# Birch-Type Reactions

**Note**: Birch-Type reactions involve the use of **water reactive materials**, **flammables**, and **toxic gas**. It is performed at **cold temperature** and, when complete and warms up, generates a substantial amount of **heat**.

Moreover, the **scale** at which this reaction is performed is rather **large**.

This reaction can **NOT** be left unattended or **performed alone**.

It is paramount that researchers be aware of the hazards associated with Birch-Type reactions.

**Areas with blue text indicate that information must be provided or modified by researcher prior to the SOP approval.**

**This SOP is not a substitute for hands-on training.**

Print a copy and insert into your laboratory SOP binder.

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

## 1. Purpose

This SOP covers the precautions and safe handling procedures for Birch-type reactions.
Birch-type reactions involve, among other chemicals, water reactive materials (WR) such as, but not restrictive to, sodium, potassium and lithium, and toxic gas such as ammonia. Those chemicals are covered by their specific class SOPs.
**Before setting-up a Birch-Type reaction, researchers must have read and sign the specific class SOPs of any chemical involved in this reaction.**

***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. Physical & Chemical Properties

For physical and chemical properties on water reactive materials, please refer to your laboratory "WR" and "Quenching of WR" Class SOPs and to specific Safety Data Sheets (SDS) of chemicals in use (See Section 11 – SDS Location).
For physical and chemical properties on ammonia gas, please refer to your laboratory "Acutely Toxic Gases" Class SOP.

## 3. Potential Hazards/Toxicity

When running Birch-type reactions, the hazards of the mixture must be considered and procedures for safe handling and quenching must reflect the hazard properties of each component.

As a reminder, the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) defines water reactive materials as "**substances and mixtures which, in contact with water, emit flammable gases**" and are designated by one or more of the following H codes and hazard statements:

**H260** In contact with water releases flammable gases which may ignite spontaneously

**H261** In contact with water releases flammable gases

GHS designates **ammonia gas** ($NH_3$ (g)) by the following H codes and hazard statements:

**H221** Flammable gas

**H280** Contains gas under pressure; may explode if heated

**H314** Causes severe skin burns and eye damage

**H331** Toxic if inhaled

**H410** Very toxic to aquatic life with long lasting effects

It is the Principal Investigator's responsibility to ensure activity-specific laboratory procedures and/or processes are taken into account when using this Hazardous Operation Class SOP.
Please, review the SDS of any chemical before use (see Section 11 – SDS Location)

## 4. Engineering Controls

The following is the set of engineering controls required when running Birch-type reactions:

- Have a sign such as "Ammonia in Use" posted on lab doors.
- Use a clean fume hood, preferably with the sliding sash windows. Keep the sash as low as possible at all times. Stand behind the sliding windows and reach around to perform the manipulations required.
- Remove any flammables (squirt bottles, solvents, oil bath) and combustibles (KimWipes, paper towel) from working area.
- All cylinders and gas cabinets must be clearly labeled with content and hazard information.
- The gas cylinder of ammonia must be placed in a fume hood and anchored using at least one chain before dispensing the reagent.

- All regulators, valves, and lines must be chemically compatible with ammonia (i.e. Tygon). Regulators shall be compatible with the size and type of gas cylinder being used and rated for full cylinder pressure.
- When evaporating ammonia, work under a continuous flow of inert gas (e.g. argon, nitrogen).
- Whenever quenching be sure that it is not done in a sealed vessel as pressure will build up.

## 5. Personal Protective Equipment

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

**Eye 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 Protection**

A. Flame-resistant lab coat (Nomex IIIA, NFPA 2112) must be worn when working with flammables and water reactive materials.

B. A combination of fire resistant (FR) liners, covered with a pair of chemical-resistant disposable gloves (e.g. nitrile gloves or those specified in the specific SDS), must be worn AT ALL TIMES. The following products are Approved FR Liners: Ansell Kevlar® Goldknit® Lightweight 70-200 and Hanz Extremity Wear Nomex® Utility.

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

## 6. First Aid Procedures and Medical Emergencies

***In the event of an injury, notify your supervisor immediately and EH&S within 8 hours. Follow up with a call to 510-643-6060 to report the incident.***

***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.

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 swallowed**

Do NOT induce vomiting unless directed otherwise by the SDS. Never give anything by mouth to an unconscious person. Rinse mouth with water.

**If inhaled**

Move into fresh air.

**Needle stick/puncture exposure**

Wash the affected area with antiseptic soap and warm water for 15 minutes. For mucous membrane exposure such as eyes, mouth and/or nose, flush the affected area for 15 minutes using an eyewash station.

## 7. Special Handling, Storage, and Disposal Requirements

**Precautions for Safe Handling and Conditions for Safe Storage**

For safe handling, storage and disposal requirements see specific Class SOPs for WR, Quenching of WR, and Acutely Toxic Gas. Lab-specific information on handling and storage may be included in Section 12 - Protocol/Procedure section.

## 8. Gas Release, Chemical Spill, and Managing Any Subsequent Fire

**Gas Release** - Dial **911**

- If gas cylinder is connected to the set-up, close the regulator valve.
- Lower the hood sash and press the emergency button (red purge button).
- Evacuate the room.
- Accidental Release – Help contaminated or injured persons. Evacuate the release area. Avoid breathing vapors. Eliminate sources of ignition. Keep others from entering this area (e.g., use caution tape, barriers, etc.).
- Contact with body or clothes – Remove clothing and rinse body thoroughly in emergency shower for at least 15 minutes. Seek medical attention.
- 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.

**Spill Response**

- In the case of a spill, announce the situation loudly in the immediate area and have any nearby persons move to a safe location.
- Immediately eliminate/remove all nearby ignition sources.
- If spill occurs in a fume hood, and WR is present, cover with Met-L-X, dry sand, or other non-combustible material, close the hood sash, and press the emergency button (red purge button), press the red purge button.
- If a spill occurs outside a fume hood, and WR is present, cover with Met-L-X, dry sand, or other non-combustible material, and stand away from the spill.
- Locate and have a proper fire extinguisher (dry chemical-based) ready in case of ignition/fire.
- Use clean, non-sparking tools to collect absorbed material and place into loosely-covered metal or plastic containers ready for disposal.
- If you cannot assess the situation well enough to be sure of your own safety, do not approach the spill.

- Keep others from entering contaminated area (e.g., use caution tape, barriers, etc.).
- Report the spill to 510-642-3073.

**Fire Response**

- Call **911** (from a cell phone: **510-642-3333**) for assistance with all fires, even if extinguished.
- If the spill ignites, and if you are trained and you feel comfortable to do so, consider extinguishing the fire with an appropriate fire extinguisher. Use only dry chemical fire extinguishers (classes ABC or D).
- A can of Met-L-X or **dry** sand in the work area, within arm's reach, might be helpful to extinguish any small fire as it can smother the flames.
- Do not use water to extinguish a WR chemical fire as it may enhance the intensity of the fire. An exception to this would be in the case of skin contact or ignited clothing/skin. In these cases rinsing any unreacted chemical off is of primary importance.

## 9. Cleaning and Decontamination

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

- Wearing proper PPE, laboratory work surfaces must be cleaned at the end of each work day.
- Dispose of contaminated materials in accordance with hazardous waste disposal guidelines referenced below.
- Clean all equipment before removing from a designated area.

## 10. Hazardous Waste Disposal

Label Waste

Label all containers with the label provided at

http://ehs.berkeley.edu/hm/279-new-hazardous-waste-program-hwp.html.

See the EH&S Fact Sheet, "Hazardous Waste Management" for general instructions on procedures for disposing of hazardous waste.

Dispose of Waste

- Dispose of regularly generated chemical waste within 6 months.
- Call EH&S with questions.

## 11. Safety Data Sheet (SDS) Location

SDS can be accessed online at http://ucsds.com

## 12. Protocol/Procedure – Birch-Type Reactions

**Section 12 must be customized to your specific needs. Delete any procedure that does not apply to your laboratory.**

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| **Preparation** | *List any other particular preparation requirements needs for this procedure (e.g., location of spill kit or keep water or ignition sources away from procedure area)*<br><br>• Before using $NH_3$(g) be sure you are in compliance with the University of Berkeley Toxic Gas Program requirements. If you have questions about Toxic Gas Program requirements, contact EH&S at 642-3073.<br>• All regulators, valves, and lines must be chemically compatible with the $NH_3$(g). Regulators shall be compatible with the size and type of gas cylinder being used and rated for full cylinder pressure.<br>• Know the location of the nearest fire extinguisher, eyewash, and safety shower before beginning work. Have a small beaker or can of Met-L-X or DRY sand in the work area, within arm's reach.<br>• Solvents must be dry.<br>• Glassware must be dry before using. Either "flame" dry or dry in an oven overnight at a minimum temperature of 120°C.<br>• Remove all other flammable materials from the hood to reduce the hazard in case of a fire. Others in the lab must know that you will be running a Birch-type reaction.<br><br>**NOTE: Larger quantities (see Scale column below) of WR chemicals can be disposed of as hazardous waste.**<br>**• Carefully package and label the wastes with current HWP labels.**<br>**• Request waste pick up** |
| **Chemical Storage and Disposal** | • Properly restrain ammonia gas cylinder within gas cabinet or fume hood at all times.<br>• The ammonia cylinder must be stored upright, with tank valves are securely closed and valve protection cap in place, and firmly secured to prevent falling or being knocked over.<br>• Protect the ammonia cylinder from physical damage; do not drag, roll, slide, or drop. Cylinder temperatures must not exceed 52 °C (125 °F). |
| **Lab Specific Information** | *Add lab-specific information not included above if needed (e.g., all work for this procedure is to take place in the designated fume hood.)* |

## Scale, Engineering Controls, Equipment and PPE

- **Scale:**

  Ammonia – 1L
  WR – 50g

**Remember to obtain EH&S evaluation and PI approval if higher scale is necessary.**

- **Engineering Controls/Equipment:**

  Conduct in a clean fume hood with a face velocity not less than 100 fpm.
  The gas cylinder of ammonia, if small enough, must be placed in a fume hood and anchored using at least one chain before dispensing the reagent. If the cylinder is too large for a normal hood, consider using a walk-in, with the cylinder anchored with two chains.
  All the reaction vessel joints (round bottom flask and cold finger) must be greased.

- **PPE:**
  - **Eye protection**: PERSONS WITH POTENTIAL EXPOSURE TO AMMONIA MUST NOT WEAR CONTACT LENSES. Wear tight-fitting safety goggles or safety glasses with side shields.
  - **Face Protection**: Wear a face shield when the hood sash does not provide adequate protection.
  - **Hand protection**: Wear a combination of flame resistant (FR) liner gloves, covered with a pair of chemical-resistant disposable outer gloves (e.g. nitrile gloves or those specified in the specific SDS).**The following products are approved FR Liners: Ansell Kevlar® Goldknit® Lightweight 70-200 and Hanz Extremity Wear Nomex® Utility.**
    For gas release or for potential contact with larger quantities, use flame resistant (FR) liner gloves, covered with double nitrile or heavier gauge nitrile or neoprene gloves.
    Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Remove gloves immediately upon contamination. Wash and dry hands after use.
  - **Clothing**: Wear Nomex IIIA (NFPA 2112) lab coat; full length pants or equivalent; and close-toed and close-heeled shoes.

## Step 1 – Connecting Gas Regulator to an Ammonia Cylinder

1. Properly restrain ammonia gas cylinder within fume hood at all times with at least one chain. Use also a ring clamp to secure the cylinder from the neck just beneath the regulator.
2. Remove gas cap, confirm tank valve is closed, and remove bolt from regulator inlet.
3. Tightly insert appropriate regulator. Do not open gas tank valve.
4. Attach regulator to gas lines connected to the instrument/equipment. All lines must be chemically compatible with ammonia gas.

## Step 2 – Dispensing and Condensing Anhydrous Ammonia into Reaction Flask (Figures 1 and 2)

**NOTE:** remember to grease all the reaction vessel joints (RBF and cold finger).

1. Flame dry glassware OR use glassware previously dried in an oven overnight at a minimum temperature of 120°C.
2. Clamp a 2L round-bottom flask (RBF) with 2 necks. On one neck, fit cold finger. Put a septum on all the necks (cold finger and side arm).
3. Pierce the septum of the cold finger with a nitrogen inlet needle, and a vent needle on the side neck.
4. Purge the system with nitrogen for about 20 minutes.
5. Replace the nitrogen inlet needle on the cold finger with a needle that has been attached to a balloon apparatus, used to provide space for venting ammonia gas.
6. Cool the flask down to < -40 °C (- 78 °C is an easier working temperature to keep the ammonia condensed). Ensure that a low temperature < -40 °C is maintained throughout the procedure.
7. Fill the cold finger with dry ice and acetone.
8. Affix a long needle to the end of the tubing from the ammonia tank. Secure tubing by clamping it.
9. Pierce the needle into the septum of the RBF side neck and slowly open the valve on the ammonia tank. Set delivery pressure to 20 psig. This will begin the transfer of ammonia to the reaction flask; ammonia will condense into the reaction flask (Figures 1 and 2).
10. Upon completion, close the regulator valve and the cylinder's valve, and remove the needle from the reaction flask. Vent the regulator before removing it. Re-attach the cylinder's cap and allow the components to vent in the fume hood for at least 10 minutes

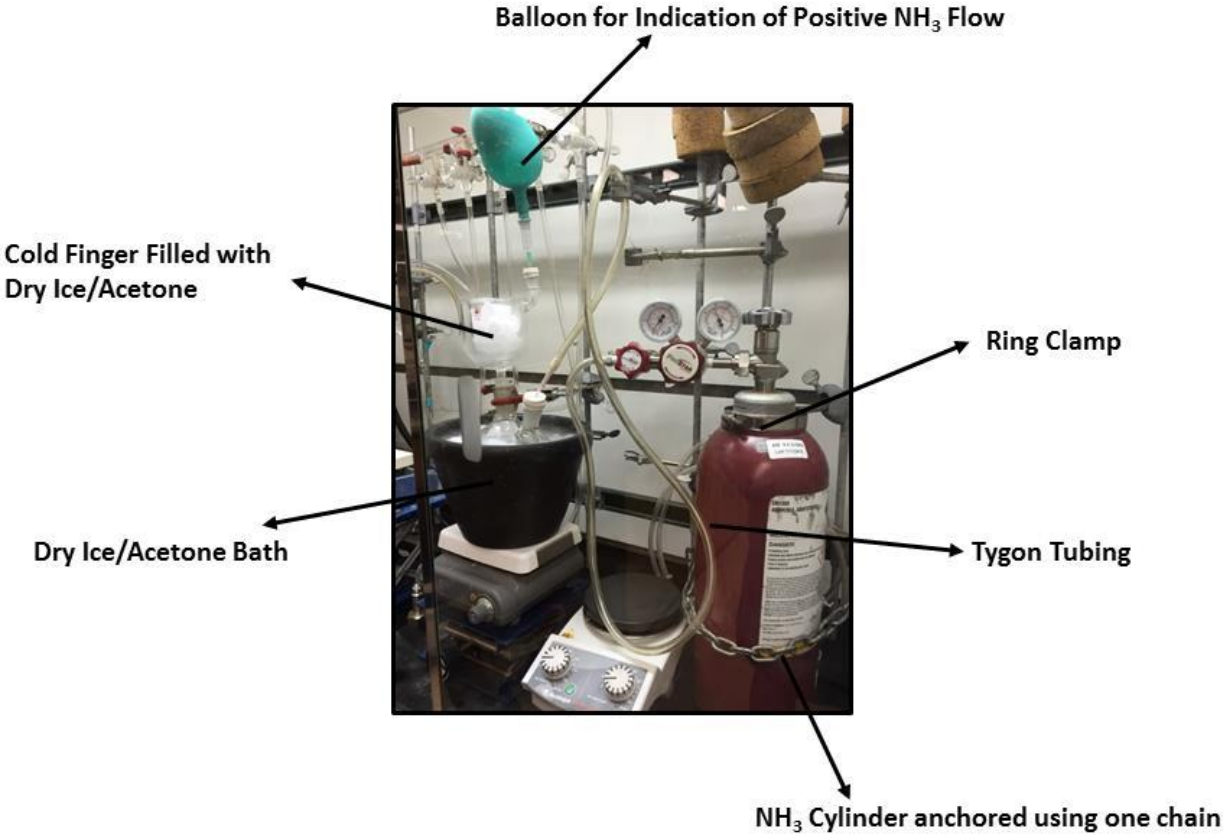


***Figure 1: Dispensing and Condensing Ammonia Gas***

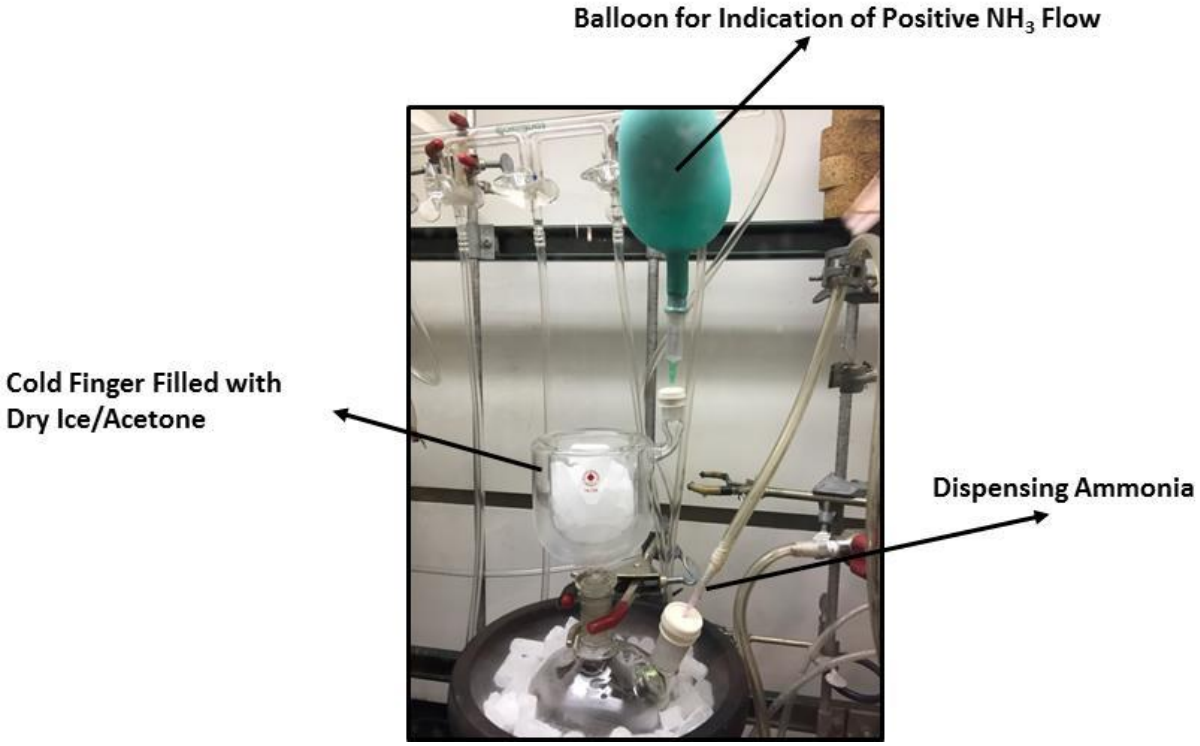


***Figure 2: Close-Up - Dispensing and Condensing Ammonia Gas***

## Step 3 – Addition of $Fe(NO_3)_3$

1. Replace the balloon with a nitrogen inlet to maintain an inert atmosphere.
2. The $Fe(NO_3)_3$ catalyst (<0.5% loading, usually between 350-700 mg) is added to the $NH_3$(l) prior to the addition of WR. Under a positive nitrogen flow, it is added through the side neck of the reaction vessel. No heat is generated upon addition of the catalyst.

## Step 4 – Removal of Oil from WR and Addition to Reaction Vessel

**NOTE:** If WR does not come in oil, it must be manipulated in a nitrogen-filled glovebox. Bring the WR (normally packaged under nitrogen) and large pair of scissors or a knife, a suitably-sized container, and hexanes (distilled and degassed; anhydrous grade packaged under nitrogen can be

purchased from Acros or Sigma Aldrich) into the glovebox. Cut the block of WR into smaller pieces and submerge it in hexanes. Once in hexanes, the WR can be removed from the glovebox and transferred (can be performed under air, away from water) to another container containing mineral oil for long term storage.

1. Pieces (~2.5 g/piece) are transferred to a beaker containing hexanes that covers the metal fully.
2. Pieces are then washed with more hexanes to remove the oil and transferred to a second beaker containing more hexanes.
3. The pieces are flattened in the beaker containing hexanes then removed, washed with hexanes and transferred slowly to the reaction vessel containing $NH_3(l)$.
4. The addition of the WR takes approximately 30 minutes. The rubber septum can be removed for short periods of time so the WR can be added into the side neck. Addition of WR generates hydrogen gas which needs to escape the vessel. Insert a vent needle on the septum of the side neck. When the WR contacts $NH_3(l)$, a brief hissing sound occurs as hydrogen gas is generated, and the solution turns dark blue. Pieces of WR must be added between 30–60 second intervals. As more WR is added, some splashing within the flask occurs, and the inside of the entire flask eventually becomes coated with a thin layer of WR. After all WR has been added, replaced the nitrogen gas inlet with a balloon or a gas bubbler to monitor hydrogen gas evolution (Figure 3).

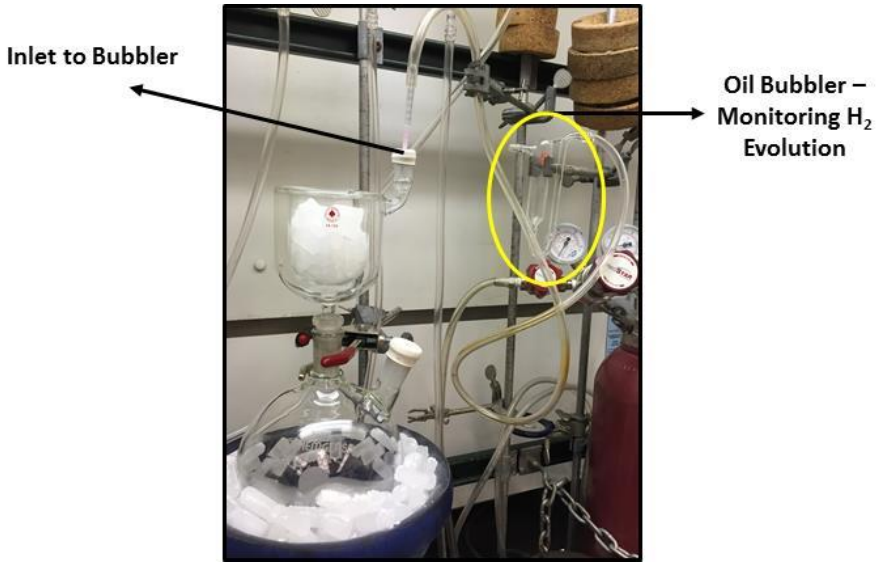


***Figure 3: Monitoring of $H_2$ Evolution Using Oil Bubbler***

## Step 5 – Addition of Alkyne Using Automated Syringe Pump

1. The alkyne is added as a neat solution directly into the reaction vessel using an automated syringe pump.
2. Set the addition rate to 1 mL/min, the addition must be directed into the center of the reaction mixture *and not* along the sides of the flask. The sides of the flask have a layer of WR metal that can react with the alkyne in an exothermic manner, causing the septa to pop off.

## Step 6 – Evaporating Ammonia (Figures 4 and 5) and Quenching of WR

1. Upon completion of the reaction, remove the cold finger and replace it with a large compatible tube directing the ammonia to the back of the fume hood.
2. Connect nitrogen to the side arm (Figure 4).
3. Keep the system under a continuous flow of nitrogen.
4. As ammonia evaporates, a layer of ice is formed on the flask which will keep the system cool as well as help to maintain a somewhat controlled rate of evaporation (Figure 5).
5. When ~2/3 of the $NH_3$(l) has evaporated, remove tubing and add slowly the desired amount of ether.
6. Cool the reaction vessel with an ice bath. **Slowly** add isopropanol to the reaction vessel to start quenching the WR, followed by the addition of methanol. This will most likely get the reaction vessel to warm-up. If the solution begins to warm up, stop and allow it cool down before continuing the addition of the quenching agent.
7. **Be Very Careful with the addition of WATER!** Even after methanol has been added, the water reactive agent can still react violently with water, especially if there hasn't been sufficient mechanical stirring of the solution. Therefore, water must be add in small aliquots.

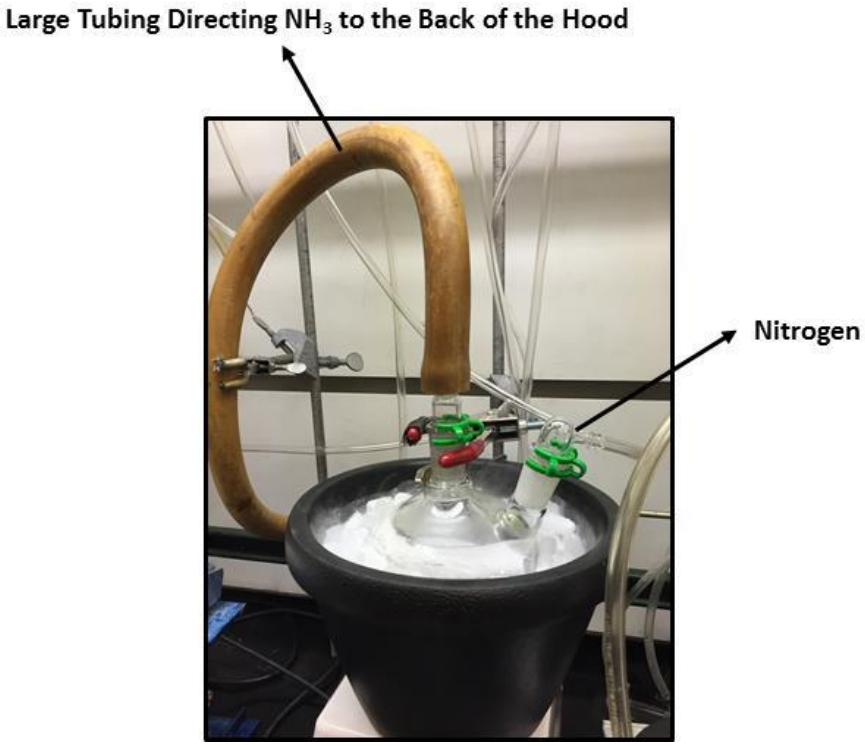


*Figure 4: Evaporating Ammonia*

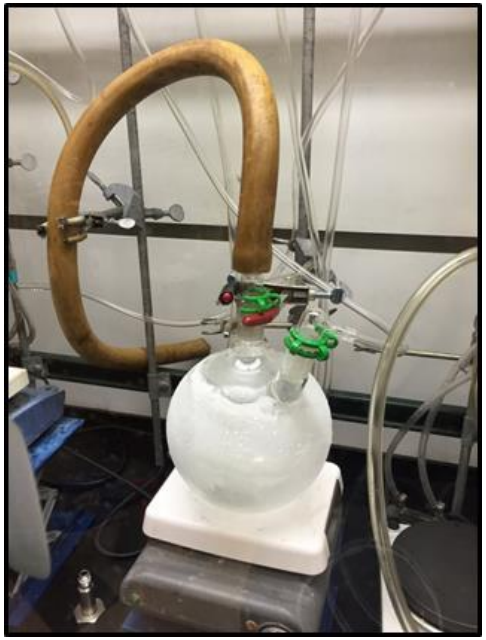

*Figure 5: Layer of Ice upon Evaporation of Ammonia*

## Step 7 – Filtration over Celite and Distillation of Desired Product

1. After the quenching process is completed, the mixture is diluted with ether, then filtered (gentle vacuum filtration) over celite (use a maximum of 500 mL ether to rinse the flask and celite pad).
2. Transfer the biphasic filtrate to a 1 L separatory funnel and remove the aqueous layer. The organic layer is washed with brine (150−200 mL), dried over anhydrous $Na_2SO_4$, and followed by gravity filtration.
3. The ether solvent is removed by distillation with mild heating (40−55˚C). The distillate normally contains a 1:1 mixture of product/ether. The use of a rotary evaporator (rotovap) causes significant loss of product.

## 13. Documentation of Training (signature of all users is required)

- Prior to conducting any Birch-type reactions, 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 water reactive material SDS provided by the manufacturer.

I have read and understand the content of this SOP:

| Name | Signature | Identifier | Date |
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