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| Acorn with solid fillACORN ENERGY LABORATORY | STANDARD OPERATING PROCEDURE SOP #1 |
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| **SOP #: 1** | **TITLE: Use of Ammonia in Membrane-Mediated Ammonia Decomposition**  |
| Author: John Locke  Date of creation: 4/10/2022 Date of last review: 4/18/2024 Date of last revision: 4/19/2024 |
| **Principal Investigator** | John Doe |
| **Location**  | Horizon 001 |
| **Designated Area** | Horizon 001, south wall, around the bench where GC is located.  |
| **1. This standard operating procedure (SOP) is for** |
| the use of anhydrous ammonia in membrane-mediated ammonia decomposition. |
| **2. Chemicals, process, experiment, or equipment description** |
| A process designed to separate H2 from N2 gas using a porous membrane. The feed consist of a H2/N2 gas mixture which is fed into the membrane module in which H2 gas is to be separated. See schematic diagram of the process attached for an overview of the process. Gas flow rate is between 0.001 to 0.1 L/min at a pressure of 10 to 20 bar using pure hydrogen, nitrogen, and ammonia gases for the 6 h of each experimental run. |
| **3. Hazard, risk and controls** |
| We have identified the following hazards and risks and have implemented corresponding controls to enable the safe conduct of the proposed experiment or activity:

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| Hazard | Risk | Controls (Engineering, Administrative, PPE) |
| *Hydrogen is a gas that is flammable, asphyxiant and cryogenic* | • Fire and Explosion• Suffocation• Frostbite  | * Cylinders are stored in gas cabinet located in the service corridor outside Room 001.
* Fitted, non-sparking wrench used to install regulators initially and during cylinder changeout.
* Flame arrestor installed between controller and membrane block.
* Leak test using Snoop performed before every experiment is run.
* H2 sensor installed inside the lab room and inside gas cabinet. Sensor calibrated every 6 months.
* Flame resistant clothing and lab coat used.
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| *Ammonia is a gas that is corrosive and flammable* | • Fire• Tissue damage• Respiratory system injury | * Cylinders are stored in gas cabinet located in the service corridor outside Room 001.
* Fitted, non-sparking wrench used to install regulators initially and during cylinder changeout.
* Leak test using Snoop performed before every experiment is run.
* NH3 sensor installed inside the lab room and inside gas cabinet. Sensor calibrated every 6 months.
* Flame resistant clothing and lab coat used.
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| *Nitrogen and helium are gases that are asphyxiant* | • Suffocation | * Purge gas vented into the fume hood.
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| *Heating block can generate high temperature and is electrical and fire hazard* | • Electrocution• Fire• Tissue burn | * Equipment is inspected for wire fraying, presence of ground pin before plugging to electrical outlet.
* Temperature stabilization to be observed during heating stage.
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| *Components of the system (see Section 5) or aspects of the process can cause* *gas leak and/or over pressurization* | * Fire
* Pressure
* Explosion
 | * Leak test using Snoop performed before every experiment is run.
* Membrane block, tubings, and fittings are rated to withstand a max of 10,200 PSIg. Operating conditions of 20 bar max (290 PSIg) will be maintained. Excess pressure is relieved through a back pressure regulator between the membrane block and the GC.
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| **4. Step-by-step Methodology (Note precautions in blue).** |
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| Task or Activity | STEPS |
| Part I. Membrane module start-up | 1) Purge the gas lines with nitrogen with a flow rate of 0.050 L/min for 2h.2) Test for leak by applying Snoop around fittings and connections. Bubbling around fittings indicate a leak. If this happens, tighten or replace the fittings.3) After gas lines are purged, increase temperature at the rate of 10 degrees Celsius per minute under flow of inert gas. |
| Part II. Separation of hydrogen from a nitrogen, hydrogen gas mixture | 1) Open valve for flow of gas for experiment at a flow rate between 0.001 to 0.1 L/min.2) Monitor temperature and pressure of set-up. The experimental temperature and pressure are T<450 °C and pressure between 10 and 20 bar.3) Wait for system to reach steady state. See #1 and 2 and specify steady state conditions4) Begin collecting data. |
| Part III. Data Collection | The system is now at steady state. However, the system needs to be attended at all times and a buddy system needs to be implemented. If you must leave, alert your buddy and make sure that the system temperature and pressure have stabilized. Do one last check to make sure that the system is stable. Make sure that there are no open flames or sources of spark nearby. After data collection is completed, you are ready to shut down the system. |
| Part IV. Shutdown | 1) Set the Membrane Module temperature to 25 °C.2) Turn off flow of experimental gases from the main cylinder and all valves downstream.3) Turn on the flow of nitrogen gas at 0.05 L/min to purge the gas lines for 30 min.4) Turn off the nitrogen gas at the cylinder valve and all valves downstream. |
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| **5. Clean-up, decontamination, and waste disposal** |
| * Wipe off any Snoop spill on the bench or around the fittings and connections.
* No hazardous liquid chemical waste will be generated from this experiment. Purge gas are to be vented directly into the fume hood in Room 001.
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| **6. Special handling procedures, transport, and storage requirements** |
| * Nitrogen and helium gas cylinders are to be secured each to the wall with a chain. Hydrogen and ammonia cylinders are to be stored in a gas cabinet in the service corridor just outside of Room 001.
* Gas cylinders are to be delivered by the supplier directly to Room 001. Empty gas cylinders will be collected from Room 001 by the gas supplier. Should there be a need to move gas cylinders, an approved transport cart fitted with a chain is to be used.
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| **7. Emergency equipment and procedures** |
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| Item | Location |
| Eyewash / safety shower |  Room 001, by the door closest to service corridor |
| First aid kit |  Black (labeled) safety cabinet against the South wall |
| Chemical spill kit |  Black (labeled) safety cabinet against the South wall |
| Fire extinguisher |  Room 001, by the door closest to service corridor |
| Fire alarm manual pull station |  By the stairwell, when you turn right after exiting the lab using the door closest to the middle corridor |
| Telephone |  No land line! Make sure you have a charged cell phone whenever you work in the lab! |
| Other |  Additional fire extinguisher is located in Room 002. |

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| Emergency | What to Do |
| Gas Leak | * If H2 and or NH3 leaks out of the system and there is sufficient gas to trigger the sensors, the alarm panel will be activated. Level 1 alarm will activate the strobe light in your lab. Stop the experiment, close the gas cylinder and all other downstream valves. Turn on the inert gas and find where the leak is and fix it.
* If there is sufficient gas leaking to trigger the Level 2 alarm, the alarm panel will activate the strobe light in your lab and in addition, you will hear a voice warning that gas has been detected and you must evacuate the building. Stop what you are doing and immediately leave the building using the nearest stairway. Proceed to your designated assembly point and be ready to provide information to the emergency responders regarding the circumstances surrounding the gas leak.
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| If personnel inhaled Ammonia  | 1. Call 911 to seek emergency medical help.
2. Assist exposed person away laboratory and into an area with fresh air.
3. Wait for emergency responder to arrive and take the person to the nearest emergency room.
4. Report incident to Tom Syfert (803) 555-5555.
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|  Life-threatening emergencies | 1. Call 911.
2. Provide dispatch the following information: your name and call back number, location of incident, material released, if known, or if there are any injured person and their location.
3. Pull the nearest fire alarm.
4. Exit the building using the nearest stairway.
5. Proceed to designated assembly area.
6. Provide information to emergency responders as able.
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| Facility malfunction (i. e., power outages, plumbing leaks, fume hood)  | Call (803) 777-9675 to report and request work order. |
| If needing medical care due to injury at work (personnel compensated by USC only) | See Section 10 Attachments for procedures on how to obtain medical treatment for work-related injuries.After seeking medical care, any Injury or illness involving any of the following: death, amputation, loss of an eye, is expected to or results in a hospitalization, must be reported to EH&S at (803) 777-5269 and Buddy Harley at (803) 528-8191 within 24 hr. |

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| **8. Training requirements** |
| EH&S Chemical and Lab Safety TrainingSafe Use and Handling of Compressed Gases Review of chemical safety data sheetDemonstrate proficiency in step-by step methodology including safety proceduresDemonstrate proficiency in executing emergency response procedures Fire Safety |
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| **9. Review, Approval and Authorized Users** |
| SOPs are reviewed and signed by the USC Chemical Hygiene Officer as applicable, approved and signed by the lab Principal Investigator, signed by the Author, and signed by all Authorized Users.*Approved by* Principal Investigator: Printed Name, Signature and Date *Prepared by* Author: Printed Name, Signature and Date\**Reviewed by* EH&S Chemical Hygiene Officer: Printed Name, Signature and Review Date \* Review by the EH&S CHO and/or the Chemical Safety Committee is **required** for SOPS involving highly hazardous chemicals (solids and liquids that are acutely toxic and/or pyrophoric, gases that are flammable, corrosive, toxic, and pyrophoric), processes that use and/or generate highly hazardous chemicals, extreme heat and/or high pressure, and equipment the poses a severe risk of injury to users. SOP review by the EH&S CHO is optional for others that do not belong to the above categories of hazardous chemicals, equipment, and processes. |
| Authorized UsersI, an Authorized User of this Standard Operating Procedure for the Use of Ammonia in Membrane-mediated Ammonia Decomposition, agree by signing below, that I have completed all required trainings listed in Section 8. I have read and understand the content of this SOP, and will follow all aspects of this SOP, including but not limited to the proper use of PPE, safe handling of hazardous materials, precautionary measures, methodology, emergency procedures, and other instructions. I agree that I have received lab-specific training on the safe use of hazardous material, equipment, and processes described in this SOP.

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| Printed Name | Signature | Date |
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**NOTE: Additional prior approval is required for any deviation from this SOP. A new SOP is required for any major deviation.** |
| **10. Safety References and other Attachment** |
| * Procedures for Work-related Injuries
* H2 Safety Data Sheet
* NH3 Safety Data Sheet
* (H2 and NH3 Safety Data Sheet are also available at <https://www.sigmaaldrich.com/US/en> by typing the chemical name on the search box)
* The safety manual for the heating block is in the drawer underneath the bench where the heating block is located.

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