pose a serious safety concern should a cylinder fail. 3. Arrange storage facilities to permit inventory rotation, using cylinders in order as received from the supplier. 4. Do not store cylinders next to doors or in corridors where they could possibly obstruct emergency exit from the building. 5. Designate an area to store empty cylinders for return to the supplier. An area on or adjacent to your building's loading dock is suitable. 6. Separate oxidizers or other incompatibles (e.g., oxygen) from flammables by at least 20 feet, or by a non-combustible wall.   **Storage Guidelines**   1. Determine which hazard class your gas belongs to by referring to the “Properties & Hazards” section above and the gas listing in Appendix A. Ensure it meets all requirements specified for the class as described in Appendix B and below. 2. Implement these ideal storage practices for class IV compressed gas cylinders:    1. Restrain cylinders - During the 1994 Northridge earthquake, gas cylinders that had been double-chained and bolted to a secure surface stayed in place. Single-chain restraints were not as successful. C-clamps did not work at all. Restrain cylinders as follows:       1. Store cylinders upright and secure them to a substantial, fixed surface with upper and lower restraints made of non-combustible material, preferably chain and Unistrut®.       2. Position the upper restraint no less than 1 foot from the shoulder of the cylinder. Position the lower restraint no less than 1 foot from the floor.       3. C-clamps or bench mounting brackets are not allowed!       4. Multiple cylinder restraint - Limit 3 cylinders to each double-chain restraint system.    2. Properly label the cylinders and storage area.    3. Cap cylinders when not in use.    4. Store cylinders away from non-compatibles.    5. Store empty cylinders separately from full cylinders. 3. Do not keep non-corrosive gases longer than 5 years from the last hydrostatic test date (usually stamped just below the neck of the cylinder) unless otherwise regulated. 4. Return all cylinders that appear unsafe or show signs of corrosion, dents, dings, pitting, bulging, etc. 5. Review your cylinder inventory monthly.    1. Return cylinders to the vendor if they're no longer being used. This removes potential hazards and saves on cylinder rental fees (cylinders are typically rented or leased, rather than purchased) and possible reconditioning fees.    2. Note: Some vendors charge a reconditioning fee on each cylinder that is not returned within 2 years. This fee may be significant in relation to the actual cost of the gas. 6. In addition to standard storage requirements listed above, employ special precautions for cylinders containing flammable, oxidizing, or corrosive gases (empty or full) as described below    1. **Flammable gases**       1. Separate from cylinders containing oxidizing gases by a minimum distance of 20 feet or by a noncombustible partition extending not less than 18 inches above and to the sides of the stored material.       2. When approved gas storage cabinets are used, the cabinets must be equipped with fire sprinklers. (**Note:** Fire code piping and connection requirements may apply for your facility. Consult the EH&S Chemical Hygiene Officer.       3. Never store flammable gas near ignition or heat sources, or unprotected electrical connections.       4. Keep quantities to a minimum. There may be circumstances where using a pure flammable gas may pose unacceptable risks. It may be necessary to purchase a reduced concentration mixture (e.g., 1% hydrogen and 99% argon).       5. If you need large volumes (more than 1 large cylinder), contact the EH&S Chemical Hygiene Officer,    2. **Oxidizing gases**       1. Do not permit oil or grease to come in contact with compressed oxidizing gases — explosions may occur!       2. Separate oxidizers from cylinders containing flammable gases by a minimum distance of 20 feet or by a noncombustible partition extending not less than 18 inches above and to the sides of the stored material.       3. Never store oxidizers near flammable solvents, combustible materials, unprotected electrical connections, or ignition or heat sources. (**Note:** Fire code piping requirements may apply in your facility. Consult the EH&S Chemical Hygiene Officer,)    3. **Corrosive gases**       1. Never store corrosives longer than 6 months (e.g., ammonia, hydrogen chloride, chlorine, and methylamine). Cylinders containing corrosives degrade over time.   **Operational Guidelines**   1. Know the hazard classification of particular gases you are working with and specific safety requirements as discussed above. 2. Label both the cylinder and gas line with the name of the gas. Do not depend on color codes. 3. Work in a well-ventilated area when using compressed gases. 4. Use the correct regulator. Ensure that each gas in use has its own dedicated regulator. Never use adapters. 5. Never permit a flame or spark to come in contact with any part of a compressed gas cylinder. Have flashback protectors installed on cylinders of flammable gases, such as oxy-acetylene torch units. 6. Use a trap or suitable check valve when discharging gas into a liquid to prevent liquid from getting back into the cylinder or regulator. 7. Handle toxic, flammable, and corrosive gases in a fume hood. Use only small cylinders of toxic gases whenever possible. Additional precautions are needed for the different hazardous gases classes (I, II, and III). Requirements are relaxed for small quantities and short-term usage (see Appendix B). 8. Avoid using lecture bottles whenever possible. Lecture bottles use universal threads and valves, and some of them are interchangeable. This increases the risk of accidentally mixing incompatible materials. 9. In addition to standard operational requirements listed above, employ special precautions for cylinders containing flammable, oxidizing, or corrosive gases (empty or full) as described below.    1. **Flammable gases**       1. Use flow restrictors to prevent a sudden large unexpected release.       2. Detection systems may be required.    2. **Oxidizing gases**       1. Diligently clean regulators and tubing used with oxidizing gases to remove oil and other reducing agents.    3. **Corrosive gases**       1. Inspect cylinder valves periodically for corrosion.          1. If a cylinder or valve is noticeably corroded, contact the gas vendor and follow their instructions.          2. Alert the vendor to any damage that might impair the integrity of the cylinder before the cylinder is returned.       2. Use caution if flow does not immediately start when a valve is opened slightly — there could be a plug in the valve.   **Transporting Gas Cylinders**   1. Leave the valve protection cap in place until the cylinder has been secured against a wall or bench or placed in a cylinder stand, and is ready for use. 2. Use a hand truck or other suitable device to transport cylinders, even for short distances. Secure the cylinder to the hand truck with a chain or strap.    1. Do not roll, drag, or slide containers.    2. Do not lift cylinders by cylinder caps. 3. Before returning empty cylinders to the supplier:    1. Close the valve. Leave some positive pressure in the cylinder.    2. Replace any valve outlet and protective caps originally shipped with the cylinder.    3. Mark or label the cylinder "empty" and store it in a designated area for the supplier. 4. Move any cylinders that have been left unattended into a secure location as soon as possible. |

**First Aid Procedures**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

Consult the Safety Data Sheet for the subject chemical for specific first aid procedures. General first aid procedures for hazardous chemicals are provided below.

**If inhaled**

Move to fresh air. Have victim rest in half-upright position. Artificial respiration victim is not breathing. Seek medical attention immediately.

**In case of skin contact**

In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately

**In case of eye contact**

Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water from emergency eyewash station for at least 15 minutes. Get medical attention immediately.

**If swallowed**

If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

# **Medical Emergency**

Be familiar with information in the UC Irvine Injuries & Medical Treatment poster ([*http://www.ehs.uci.edu/MedEmergPoster.pdf*](http://www.ehs.uci.edu/MedEmergPoster.pdf)*)*

**a. Life Threatening Emergency** (all times: Business Hours, After Hours, Weekends and Holidays)--CALL 911 if the condition is LIFE THREATENING or REQUIRES IMMEDIATE MEDICAL ATTENTION. *Note: All serious injuries must be reported to EH&S at* ***x46200*** *within 8 hours.* Complete online incident report at[*https://www.ehs.uci.edu/apps/hr/index.jsp*](https://www.ehs.uci.edu/apps/hr/index.jsp)

**b. Non-Life Threatening Emergency** – Notify your supervisor or faculty staff if condition is not life threatening or does not require immediate medical attention.

**ALL WORK RELATED INJURIES MUST BE REPORTED via the On-line Incident Form** <https://www.ehs.uci.edu/apps/hr/index.jsp>  **or call Human Resources, Workers Compensation (949) 824-9152.**

**Spill & Accident Procedure**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

Evacuate the spill area. Post someone or mark-off the hazardous area with tape and warning signs to keep other people from entering the area. Keep the appropriate fire extinguisher nearby. Avoid incompatible extinguishing agents. Use Class A-B-C or B-C for flammable liquids. **Fire extinguishers containing water are not suitable for flammable liquid fires.**

**Spill** – Assess the extent of danger. Help contaminated or injured persons if safe to do so. Evacuate the spill area. Avoid breathing vapors. If possible, confine the spill to a small area using a spill kit or absorbent material. Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).

**Small (<1 L, <100 g)** – If you have training, you may assist in the clean-up effort. Use appropriate personal protective equipment and clean-up material for chemical spilled. Double bag spill waste in clear plastic bags, label and take to the next chemical waste pick-up.

**Large (>1 L, >100 g)** – Dial **911** and EH&S at x46200 for assistance.

**Chemical Spill on 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 at x46200 immediately.*

**Chemical Splash Into Eyes** – Immediately rinse eyeball and inner surface of eyelid with water from the emergency eyewash station for 15 minutes by forcibly holding the eye open. Seek medical attention. *Notify supervisor and EH&S at x46200 immediately.*

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| Band-specific practices:   1. In case of cylinder leaks that can't be stopped by tightening the valve gland or packing nut, do the following:    1. For hazardous gases:       1. Leave the room, closing the door behind you.       2. Secure the room to prevent entry.       3. Sound the fire alarm.       4. Call for emergency assistance. Dial 9-1-1, preferably from a cell phone. Tell the dispatcher the name of the gas.    2. For non-hazardous gases:       1. Close the leaking valve. If it is still leaking, replace the cylinder cap and notify EHS. |

**Decontamination/Waste Disposal Procedure**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

All of the subject chemicals must be disposed as a hazardous waste.

**Label Waste**

* Hazardous waste labels must be placed on the hazardous waste container upon the start of accumulation. Labels are available online at [www.ehs.uci.edu/programs/enviro/](http://www.ehs.uci.edu/programs/enviro/).

**Store Waste**

* Hazardous waste containers must be kept closed, except when adding waste.
* Hazardous waste containers must be stored in secondary containment to adequately contain all of the contents of the container.
* Hazardous waste containers must be inspected weekly for signs of leaks, corrosion, or deterioration.

**Dispose of Waste**

* Hazardous waste must be transferred to EH&S for disposal within 6 months of being generated.
* Empty Containers: At no time should full or partially full containers be placed in the trash. For more information on empty container management visit [www.ehs.uci.edu/programs/enviro/.](file:///C:\Users\derodrav\AppData\Local\Microsoft\Windows\Temporary%20Internet%20Files\Documents%20and%20Settings\jmnorthr\Local%20Settings\Temp\www.ehs.uci.edu\programs\enviro\)
* Hazardous Waste Disposal:
  + Visit [www.ehs.uci.edu/programs/enviro/](http://www.ehs.uci.edu/programs/enviro/).
  + Fill out the “Chemical Waste Collection” form.
  + EH&S will pick up your waste within 1-3 days.
* Do not dispose of chemicals by pouring them down the drain or placing them in the trash.
* Do not use fume hoods to evaporate chemicals.

**Safety Data Sheet (SDS) Location**

Online SDSs can be accessed at <http://www.ehs.uci.edu/msds.html>

**Required Training/Approvals**

In addition to the practices described below, follow procedures as specified in the lab-specific and special handling/use sections of this SOP.

All work with the subject chemicals requires the following prior to beginning work:

1. Must be pre-approved by the Principal Investigator prior to use and all training must be well documented.
2. Must be familiar with the UC Irvine Chemical Hygiene Plan. <http://www.ehs.uci.edu/programs/lsg/CHP2013.pdf>
3. Must have documented Laboratory Safety training.
4. Must read the relevant Safety Data Sheet (formerly referenced as Material Safety Data Sheets).
5. Any additional laboratory specific training that is needed is referenced in the 'Laboratory Specific Use Procedures' section. Signed and dated training documents must be uploaded into each assigned researchers training records.

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| Band-specific practices:   1. All personnel working with compressed gases must have completed the “Safe Handling of Compressed Gases” training through EHS. |

**Additional Notes**

Any deviation from this SOP requires approval from PI.

**Documentation of Training**

* Prior to conducting any work with the subject chemicals, designated personnel must provide training to his/her laboratory personnel specific to the hazards and procedures involved in working with these substances.
* The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.
* The Principal Investigator must ensure that his/her laboratory personnel have attended appropriate laboratory safety training or refresher training within the last one year.

I have read and understand the content of this SOP:

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| --- | --- | --- | --- |
| **Name** | **Signature** | **Identification** | **Date** |
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**APPENDIX A:**

**Lab-Specific Use Procedures**

# **Lab-Specific Use Procedures**

# The following describe how the subject chemicals are used in this laboratory beyond the practices described above.

This section must describe lab-specific procedures to address the safe use of all highly hazardous chemicals from this band in use in the laboratory. These procedures may be organized around specific chemicals, specific tasks or the band as a whole. The following minimum requirements must be met:

* Identify designated use areas within the laboratory for highly hazardous chemicals in the following hazard bands:
  + Carcinogens
  + Reproductive Toxins
  + Toxic Chemicals
* Identify maximum use quantities for which the procedures in this band apply.
* If it is determined that this hazard band SOP is sufficient to address the safe use of all subject chemicals in this lab, then include the following statement in this section: *“Procedures described in this hazard band SOP are sufficient for addressing the safe use of subject chemicals in this laboratory within the listed quantity limitations.”*
* If it is determined that this hazard band SOP is not sufficient to address the safe use of all chemicals from that band in the lab, then write lab-specific procedures for to address these high hazard operations. Such operations are generally indicated by:
  + tasks requiring the use of specialized PPE,
  + tasks using highly hazardous chemicals outside of the fume hood,
  + tasks using larger quantities of hazardous chemicals,
  + tasks involving the use of particular chemicals considered by UCI EHS to be extremely hazardous, and
  + tasks considered to present high risk by lab personnel.

A few examples of what lab-specific tasks may look like are provided below:

***Task #1: Title of the specific procedure being done.***

1. Provide step-by-step instructions in a numbered/lettered format.
2. Include in the procedure any relevant:
   1. Locations of “designated areas” as called for in the special handling section of the SOP, or as otherwise required by regulations. The entire laboratory,fume hood, or a portion of the laboratory may be considered as a designated area.
   2. Use of specific administrative, engineering and PPE controls.
   3. Specific quantity use limits/restrictions.
   4. Specific storage requirements.
   5. Specific first aid and spill procedures (including what should be handled by whom).
   6. Specific disposal procedures.
   7. Process-specific PI approvals required.

***Task #2: Making dilutions of the acids and bases.***

1. Consult with PI and obtain approval if quantities greater than 4 L are needed.
2. In a fume hood, add the appropriate amount of concentrated acid or base to the calculated amount of water.
3. Return the concentrated acids/bases to the proper secondary containment or cabinet.

***Task #3: Using the pH meter.***

1. Calibrate on the day of pH testing using at least 2 standards.
2. Before use, rinse the electrode with deionized water and blot dry with a kim-wipe.
3. Transfer the electrode to the test solution.
4. If using a stir plate, make sure the electrode does not touch the stir bar.
5. Record the pH when the reading is stable (5–20 seconds after insertion of the electrode into the solution)
6. Add dilute acid or dilute base drop-wise until the correct pH is reached.
7. Rinse the electrode with deionized water and store according to the manufacturer’s instructions.
8. Make sure the acid and base caps are on tightly.

Add as many tasks as necessary.

**APPENDIX B:**

**UCI Hazardous Gas Classification Table**

| **Gas and Formula** | **CAS and UN or NA No.** | **UBC / CFC Class**[**1**](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#1) | **UCI Class**[**2**](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#2) | **IDLH**[**3**](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#3) | **LC50**[**4**](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#4) | **PEL**[**5**](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| --- | --- | --- | --- | --- | --- | --- |
| Ammonia – NH3 | 7664–41–7, UN1005 | Corrosive[6,7](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6), flammable | III | 300 ppm | 4000 ppm | 50 ppm |
| Arsine – AsH3 | 7784–42–1, UN2188 | Highly toxic, flammable | I | 3 ppm | 20 ppm | 0.05 ppm |
| Boron Tribromide – Bbr3 | 10294–33–4, UN2692 | Toxic | II | 50 ppm | 380 ppm | 1 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Boron Trichloride – BCl3 | 10294–34–5, UN1741 | Corrosive[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 25 ppm[8](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#8) | 2541 ppm | 5 ppm |
| Boron Trifluoride – BF3 | 7637–07–2, UN1008 | Toxic | II | 25 ppm | 806 ppm | 1 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Bromine – Br2 | 7726–95–6, UN1744 | Highly toxic, corrosive, oxidizer | I | 3 ppm | 113 ppm | 0.1 ppm |
| Carbon Monoxide – CO | 630–08–0, UN1016 | Flammable[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 1200 ppm | 3760 ppm | 50 ppm |
| Chlorine – Cl2 | 7782–50–5, UN1017 | Toxic, corrosive, oxidizer | II | 10 ppm | 293 ppm | 1 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Chlorine Dioxide – ClO2 | 10049–04–4, NA9191 | Toxic, oxidizer | II | 5 ppm | 250 ppm | 0.1 ppm |
| Chlorine Trifluoride – ClF3 | 7790–91–2, UN1749 | Toxic, oxidizer | II | 20 ppm | 299 ppm | 0.1 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Diborane – B2H6 | 19278–45–7, UN1911 | Highly toxic, flammable | I | 15 ppm | 80 ppm | 0.1 ppm |
| Dichlorosilane – SiH2Cl2 (HCl) | 4109–96–0, UN2189 | Toxic, corrosive, flammable | II | 50 ppm | 314 ppm | 5 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Ethylene Oxide – C2H40 | 75–21–8, UN1040 | Flammable[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 800 ppm | 4350 ppm | 1 ppm |
| Fluorine – F2 | 7782–41–4, UN1045 | Highly toxic, oxidizer | I | 25 ppm | 185 ppm | 0.1 ppm |
| Germane – GeH4 | 7782–65–2, UN2192 | Toxic, flammable | II | 6 ppm[8](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#8) | 622 ppm | 0.2 ppm[9](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#9) |
| Hydrogen Bromide – HBr | 10035–10–6, UN1048 | Corrosive[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 30 ppm | 2860 ppm | 3 ppm |
| Hydrogen Chloride – HCl | 7647–01–0, UN1050 | Corrosive[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 50 ppm | 2810 ppm | 5 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Hydrogen Cyanide – HCN | 74–90–8, UN1051 | Highly toxic, flammable | I | 50 ppm | 40 ppm | 10 ppm |
| Hydrogen Fluoride – HF | 7664–39–3, UN1052 | Toxic | II | 30 ppm | 1300 ppm | 3 ppm |
| Hydrogen Selenide – H2Se | 7783–07–5, UN2202 | Highly toxic, flammable | I | 1 ppm | 2 ppm | 0.05 ppm |
| Hydrogen Sulfide – H2S | 7783–06–4, UN1053 | Toxic, flammable | II | 100 ppm | 712 ppm | 20 ppm |
| Methyl Bromide – CH3Br | 74–83–9, UN1062 | Toxic, flammable | II | 250 ppm | 1007 ppm | 20 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Methylisocyanate – CH3NCO | 624–83–9, UN2480 | Highly toxic, flammable | I | 3 ppm | 22 ppm | 0.02 ppm |
| Methyl Mercaptan – CH3SH | 74–93–1, UN1064 | Toxic, flammable | II | 150 ppm | 1350 ppm | 10 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Nickel Carbonyl – Ni(CO)4 | 13463–39–3, UN1259 | Highly toxic, flammable | I | 2 ppm | 18 ppm | 0.001 ppm |
| Nitric Oxide – NO | 10102–43–9, UN1660 | Highly toxic, oxidizer | I | 100 ppm | 115 ppm | 25 ppm |
| Nitrogen Dioxide – NO2 | 10102–44–0, UN1067 | Highly toxic, oxidizer | I | 20 ppm | 115 ppm | 5 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Phosgene – COCl2 | 75–44–5, UN1076 | Highly toxic | I | 2 ppm | 5 ppm | 0.1 ppm |
| Phosphine – PH3 | 7803–51–2, UN2199 | Highly toxic, pyrophoric | I | 50 ppm | 20 ppm | 0.3 ppm |
| Phosphorus Oxychloride – POCl3 | 10025–87–3, UN1810 | Highly toxic | I | 0.96 ppm[8](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#8) | 96 ppm | 0.1 ppm[9](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#9) |
| Phosphorus Pentafluoride – PF 5 | 7647–19–0, UN2198 | Toxic, oxidizer | II | 2.6 ppm[8](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#8) | 260 ppm | 3 ppm |
| Phosphorus Trichloride – PCl3 | 7719–12–2, UN1809 | Toxic, oxidizer | II | 25 ppm | 208 ppm | 0.5 ppm |
| Selenium Hexafluoride – SeF6 | 7783–79–1, UN2194 | Highly toxic | I | 2 ppm | 50 ppm | 0.05 ppm (as Se) |
| Silicon Tetrachloride – SiCl4 (HCl) | 10026–04–7, UN1818 | Toxic, corrosive | II | 50 ppm | 750 ppm | 5 ppm[5(C)](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#5) |
| Silicon Tetrafluoride – SiF4 (HF) | 7783–61–1, UN1859 | Toxic | II | 30 ppm | 450 ppm | 0.1 ppm |
| Stibine – SbH3 | 7803–52–3, UN2676 | Highly toxic, flammable | I | 5 ppm | 20 ppm | 0.1 ppm |
| Sulfur Dioxide – SO2 | 7446–09–5, UN1079 | Corrosive[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 100 ppm | 2520 ppm | 5 ppm |
| Sulfuryl Fluoride – SO 2F2 | 2699–79–8, UN2191 | Corrosive[6](http://blink.ucsd.edu/safety/research-lab/chemical/gas/toxic.html#6) | III | 200 ppm | 3020 ppm | 5 ppm |
| Tellurium Hexafluoride – TeF6 | 7783–80–4, UN2195 | Highly toxic | I | 1 ppm | 25 ppm | 0.02 ppm (as Te) |
| Titanium Tetrachloride – TiCl4 | 7550–45–0, UN1838 | Highly toxic, corrosive | I | 1.3 ppm | 119 ppm | — |
| Tungsten Hexafluoride – WF6 (HF) | 7783–82–6, UN2196 | Toxic, corrosive | II | 30 ppm | 217 ppm | 0.1 ppm |

(Table adapted from Santa Clara County's Hazardous Gas Table.)

**Footnotes:**

1. UBC/ CFC Class:
   1. UBC (Uniform Building Code)
   2. CFC (California Fire Code)
   3. Class as defined in CFC:
      1. Health hazards per Article 2
      2. Highly toxic = < 200 LC50
      3. Toxic = 201–2000 LC50
   4. Physical hazards per CFC Standard 7903.
2. UCSD Hazard Class defined as:
   1. Class I = < 200 LC50
   2. Class II = 201–2000 LC50
   3. Class III = 2001–5000 LC50
3. IDLH values published in 1994 by the National Institute for Occupational Safety and Health (NIOSH).
4. LC50 data: Lowest reported value, 1 hour adjusted, taken from Dept. of Transportation, Compressed Gas Association, Registry of Toxic Effects of Chemical Substances.
5. PEL (Permissible Exposure Limit) values published by Occupational Safety & Health Administration (OSHA), 29 Code of Federal Regulations, Part 1910.1000, Table Z–1, 7/1/95. OSHA values used if available; otherwise, Threshold Limit Values (TLV) from American Conference of Governmental Industrial Hygienists (ACGIH) or California Division of Occupational Safety and Health (Cal/OSHA) values used.  
   (C) = TLV-ceiling limit, an exposure limit not to be exceeded under any circumstances.
6. Moderately toxic as adopted by the cities of San Jose, Santa Clara, and Milpitas: LC50 = 2,000–5000.
7. When used as a refrigerant, Uniform Building Code Class does not apply.
8. IDLH determined by 0.01 of LC50.
9. Cal/OSHA PEL, Title 8, Section 5155, 9/1/95.

**APPENDIX C:**

**UCI Safety Requirements for Compressed & Hazardous Gases**

Follow these safety requirements for use of compressed gases according to hazard class. Check

Appendix A to determine the hazard class of your material. Then follow the appropriate usage requirements indicated in the table and discussed in greater detail below. Some exemptions for small quantities and short-term usage apply.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Requirements** | | **Class**  **IV** | **Lab Use Exemption** | **Class III** | **Class II** | **Class I** |
| 1. | Exhausted enclosures (gas cabinets or fume hoods) |  | X | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | X | X |
| 2. | Treatment to 1/2 IDLH at atmosphere |  | X | X | X | X |
| 3. | Leak check (of installed system) |  | X | X | X | X |
| 4. | Emergency response plan, team, and drills |  | X | X | X | X |
| 5. | Flow-limiting device or flow-restricting orifice |  | X | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | X | X |
| 6. | Use in sprinkled spaces |  | X | X | X | X |
| 7. | Documented annual maintenance |  |  | X | X | X |
| 8. | Compatible piping |  |  | X | X | X |
| 9. | Purge system |  |  | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | X | X |
| 10. | Detector system |  | X (class I) | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | X |
| 11. | Emergency alarms (and explanatory signs) |  | X (class I) | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) | X | X |
| 12. | Welded, compatible piping |  |  |  | X | X |
| 13. | Local shut-off |  |  |  | X | X |
| 14. | Interlocks |  |  |  | X | X |
| 15. | Emergency power (alarm, detector, ventilation) |  | X (class I) |  | X | X |
| 16. | Monitored secondary containment |  |  |  |  | C[1](http://blink.ucsd.edu/safety/research-lab/chemical/gas/safety.html#note) |
| 17. | Auto shut-off (manual or detector triggered) |  |  |  | X | X |
| 18. | Exhaust flow alarm |  | X (class I) |  |  | X |

1 C = These systems are conditional and will be determined by the EH&S Chemical Safety Officer,

**Exemptions**

Requirements are relaxed for small quantities and short-term usage as follows:

1. Less than 340 standard cubic feet (SCF) of class II and class III materials used for less than 30 consecutive days require:
   1. Initial consultation with the EH&S Chemical Hygiene Officer.
   2. Basic gas safety, including an emergency response plan and drills
   3. No lecture bottles
   4. Flow-restricting orifice (FRO)
   5. Exhausted enclosure adequate to dilute full release to 1/2 IDLH
   6. Leak check procedures for receiving cylinders and for manifolds
   7. Use in a sprinkled space
2. Less than 20 SCF of class I materials used for less than 30 consecutive days require above items, plus:
   1. Gas and exhaust system flow-detector systems connected to alarm system
   2. Emergency power for detectors and alarms
3. Requirements above may be relaxed for quantities less than 2 pounds; no single cylinder more than 1 pound (1/4 pound for class I). Quantities over threshold levels raise the level of classification.

**Requirements Detail**

1. **Exhausted enclosures (gas cabinets or fume hoods)**
   1. All class I and II gases must be kept in an exhausted enclosure at all times. Class III gases, flammable gases, and oxidizing gases are conditional depending on the application and the specific gas in question. Gas cabinets must be equipped with automatic fire sprinkler system protection, and must be constructed and ventilated according to code requirements. Exhausted enclosures must:
   2. Operate at negative pressure in relation to the surrounding area
   3. Be provided with self-closing limited access ports or non-combustible windows to give access to equipment controls — the average face velocity at the face of the access ports or windows shall not be less than 200 feet per minute (1.01 m/s) with a minimum of 150 feet per minute (0.76 m/s) at any 1 point of the access port or window
   4. Connect to an approved exhaust system
   5. Be provided with self-closing doors
   6. Be constructed of not less than 0.097 –inch (2.46 mm) (12 gage) steel
   7. Not contain more than 3 cylinders in a single gas cabinet
      1. Exception: Cabinets containing cylinders not exceeding 1 pound (0.4536 kg) net contents each shall not exceed 100 cylinders.
   8. Be seismically restrained
   9. Be certified annually by EH&S for proper air flow
   10. Gas cabinet reference guide:
       1. [Safety Equipment Corp.](http://www.safetyequipmentcorp.com/) (http://www.safetyequipmentcorp.com/)
       2. [Matheson Tri-Gas](http://www.mathesongas.com/catalog/cyl_enclosures_manifolds_panels.aspx) (http://www.mathesongas.com/catalog/cyl\_enclosures\_manifolds\_panels.aspx)
       3. [Thermo Fisher Scientific Inc.](http://www.thermofisher.com/global/en/home.asp) (http://www.thermofisher.com/global/en/home.asp)
2. **Treatment to 1/2 IDLH at atmosphere**
   1. Treatment systems must be designed to reduce the maximum allowable discharge concentration of the gas to 1/2 IDLH (Immediately Dangerous to Life and Health) at the point of discharge to the atmosphere. When more than 1 gas is emitted to the treatment system, the treatment system must be designed to handle the worst-case release based on the release rate, the quantity, and the IDLH for all the gases stored or used.
3. **Leak check (of installed system)**
   1. Gas systems must be leak tested at the following intervals:
   2. Upon receipt
   3. At installation
   4. Periodically during operation
   5. At disconnect / shipping
   6. It is critical that these gases also be leak tested prior to removal from their exhausted enclosures and subsequent to transport, or if you have reason to believe that the system has been compromised.
4. **Emergency response plan, team, and drills**
   1. All laboratories must have an emergency response plan that addresses the use and/or storage of compressed gases
5. **Flow-limiting device or flow-restricting orifice**
   1. Use a flow-limiting device to restrict hazardous gas flow rates to just over maximum flow required (e.g., flow restricting orifice). These devices must be installed immediately downstream of each gas cylinder.
   2. For small scale experiments, such as fume hood use, a needle valve is sufficient.
   3. For large cylinders, a flow restricting orifice must be installed by the gas supplier in the cylinder valve or installed in the gas purge panel.
   4. Reference guide:
      1. [Matheson Tri-Gas](http://www.mathesongas.com/catalog/cyl_enclosures_manifolds_panels.aspx) (http://www.mathesongas.com/catalog/cyl\_enclosures\_manifolds\_panels.aspx)
6. **Use in sprinkled spaces**
   1. Sprinkler protection is required in all spaces unless otherwise approved.
7. **Documented annual maintenance**
   1. Keep records of all maintenance associated with gas systems (e.g., gas detection calibration and/ or repairs).
8. **Compatible piping**
   1. Piping, tubes, valves, fittings, and related components must be:
   2. Designed and fabricated from materials compatible with the material to be contained
   3. Of adequate strength and durability to withstand the pressure, structural and seismic stress, and exposure to which they are subject
   4. Identified in accordance with nationally recognized standards to indicate the material conveyed
9. **Purge system**
   1. The ability to purge the area between the cylinder valve and the regulator with an inert gas prior to maintenance or cylinder change out is required. Inert gases used for this purpose must be used solely for this purpose and no other operation.
10. **Detector system**
    1. A continuous gas-detection system is required to detect the presence of gas at or below the permissible exposure limit or ceiling limit. The detection system must:
    2. Initiate a local alarm and transmit a signal to a constantly attended control station (exceptions may apply)
    3. Be capable of monitoring the room or area in which the gas is stored at or below the permissible exposure limit or ceiling limit and the discharge from the treatment system at or below 1/2 IDLH (Immediately Dangerous to Life and Health) limit
    4. The alarm must be both inside and outside the storage area. The audible alarm must be distinct from all other alarms.
    5. Note: Exceptions to detection systems may exist for class II gases.
11. **Emergency alarms (and explanatory signs)**
    1. Alarm system must be posted with information on:
    2. What the alarm states mean
    3. What actions to take
    4. Who to contact
12. **Welded, compatible piping**
    1. Piping and tubing must:
    2. Have welded or brazed connections throughout unless an exhausted enclosure is provided
    3. Not be located in any portion of a corridor unless otherwise approved by the UCI Fire Marshal
    4. See the section on Compatible Piping for addition information.
13. **Local shut-off**
    1. Personnel must be able to shut the system off at the source.
14. **Interlocks**
    1. An automatic shut down of gas flow must be initiated when any of these conditions occur:
    2. Hazardous condition is detected
    3. Seismic disturbance
    4. Loss of power – see Emergency Power section for more information
    5. Excess-flow-triggered shut-off – Where gases are carried in pressurized piping above 15 psig (103.4 kPa), excess flow control must be provided
    6. Loss of vacuum
    7. Loss of cooling
    8. Loss of ventilation
15. **Emergency power (alarm, detector, ventilation)**
    1. Emergency power must be provided for these systems:
    2. Exhaust ventilation (including the power supply for treatment systems)
    3. Gas cabinet ventilation
    4. Exhausted enclosure ventilation
    5. Gas-detection
    6. Emergency alarm
16. **Monitored secondary containment**
    1. Any secondary containment system must have a detection system.
17. **Auto shut-off (manual or detector triggered)**
    1. When a short-term hazard condition is detected, the gas detection system must automatically close the shut-off valve at the source on gas supply piping and tubing related to the system being monitored for which gas is detected.
18. **Exhaust flow alarm**
    1. Should ventilation become inadequate, an audible and visual alarm must be available.