**General Use Standard Operating Procedure (SOP)**

**Hydrogen Gas**

**(Pure and Mixtures)**

*CAS Number: 1333-74-0*

**Note**: This SOP is intended to provide general guidance on how to safely work with hydrogen gas and only addresses safety issues specific to pure or mixtures of hydrogen gas. Other hazard classes may also apply. Review Safety Data Sheets (SDS) and refer to other general use SOPs relevant to the chemical(s) you are working with. Contact the Principal Investigator/ Laboratory Supervisor or the WSU Chemical Hygiene Officer for questions concerning the applicability of any item listed in this SOP (OEHS: 313-577-1200).

# **Hazard Description**

Hydrogen is an extremely flammable (NFPA Flammability Rating = 4), colorless, odorless compressed gas. It poses an immediate fire and explosive hazard when concentrations in air are between 4% and 75% and can be ignited by static electricity. This means that even a small leak can cause a hazardous fire. Hydrogen gas mixed with another gas may shift the flammable concentration range. Below are the highest concentrations of Hydrogen in balance gas that are non-flammable:

* 3.1% Hydrogen Balance Argon
* 4.97% Hydrogen Balance Helium
* 5.5% Nitrogen Balance Nitrogen
* 3.9% Hydrogen Balance Carbon Dioxide

Hydrogen is the lightest known gas and quickly rises if released. It may leak out of systems that are air-tight for other gases and may collect in poorly ventilated upper reaches of buildings. Hydrogen gas burns with an invisible flame which makes finding and fighting a hydrogen gas fire difficult. Chemical fume hood fans at Wayne State University are not explosion proof. Therefore, discharging more than 1 liter of hydrogen gas into a fume hood may result in an explosion on the roof. Hydrogen has the unique characteristic of making certain metals brittle after prolonged use. Some metal tools, such as ferrous tools may create sparks which could ignite the hydrogen. Use caution when working with metal tools and devices. Hydrogen gas can displace oxygen causing suffocation if enough is released in an enclosed area. Liquid hydrogen may cause severe frostbite to the eyes and skin.

| **Hazard Pictograms** | **Hazard Statements** |
| --- | --- |
| **Globally Harmonized System pictogram Indicating a chemical is a Flammable Chemical** | Extremely flammable gas. Burns with invisible flame. May form explosive mixtures with air. |
| **Globally Harmonized System pictogram Indicating a chemical is a Compressed gas** | Contains gas under pressure; may explode if heated. May displace oxygen and cause rapid suffocation. |

*Note: Hazard pictograms and statements above are for hydrogen that is not mixed with any other gas. Additional hazards may be present, depending on the gas mixture.*

*More hazard information may be obtained from the SDS or from* [*PubChem*](https://pubchem.ncbi.nlm.nih.gov/compound/783)*.*

# **Control of Hazards – General**

* Conduct a hazard assessment to identify proper use and handling techniques, fire safety, and storage specific to the laboratory’s use of hydrogen gas.
* For labs who regularly use high or ultra-high purity hydrogen, consider purchasing a desktop hydrogen generator instead of using gas cylinders. This will eliminate storage concerns, reduce sources of leaks, and will eliminate the need for purchasing a flammable gas storage cabinet as well as gas detection and alarm systems since generators have internal safeguards.
* Open flames shall never be used near areas where hydrogen is used.
* Work in an area with plenty of ventilation, preferably in a chemical fume hood.
* When transferring hydrogen to an instrument, chemical reactor (e.g., hydrogenator), or a balloon make sure that you are properly grounded before working with hydrogen. Rubber soled shoes prevent you from being grounded, so you should touch a grounded object to discharge static electricity before beginning work. Alternatively, use anti-static PPE or stand on an anti-static mat when working with hydrogen.
* Electrical equipment (e.g., magnetic stirrers, Parr shakers) located within 15 feet of the hydrogen gas should be rated explosion proof. Otherwise, remove the electrical equipment from the vicinity of the hydrogen gas cylinder.
* Remove electronic devices (e.g., cell phones) from the vicinity of hydrogen gas. Even invisible small sparks from electronic devices could ignite hydrogen.
* If the hydrogen gas cylinder is used infrequently (less than once per week), then, immediately after use, remove the regulator and secure in place the cylinder valve cover.
* Do not “open” the hydrogen cylinder valve before connecting it to your equipment or apparatus since self-ignition may occur. If you have difficulty operating the cylinder valve, discontinue use and contact the vendor to arrange for a new cylinder.
* Regularly test the connections and gas regulators for leaks using an appropriate leak detection solution (e.g., soapy water) or a hand-held hydrogen leak detector. Installation of a hydrogen gas leak detector is also recommended.
* Never exchange regulators, hoses and other appliances used for hydrogen gas to be used with other gases.
* Limit the number of hydrogen gas cylinders in a lab to what is immediately needed for use. If multiple flammable gas cylinders are being used in a lab, consult with the WSU Fire Marshal for required safety precautions. There are limits to the number of flammable gas cylinders allowed per room. Additional hydrogen gas cylinders should be stored in the building’s main gas cylinder storage area.
* Never work alone when using hydrogen gas.
* All users should have hands-on training to work with highly flammable gases. The training should be documented.
* Anyone using hydrogen should have some level of fire extinguisher training. Information can be found on [WSU Fire Safety](https://risk.wayne.edu/fire-safety) website.

# **Engineering/Ventilation Controls**

* Hydrogen filling inside a balloon must be conducted inside a chemical fume hood.
* Chemical reactions using hydrogen gas enclosed in a balloon should be conducted inside of a chemical fume hood. The chemical fume hood must be approved and certified by OEHS and have a face velocity between 70 and 130 feet per minute.
* To keep the concentration of hydrogen gas in the hood below the 4% limit in the event of balloon failure, no more than 1-L of hydrogen should be used (i.e., the diameter of the balloon should not exceed 12 cm).
* Use only hydrogen gas compatible CGA connections and gas regulators (CGA 350). Flammable gas regulators are “reverse-threaded” which means to tighten the regulator to the tank you must turn it to the left and to loosen the regulator from the tank it must be turned to the right. NEVER modify a regulator or tank to make the regulator fit. Never insert an object (i.e., wrench) into valve cap openings.
* A flash arrestor or excess flow control valve attached to the regulator outlet is recommended.
* Use only non-ferrous, non-sparking tools on hydrogen gas connections.
* Do not use non-conductive or plastic tubing to dispense hydrogen. Keep the tubing length to a minimum and positioned so that it will not become heated, damaged, or disconnected.
* When dispensing hydrogen from a stand-alone cylinder (such as into a balloon), electrically ground the hydrogen gas cylinder to a building ground. Contact OEHS or the WSU Fire Marshal for helping in identifying a good building ground.
* When the hydrogen gas cylinder is connected directly to an instrument (e.g., Gas Chromatograph) or chemical reactor (e.g., hydrogenator):
	+ Use piping and equipment adequately designed to withstand the pressures to be encountered.
	+ Use only approved CGA connections compatible with hydrogen gas. Refer to [Air Liquide Design and Safety Handbook for Specialty Gas Delivery Systems](https://industry.airliquide.us/design-and-safety-handbook-specialty-gases?msclkid=2dbfe3aabb3e11ec81894fcb85349a72) to identify hydrogen gas compatible connections and tubing. Or contact the gas vendor for recommendations.
	+ Use metal piping to convey hydrogen gas to an instrument or chemical reactor. Teflon tubing is only acceptable if specified by the manufacturer to be safe with hydrogen.
	+ [Electrically bond the hydrogen gas cylinder](https://www.ucop.edu/safety-and-loss-prevention/_files/safety-spotlight/August-2017-Safety-Spotlight-Poster.pdf) to the equipment it is connected to and ground the hydrogen gas cylinder to a building ground. Contact OEHS or the WSU Fire Marshal for helping in identifying a good building ground.
* It is preferred that a hydrogen gas cylinder be placed in a flammable gas protected safety cabinet. Gas cylinders which are not in protected safety cabinets should be secured to a stable structure and protected against mechanical damage from falling objects or other accidents.
* An eyewash and safety shower must be available in the immediate work area for any work with hydrogen.

# **Personal Protective Equipment**

In addition to proper street clothing (long pants or equivalent that cover legs and ankles, close-toed non-perforated shoes that completely cover the feet), wear the following Personal Protective Equipment (PPE) when performing lab operations/tasks:

* Preferably 100% cotton street clothes
* Safety glasses with side shields or tightly fitting safety goggles. Use a face shield (8 inch minimum) over goggles when appropriate. Eye protection should be marked as tested and certified under the ANSI Z87.1 standard.
* A flame-resistant lab coat, such as Nomex, fully buttoned.
* Disposable gloves, such as nitrile.
	+ Refer to Section 8 “Exposure controls/personal protection” of SDS for appropriate glove material and type.

# **Special Handling and Storage Requirements**

* Protect gas cylinders from physical damage; do not drag, roll, slide or drop a gas cylinder.
* While moving a gas cylinder, always ensure the valve cover/cap is securely in place.
* Never attempt to lift a cylinder by its cap or valve. The cap is intended solely to protect the valve.
* When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport gas cylinders.
* Wear appropriate personal protective equipment when transporting gas cylinders.
* Review specific storage guidance provided in SDS documentation.
* A protected safety cabinet is the preferred method for storing hydrogen gas cylinders.
* Gas cylinders which are not in protected safety cabinets should be secured to a stable structure and protected against mechanical damage from falling objects or other accidents.
* Store cylinders only where the temperature will not exceed 125°F (52°C).
* Install valve protection cap firmly in place when the container is not in use.
* Post flammable/compressed gas hazard warning signage in the storage and use areas. See Appendix I for an example.
* For maximum safety, hydrogen gas cylinders should be stored and used as far away as possible from:
	+ ignitable liquids with flash points less than 200 °F (93 °C), oxidizing gases and readily combustible materials such as paper or cardboard (at least 20 ft away)
	+ open flames, ordinary electrical equipment (non-explosion proof), electrical panels/circuit breakers and other sources of ignition (preferably 25 ft away)
	+ ventilation intakes, air-conditioning equipment, air compressors and other flammable gas storage (preferably 50 ft away)

# **Waste Disposal**

Empty, partially used (no longer needed), or damaged (rusted or structurally compromised) gas cylinders should be returned to the vendor (e.g., Airgas) as soon as possible. Lecture bottles that cannot be returned to the vendor should be disposed of through OEHS by submitting a [Chemical Waste Pickup Request](https://research.wayne.edu/oehs/hazardous/chemical-waste). Do not attempt to empty a partially used gas cylinder, as this may create an explosion and/or asphyxiation hazard.

# **Leak Response**

1. **Significant Leak**

For a hydrogen gas leak which poses a significant hazard to local personnel due to the amount of gas leaked or leakage in combination with other serious hazards:

* 1. If this can be done safely without risk to personnel, turn off the gas supply and eliminate ignition sources.
	2. Evacuate the building, pressing the emergency power button while leaving the laboratory (if available), and activating the fire alarm. Go to your Emergency Assembly Point (can be found on building maps located in each building or at the [WSU Emergency Contingency Plan](https://research.wayne.edu/oehs/hazardous/emergency-plan) webpage).
	3. Call WSU Police (313) 577-2222. Available 24 hours a day, 7 days a week.
	4. Remain in the vicinity until emergency personnel arrive and provide them with information on the gases, chemicals, and any other relevant hazards involved.
	5. Once personal safety is established, call OEHS at (313) 577-1200.
1. **Small Leak**

In the event of a relatively small leak that would not result in significant release before shut-off and relief valves can be made operational:

* 1. Alert personnel in the immediate area of the leak and restrict access.
	2. Turn off the gas supply and eliminate all sources of ignition.
	3. Increase ventilation in area (turn on fume hood and open sash, open windows). Vent to outside of building only.
	4. Don appropriate PPE (if not already wearing).
	5. Testing connections and tubing using an acceptable, approved leak detection solution (e.g., soapy water).
	6. If the leak is in the gas supply system, close cylinder valve and tighten leaking connections. Repair or replace connections or tubing if needed.
	7. If the leak is from the cylinder (e.g., valve stem, valve seal, valve threads, pressure safety device, etc.), the cylinder shall be tagged as defective and returned to the supplier as soon as possible. Do not attempt to correct the leak by tightening the valve stem or pressure safety device while the cylinder is under pressure.

# **Emergency Procedures**

**\*\*If medical attention required, call WSU police (313-577-2222) immediately\*\***

* **Fire Extinguishers** – Refer to section 5 of the SDS for chemical specific firefighting measures. Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires.
* **Eyewash/Safety Showers** – Depending on the chemical hazard type, an eyewash station and safety shower may be required, easily accessed, and available within 10 seconds travel time for emergency use. Instruct personnel on the locations of eyewashes and safety showers, and how to activate them, prior to an emergency. Refer to [MIOSHA Fact Sheet: Eyewashes and Safety Showers](https://www.michigan.gov/documents/lara/lara_miosha_cet0199_628109_7.doc) for more information on requirements and use.

Please note: Additional hazards present in the laboratory may require that an eyewash or safety shower be present. This emergency equipment is required for treating exposures to workplace hazards such as chemical splashes, biological agents, welding sparks, metal shavings, or fine particulates like dust, dirt, and sand.

1. **Health Threatening Emergencies**
	1. **Injuries and Exposures:**
		1. Remove the injured/exposed individual from the area unless it is unsafe to do so because of the medical condition of the victim or the potential hazard to rescuers. **IF A PERSON IS UNCONSCIOUS DUE TO A SIGNIFICANT GAS LEAK (SIGNIFICANT DISPLACEMENT OF OXYGEN IN THE ROOM), THEN IT IS NOT SAFE FOR ANY PERSONNEL TO ATTEMPT TO RESCUE THE UNCONSCIOUS PERSON WITHOUT AN AIR-SUPPLIED RESPIRATOR.**
		2. Call WSU Police (313) 577-2222.
		3. Administer first aid as appropriate.
			1. Eye contact: Check for and remove any contact lenses. Promptly flush eyes with copious amounts of water for a prolonged period (at least 15 minutes). Seek medical attention. Contact an ophthalmologist.
			2. Ingestion: Ingestion is not considered a potential route of exposure.
			3. Skin contact: Adverse events are not expected from skin exposure to hydrogen gas.
			4. Inhalation: Get to a source of fresh air. Loosen tight clothing such as a collar, tie, belt or waistband. If not breathing, give artificial respiration. If breathing is difficult trained personnel should administer oxygen. Seek medical attention.
		4. Call OEHS (313) 577-1200, to report the exposure.
		5. After seeking medical attention, complete and submit a Report of Injury Form to [Enterprise Risk Management & Insurance Programs](https://risk.wayne.edu/), 313-577-3112.
		6. Bring to the hospital copies of the Safety Data Sheets for all chemicals to which the victim was exposed.
2. **Non-Health Threatening Emergencies**
	1. **Injuries and Exposures**

For injuries and exposures that are not considered serious or a medical emergency, visit:

Henry Ford Occupational Health – Harbortown

3300 East Jefferson, Suite 100

Detroit MI 48207

(313) 656-1618

Monday – Friday 8:00 AM to 6:30 PM

If Henry Ford Occupational Health Center is closed or for serious injuries, visit:

Henry Ford Hospital – Emergency Room

2799 W. Grand Blvd.

Detroit MI 48202

(313) 916-8742

OR

Detroit Receiving Hospital - Emergency Room

4201 St. Antoine St, Detroit, MI 48201

Phone: (313) 745-3000

# **Minimum Training Requirements**

1. **General Training:**
* Online through the [Collaborative Institutional Training Initiative (CITI)](https://about.citiprogram.org/en/homepage/).
	+ Laboratory Safety Training (general lab & chemical safety issues)
	+ Hazard Communication
* [Fire Safety](https://risk.wayne.edu/fire-safety).
1. **Laboratory Specific Safety Training:**
* [Laboratory-Specific Safety Training](https://research.wayne.edu/oehs/docs/lab-safety-training-checklist.doc) checklist
* Review of SDS for chemicals involved in process/experiment.
* Review of this SOP.
* Review [WSU Hazardous Waste Management](https://research.wayne.edu/oehs/hazardous/chemical-waste) guidelines.
* Other:

# **References**

1. Air Liquide. (2015, October 8). [Design and Safety Handbook for Specialty Gases](https://industry.airliquide.us/design-and-safety-handbook-specialty-gases?msclkid=2dbfe3aabb3e11ec81894fcb85349a72).
2. Chandra, T., & Zebrowski, J. P. (2016). Hazards associated with laboratory scale hydrogenations. Journal of Chemical Health & Safety, 23(4), 16-25. doi:10.1016/j.jchas.2015.10.019
3. [Chemical Compatibility of the Tubing Materials](https://www.bnl.gov/esh/shsd/pdf/compressed_gas/chem_comp_tubing_material.pdf?msclkid=12017129cf9811ec8b3cb41fc523c58d). Brookhaven National Laboratory
4. [Non-Sparking Tools - Quick Tips #381](https://www.grainger.com/know-how/safety/emergency-response/fire-protection/kh-non-sparking-tools-381-qt). Grainger KnowHow (2017, May 1).
5. Ngai, E., & Ngai, C. (2021). Compressed Gas Safety at the University. Journal of Chemical Education, 98, 57-67. doi:10.1021/acs.jchemed.0c00138

# **Laboratory Personnel Review**

Prior to initiating work, lab personnel using these types of chemicals must complete the table below confirming that they have read and understood the above SOP and the associated hazards.

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| **Name** | **Signature** | **Date** |
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**Appendix I: Hazard Signage**



**HYDROGEN**

**EXTREMELY FLAMMABLE GAS**

**NO OPEN FLAMES IN THIS AREA!**

PI/Responsible Person(s):

Contact Information: