Safe Handling of Pyrophoric (PP) Reagents

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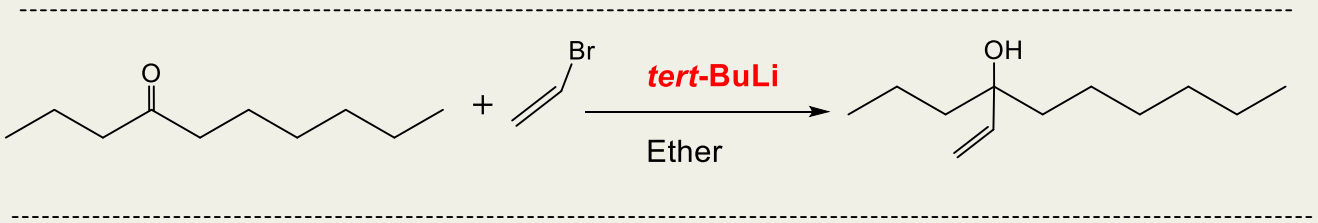
Purpose

This PowerPoint presentation offers a detailed description on the safe handling, use and storage of pyrophoric liquids. The information provided can assist lab personnel with conducting a risk assessment, training and developing an SOP before using pyrophoric liquids such as *tert*-Butyllithium, diethyl zinc etc.



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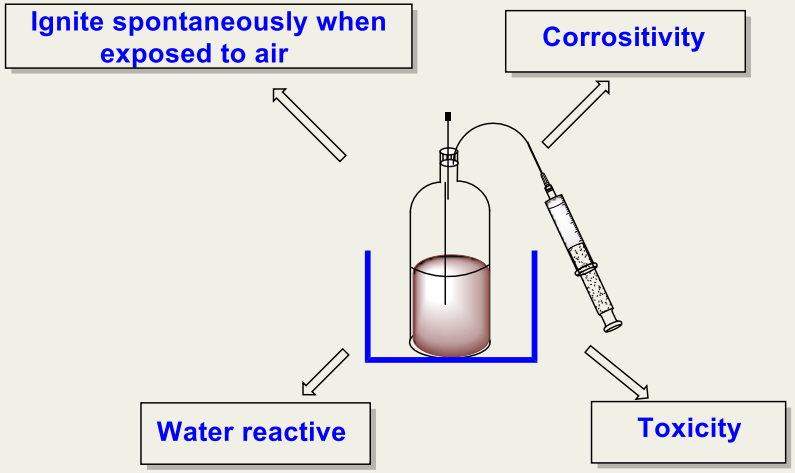
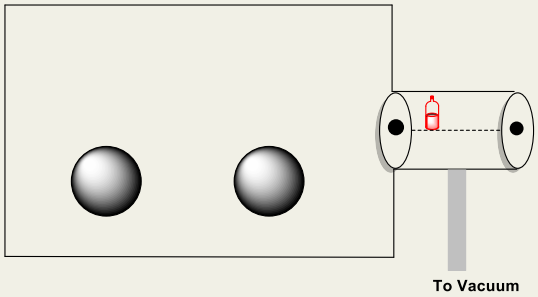
Hazards Attributed to the PP Reagent Manipulations

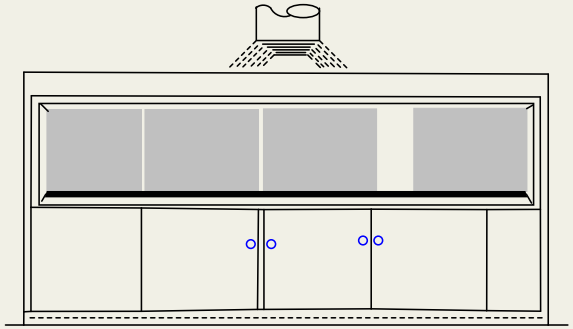
Pyrophoric reagents ignite spontaneously when exposed to air, and can cause severe **caustic injuries** or burns on contact with skin, eyes and mucous membranes as they react with moisture resulting in the generation of alkaline hydroxide. Fumes arising from the combustion of PP compounds are mainly lithium oxide and lithium hydroxide. They also have a burning (caustic) effect.



Engineering Controls

Because of the dangers of reactivity (spontaneous ignition), special precautions must be engaged when working with pyrophoric reagents. All operations with solid and concentrated *reagents* should be performed in a properly functional chemical fume hood. A fire extinguisher, emergency safety shower and eye wash should be readily available within **10** second travel time. Small scale pyrophoric manipulations can be carried out easily in a glove box, they provide excellent inert atmosphere for pyrophoric chemicals.





Administrative Controls

Avoid working alone while conducting experiment with PP *reagents*. The buddy system provides added protection in the event of an emergency. Know exact location of eye wash station, safety shower and fire extinguishers before starting experiment.

Personal Protective Equipment

Eye Protection

Safety glasses or **goggles** should always be worn to protect the eyes from the corrosivity of PP compounds. Additional eye protection, provided by a face shield, is recommended in experiments where higher volumes of PP reagents are employed and PP solutions are pressurized, for instance in order to transfer them via tubing.

Body Protection

A long-sleeved fire-resistant laboratory coat which is closed should be worn at all times when working with pyrophoric chemicals. In addition, it is recommended to wear fire-resistant clothing underneath, as opposed to synthetic clothing not intended to be fire resistant while working with pyrophoric chemicals.

Gloves

Nitrile gloves are acceptable for manipulating PP reagents in a general laboratory operation but they are combustible. Dry and clean Nomex® gloves serve for protection of the hands.

Nitrile

Nomex

Flame resistant lab coats

Fig. 1

Laboratory Scale Checklist Before Working with Pyrophoric (PP) Reagents

Items	Y	N
Secure latest version of SDS/MSDS of **PP** solution of interest from vendor		
Read latest version of SDS of **PP** solution of interest from vendor		
Are safety glasses, goggles and face shield available?		
Is a flame resistant lab coat or coveralls available?		
Are gloves of **Viton® or nitrile** available?		
Are extended sleeve gloves available?		
Are leather, closed toe shoes available?		
Is an appropriately sized bottle tote safety carrier available?		
Is a Class B fire extinguisher available?		
Know the location of nearest **eye wash** and safety shower?		
Did you order the minimum amount of **PP** solution necessary for the experiment?		
Has the **PP** solution bottle been stored at < 10 ^{o}C in a tightly closed container?		
Is a suitable laboratory fume hood available to conduct the experiment?		
Is the hood free from clutter (solvent bottles, samples, combustible materials)?		

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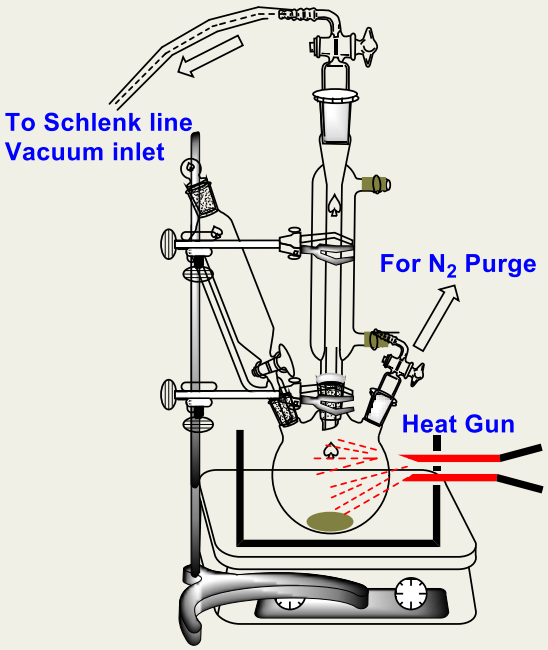
Items	Y	N
Is inert gas (dry nitrogen or argon) available in the hood?		
Is an inert gas delivery system (Schlenk line) or manifold available in the hood?		
Is a glassware drying oven or heat gun available to dry the equipment?		
Is a glass desiccator available of sufficient size to allow the dry glassware to cool to room temperature?		
Is a vacuum pump available, to evacuate the equipment, if this technique is selected?		
Is an explosion proof refrigerator or cold room available to store **PP** solution?		
Have you alerted your lab mates / co-workers that you will be handling PP solutions?		
Have you rehearsed your emergency response procedure?		
Are there two inert gas bubblers available?		
Is there a syringe available with a sufficiently long needle? Or, is there a cannula available?		
Has all the equipment been dried in an oven at **125 ºC** for at least four hours?		
Was the equipment assembled hot and allowed to cool to room temperature in stream of inert gas?		
Is there a metal bowl under the reaction flask as a secondary containment?		
Is sufficient time available to complete the experiment?		
Is a co-worker available during the **PP** transfer?		
Is there an inert gas purge on during the entire experiment?		

Methods: Small/Large Glass Assembly Drying



(Fig. 2)

Small flasks and a condenser are easy to dry in an oven and cool under a calcium chloride desiccator, but a large scale assembly (condenser, 1 lit flask and dropping funnel) cannot be dried in a desiccator.

A heat gun and vacuum is appropriate for such assembly. After assembling the set-up in a fume hood, connect the assembly to a vacuum using a suitable take off. A Schlenk line (SL) is appropriate for this drying where nitrogen is used as an inert gas.

Heat the assembly using a heat gun and continuously evacuate the assembly. Do not heat Tygon® tubes used for chilled water fitted to the condenser and Keck Clips during the drying process.

***Keck® clips** lose their holding capacity if they are heated under high temperature or used incorrectly.*

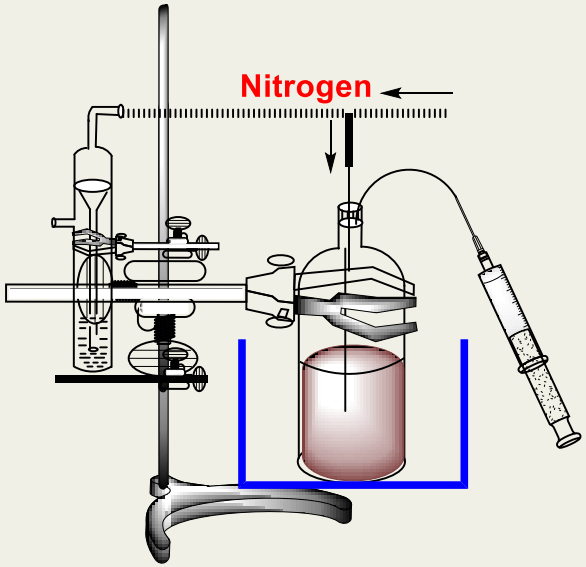
*Make sure the size of the bar is appropriate to the flask size and never use large bars for a small flask. There is always possibility of **breaking the flask during** stirring.*

Safety Measures & Techniques

- In the first step clean and dry glassware in an oven above 120 ^{o}C for 4 h or using a heat gun then cool in a glass desiccator over anhydrous calcium chloride.
- Inspect your glassware and reaction set-up for any **deep notching** star cracks, or any cracking at all in the flasks, you should replace it immediately if the glassware is cracked.
- Use a **secondary containment** to support the reaction flask in case of any emergency or other purposes such as heating and cooling.
- **Do not cannulate** PP reagents or any pyrophoric chemicals to any open glassware.
- The hood sash should be closed as much as possible during the transfer operation and reaction, to provide an additional level of personnel protection.

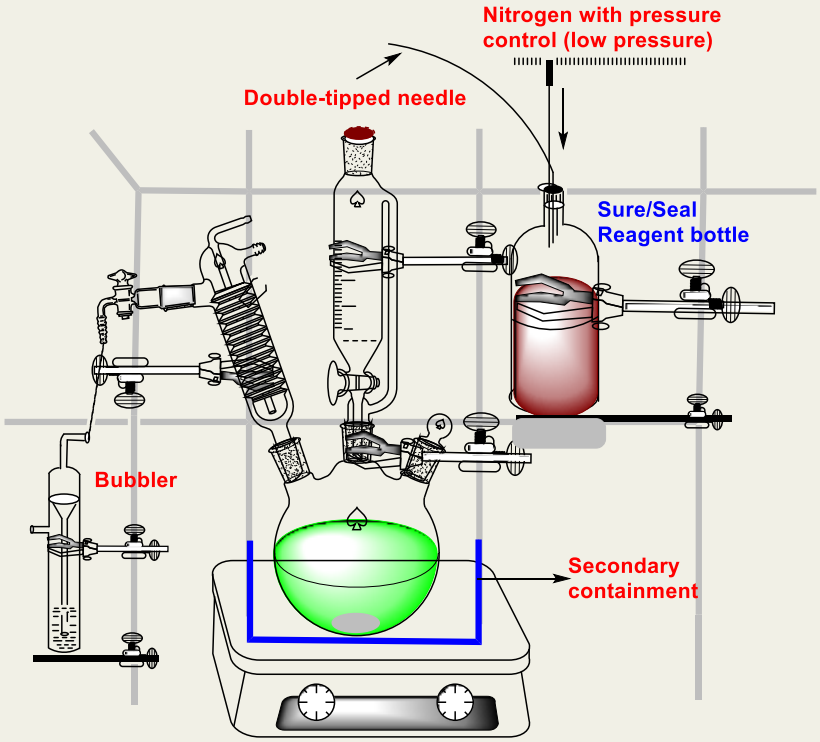
Note: Nitrogen under certain conditions, reacts exothermically with lithium and lithium containing compounds. Therefore, use of argon as the inert atmosphere is usually prudent if you are unclear about the reactivity of the reagent with nitrogen.

Techniques for Transferring *tert*-Butyllithium (for transferring >10 mL Double Tipped Needle/Cannula Method)



(Fig. 3a)

Small-scale pyrophoric reagent transfer

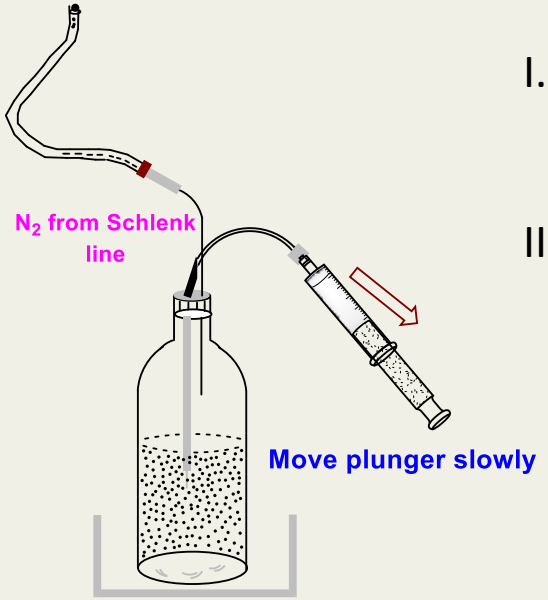


(Fig. 3b)

Reaction assembly for large-scale pyrophoric reagent transfer

Transferring Pyrophoric Reagents with a Syringe

Transfer of pyrophoric reagents via syringe is convenient, but **should not be used for more than 10 mL.** You will need a small positive pressure in the reagent bottle in order to draw the reagent into syringe. Ensure that excess pressure is released through the mineral oil bubbler that is attached to the gas line. **SL** equipped with a pressure release system, where the inert gas line is vented through an oil bubbler is a good option.



I. It is recommended that the syringe be at least ***twice the volume of the PP*** to be dispensed.

II. The syringe should be dried in an oven at 125 °C for **at least 4 h**, placed in a desiccator (small glass items) to cool to ambient temperature, and then purged with a stream of inert gas (plastic syringe can be dried in a desiccator without heating).

Fig. 4 filling syringe with slight N_2 pressure

Pyrophoric Reagents Transfer with Syringe

I. Insert the needle, connected to the inert gas line (bubbler), through the septum into the headspace above the reagent maintaining a small positive pressure inside the Sure/Seal™ pyrophoric reagent bottle. (***never over-pressurize reagent bottle containing PP reagents***).

II. Insert needle of a luer-lock syringe through the septum into the reagent bottle.

III. Pull the plunger back slowly to fill the syringe with the required volume of reagent. Always keep the plunger in your grasp and avoid pulling back the plunger quickly as this action causes leaks and builds gas bubbles.

IV. Once the required volume is attained, slowly pull up the syringe needle from the pyrophoric reagent to the overhead space above the liquid.

V. Pull the plunger up slowly and allow the inert gas to push the reagent trapped in the needle into the syringe.

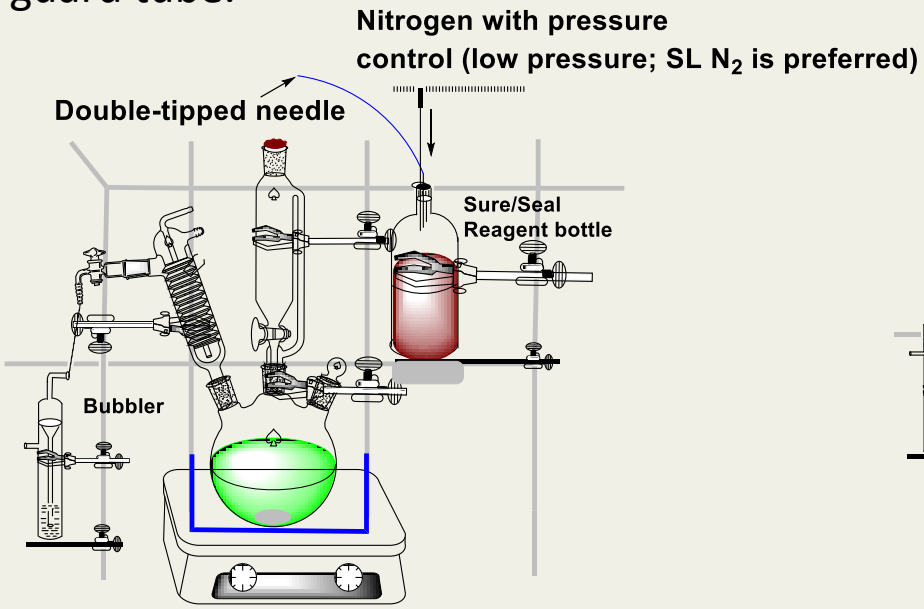
VI. Shut the inert gas line off and slowly pull the needle out from the assembly to complete the transfer.

VII. Rinse syringe and needle with a non-reacting solvent after transferring reagent, and quench the residue under an inert atmosphere using isopropanol.

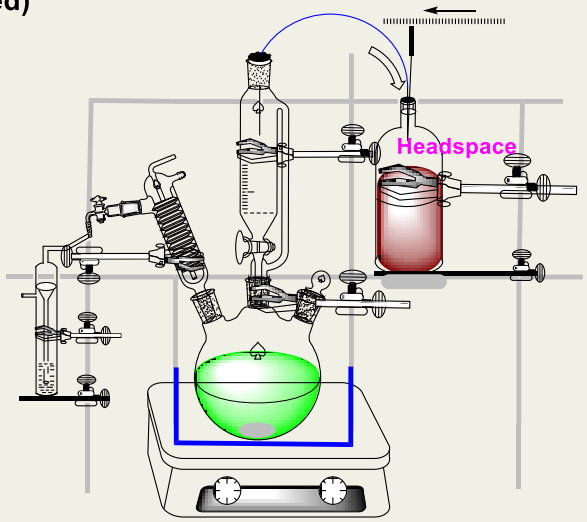
Pyrophoric Liquid Transfer: Cannula Method

- **Pre-measure** the volume you require into an addition funnel, mark it correctly then dry the glassware thoroughly as your set-up under inert gas or oven. Do not over-pressurize the reagent bottle and use of Schlenk line nitrogen is recommended.

- Secure the bottle with clamp then **slightly pressurize** the Sure/Seal™ bottle with nitrogen or argon. Insert the double-tipped needle through the septum into the **headspace** above the reagent. Nitrogen will pass through the needle (**Fig. 5a**).
- Insert the other end through the septum at the graduated dropping funnel **(Fig. 5b)** of the reaction apparatus which must be equipped with a gas line to a bubbler or calcium chloride guard tube.



5a) Double tipped needle/cannula insertion to the reagent bottle



5b) Insertion of cannula to dropping funnel

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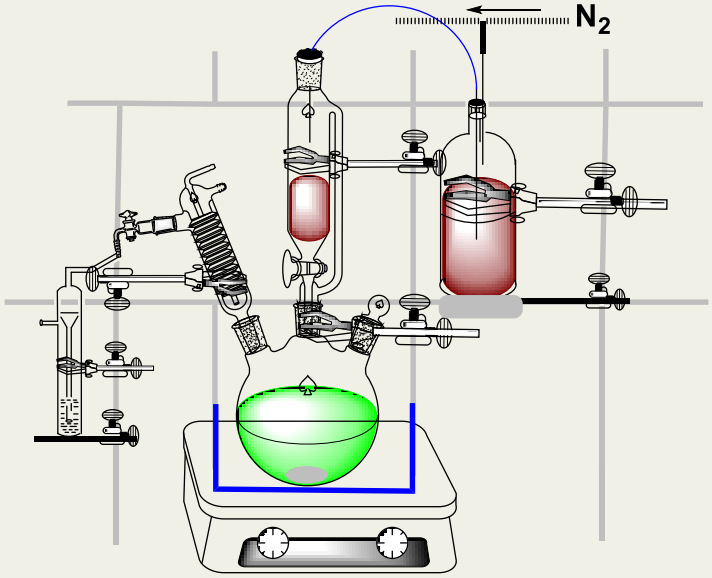
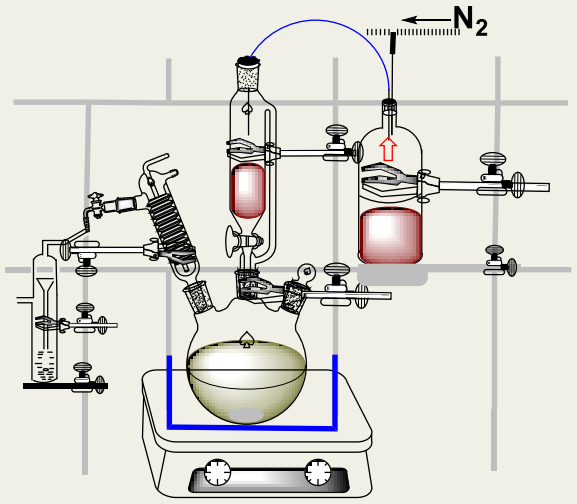
Pyrophoric Liquid Transfer: Cannula Method

- Push the needle into the liquid in the Sure/Seal reagent bottle and transfer the desired volume **(Fig. 5c)**. To control the flow rate, fit a Luer lock™ syringe valve connecting two elongated needles.
- Then withdraw the needle to above the liquid level (head space, **5d**). Allow nitrogen to flush the needle or cannula **(Fig. 5a & 5d)**. Take out the needle from the reaction apparatus first and then from the reagent bottle **(Fig. 5e)**.



5c) Reagent transfer



5d) Removal of cannula from reagent surface and cannula flushing

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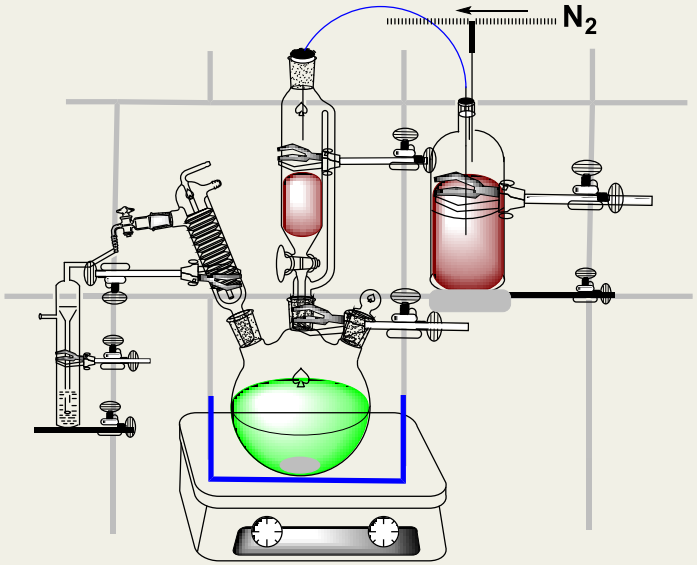
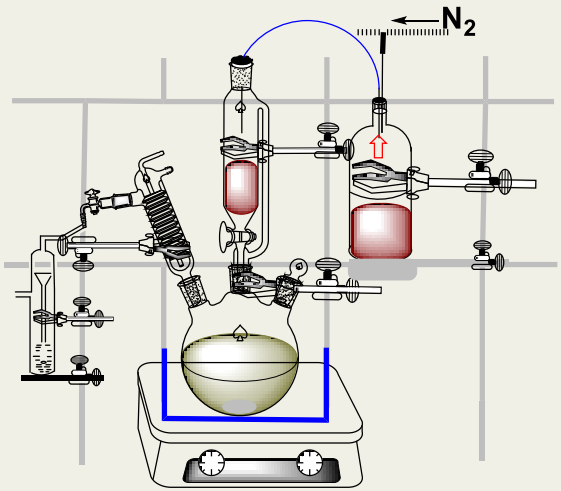
Pyrophoric Liquid Transfer: Cannula Method



5c) Reagent transfer



5d) Removal of cannula from reagent surface and cannula flushing

Storage of PP Reagents

Always store pyrophoric chemicals under an **inert atmosphere**. Procure smallest volume of PP reagent for use. PP reagents will degrade over time. Avoid areas with heat/flames, oxidizers, and water sources. Bottles with pyrophoric materials must be clearly labeled with the correct chemical name (**full name and no acronym**) and hazard warning.

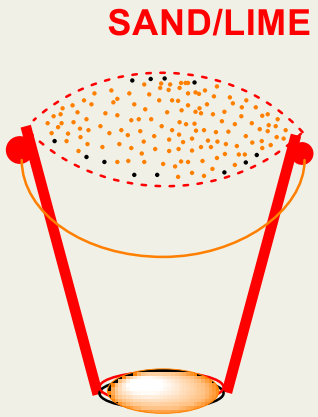
Store in cool, dry and well-ventilated area away from incompatible materials (RT stable PP Reagents). "**Use a lab safe**" Refrigerator for storing temperature sensitive PP reagents. Never allow PP reagents to get in contact with moisture during storage.

Keep containers **tightly closed**. Never return excess reagent to the original container.

Managing Spills Involving PP Reagents

For small spills inside chemical fume hood, **use dry sand/lime**, or other non-combustible Material for covering the spill material, close the hood sash.

If a spill occurs outside a fume hood and you are unable to handle the spill call immediately **911.**



Disposal of Pyrophoric Reagents

Large quantity of PP reagent should be disposed of through safety dept. Small amounts of unused or unwanted PP materials must be destroyed by careful quenching of the residue.

Transfer the materials to an appropriate reaction flask for Hydrolysis or neutralization. Dilute significantly with an unreactive solvent such as heptane or toluene and place the flask in an ice water cooling bath. Slowly add isopropanol to quench pyrophoric materials. Upon completion, add methanol as a more reactive quenching agent to ensure completion. Finally, add water drop-wise to make sure there are no pockets of reactive materials.

AVOID low boiling diluents such as **ether and pentane** that tend to condense water upon evaporation. Do not leave containers with residues of pyrophoric materials open to the atmosphere due to uncontrolled ignition.

Transfer neutralized mixture into solvent carboy* for disposal purpose.

**Before transferring quenched material into solvent carboy, make sure there is no reactive PP reagent present (fire hazards).*

References

- ***Org. Process Res. Dev*.** 18, **2014**, 1192−1210.
- https://www.pnl.gov/main/publications/external/technical_reports/PNNL-18668.pdf
- Methods for the safe storage; handling; and disposal of pyrophoric liquids and solids in the laboratory ***J. Chem. Health & Saf.*** *18(1),* ***2011****, 5-10.*
- Management of time-sensitive chemicals (III): stabilization and Treatment ***J. Chem. Health Saf***., 13 (1) **2006**, 24-29.
- http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Aldrich/Bulletin/al_techbull_al134.pdf
- http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Aldrich/Bulletin/al_techbull_al164.pdf
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