Columbia University Environmental Health and Safety

The Safe Use of Pyrophoric Reagents

Authored By: Kevin McGhee, EH&S
Professor Jack Norton, Dept. of Chemistry

Revised November 2009, March 2010
and May 2010

Written April 2009

EXECUTIVE SUMMARY

November, 2009—Due to a recent incident involving the use of dry powder *sodium hydride*, EH&S has made some additions to this document to place greater emphasis on the use of solid pyrophorics. A brief section has been added before the techniques outlining the manipulation of liquid reagents to address issues concerning the use of metallic hydrides. All other material erstwhile contained herein is still held to be valid.

INTRODUCTION

In light of the recent fatal accident at UCLA, Columbia University EH&S has developed the following bulletin to serve as a guide for those who currently, or might in the future, use pyrophoric reagents. This guide is NOT to serve as a replacement for formal training in lab techniques or lab safety. Only qualified and experienced laboratory workers should ever attempt to manipulate these materials, and only after they have extensively researched and consulted knowledgeable peers with regard to the correct techniques for doing so. Failure to follow proper handling precautions can result in the exposure of these materials to the atmosphere, with consequences including serious injury or death.

Pyrophoric compounds are widely used in labs at Columbia. Here are some examples of the more common reagents:

Organolithiums, such as t-Butyllithium
Organozincs, such as diethylzinc
Organomagnesiums (Grignard reagents)
Aluminum alkyls, such as trimethyl aluminum
Metallic hydrides, such as sodium hydride, potassium hydride, lithium aluminum hydride and some boranes.
Finely divided metals, such as: aluminum, lithium, magnesium, titanium, zinc, zirconium, sodium, and potassium.

HAZARD INFORMATION

Pyrophoric reagents are extremely reactive to oxygen and moisture, and precautions must always be taken to prevent their exposure to air, which usually leads to spontaneous ignition. The danger of this reactivity is often exacerbated by the fact that these reagents are sold in solvents that are extremely flammable, such as ethyl ether, tetrahydrofuran (THF), or pentanes. When possible, compounds stored in pentanes or hexanes should be avoided, as storage in heptanes is *slightly* less hazardous.

The hazards from using these chemicals stem from fires that could result from the chemicals themselves and the solvents containing them, as well as any secondary fires that may spread to nearby flammable or combustible materials. Segregating combustible materials from storage as well as work areas is the best way to prevent dangerous secondary fires that could cause serious property damage and personal injury.

CONTROL MEASURES

Engineering Controls

- Solid pyrophorics must only be handled in an inert atmosphere glove box. Less expensive inert atmosphere glove bags are also available (http://www.sigmaaldrich.com/labware/products/aldrich-atmosbag.html).
- Pyrophoric liquids, or compounds dissolved in a liquid, should be stored in sealed containers with PTFE-lined septa to prevent air exposure.
- Handling of liquid pyrophorics must be conducted via cannula or syringe transfer to prevent exposure to air if not manipulated within an inert atmosphere (see below for more details).
- Manipulation of these reagents via syringe or cannula should always be conducted in a certified chemical fume hood, over a spill tray if possible, with the sash at the lowest practicable working height.
- Needles should be equipped with locking mechanisms to prevent accidental disconnection and release of reagents.
- Mineral oil bubblers must be employed at all times to release excess pressure from reagent or reaction vessels that can contribute to accidents. Balloons used for air-sensitive reagents are not suitable with pyrophorics.
- A blast shield is excellent, if available.

Administrative Controls/Safe Work Practices

- All users of pyrophoric reagents must first go through EH&S Lab Safety and Fire Safety training before working in a lab (http://www.ehs.columbia.edu/Training.html).
- Users must be trained thoroughly by a qualified and experienced supervisor on techniques for handling pyrophorics, and must be directly supervised when first starting with these techniques. It is best to try a few "dry runs" with the techniques using something less hazardous prior to using an actual pyrophoric material. Supervisors must also understand the hazards associated with these materials along with emergency response procedures, and relay this information to new users.

Pyrophoric materials must only be used while other knowledgeable and experienced lab workers are present and aware of the procedure.

Pyrophoric materials must be used and stored away from all other flammable and combustible materials such as paper, bench liners, and solvents. Even open containers of water should be kept away due to the potential for a violent reaction.

Reagent bottles typically come in secondary containment within metal cans. If it is resealable, keep the manufacturer's can for storage of your reagents when not in use, and for disposal of the bottle after completion of the experiment involving the material. Otherwise, store in a clean, dry desiccator.

Highly flammable synthetic clothing is to be avoided, as well as loose clothing. Always wear long pants and closed-toe shoes in the lab. Tie back all loose hair to prevent ignition in the event of a flash fire.

Purchase only the smallest amounts necessary for your work, and discard old materials promptly. Reagents should be viewed with skepticism if older than six months, or if the septa have been pierced more than six times.

Personal Protective Equipment (PPE)

At a minimum, gloves, safety glasses, and a protective lab coat must be worn.

A lab coat made of fire resistant material, such as Nomex, is preferred to polyester or cotton.

It is recommended that you wear leather or Kevlar gloves beneath nitrile gloves for fire protection purposes.

Fully enclosed safety goggles or a face shield are preferred, if available, as they offer greater facial protection than safety glasses.

Emergency Preparedness and Response

Always know the exact location of your eyewash and shower and how to use all emergency equipment. Test your eyewash regularly. Keep the area around them clear from obstruction at all times.

It is best to choose the chemical fume hood closest to the safety shower to perform this work.

Users may encounter small fires at the tips of needles – know to expect this, and do not panic. A beaker of sand is useful for extinguishing this "pilot light".

For skin exposures, if there are no severe burns, rinse with water for 15 minutes and seek first aid.

Keep a container of soda ash or sand within arm's reach in case a small fire occurs, as this can be safely used to smother the flames.

Class ABC dry chemical extinguishers can be safely used for most organometallic reagents that are dissolved in organic solvents, such as T-Butyllithium in heptanes.

For aluminum alkyl fires involving neat reagents, use MET-L-KYL® extinguishing powder, made by Ansul, Inc.

If you have access to Class D fire extinguishing material, know where it is and how to use it. Typically, Class D extinguishing material is used for large quantities of fires involving combustible metals. Contact EH&S at (212) 854-8749 (Morningside) or (212) 305-6780 (CUMC) to determine what type of extinguishing material is needed.

DO NOT use a CO_2 extinguisher to attempt to quench a fire with pyrophoric reagents – this can greatly exacerbate the problem.

Sodium Hydride (and other metallic hydrides)—Special Considerations

Sodium hydride is extremely reactive toward water, to the point that it will spontaneously react with moisture in air and ignite. As such, it should be treated with extreme caution as a solid pyrophoric material. It is strongly recommended that you substitute a mineral oil dispersion of sodium hydride for the "dry powder" form whenever possible. If this substitution cannot be made, "dry powder" sodium hydride, or any other metallic hydride such as lithium aluminum hydride or potassium hydride, must only be manipulated in an inert atmosphere, and must never be exposed to air. If a fire ever results during the use of a metallic hydride, use copious amounts of sand to smother the flames and the reagent. Never use an ABC fire extinguisher in an effort to put out a fire involving sodium hydride, as the force from the extinguisher can rapidly disperse fine powders.

TECHNIQUES FOR REAGENT TRANSFER

Equipment Preparation

Locate a needle of appropriate length and gauge. A sixteen-gauge needle is recommended if you plan to draw from the reagent container several times, as anything larger than this will leave a hole too large for the Teflon septum on the reagent bottle to reseal. A long needle is best if using a syringe. A long double-tipped flexible needle can be used for cannula transfer. Luer lock needles, or needles otherwise equipped with a locking mechanism, are highly recommended as a guard against the needles becoming detached.

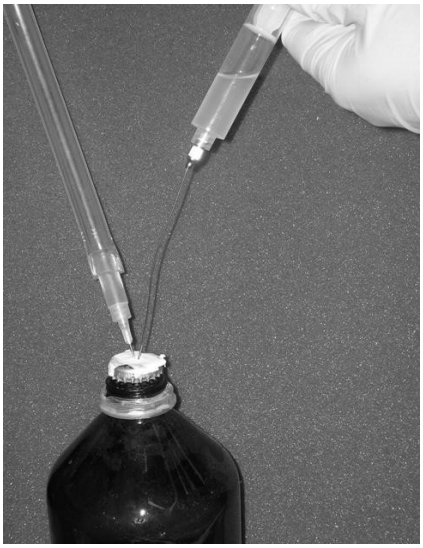


Fig. 1 Drawing reagent into syringe from reagent container, with inert gas line inserted

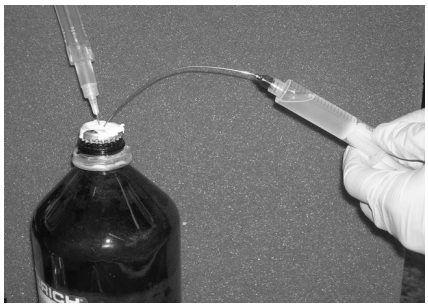


Fig. 2 Syringe is flipped needle-up after drawing liquid to allow inert gas bubbles to rise to needle

Flush your syringe-needle assembly, if using one, with dry, high-quality inert gas such as nitrogen or argon before starting. Ensure that it is leak-free by inserting the needle into a rubber stopper. You should be able to compress the syringe to half its original volume without any leaks. The needle can be left in the rubber stopper when not in use to prevent the entry of air.

Ensure that all glassware and other equipment involved in the procedure are clean and dry. Glassware should be heated in an oven to remove moisture, and cooled in an inert atmosphere.

Prepare an inert gas line for supplying positive pressure to the reagent container. Use a dry, high quality inert gas cylinder with a pressure regulator set to the lowest pressure sufficient for your work (no more than 5 psi), attached to flexible plastic tubing. A mineral oil bubbler should be added to the line, typically off of a manifold, to release excess pressure. A hypodermic needle at the end of the tubing can be used to insert the line through the septum of the reagent container. This needle can be inserted into a rubber stopper when not in use to prevent the entry of air.

The reaction vessel will also need to be supplied with a small amount of positive pressure during the reaction to prevent any pressure reversals that could cause air to enter the vessel. An inert gas line equipped with a mineral oil bubbler to relieve excess pressure will be needed for this. Run the reaction in a Schlenk flask that is under positive pressure from the inert gas line, connected via the tubing adapter. If the reaction vessel has a septum inlet, a hypodermic needle attached to the gas line can be pushed through the rubber septum to the reaction vessel, though the Schlenk vessel is better suited for controlling the atmosphere.

Syringe Transfer

Transfer of pyrophoric reagents via syringe is convenient, but should not be used for 20 mL or more.

Clamp your reagent container firmly. You will need a small amount of positive pressure in the reagent container in order to draw the reagent

Fig 3. Inert gas bubbles and excess liquid are forced back into reagent bottle

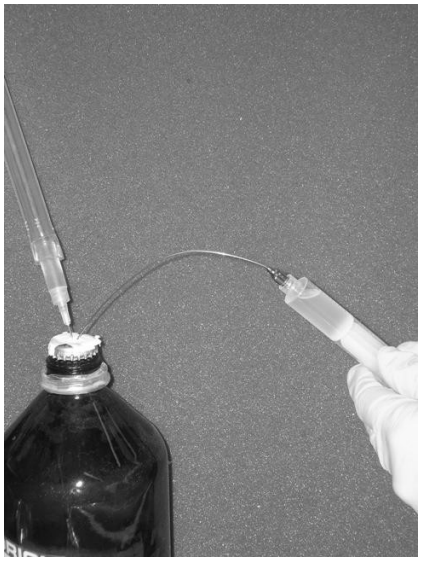


Fig. 4 Needle tip is brought into head-space of bottle, and an inert gas layer is drawn into syringe

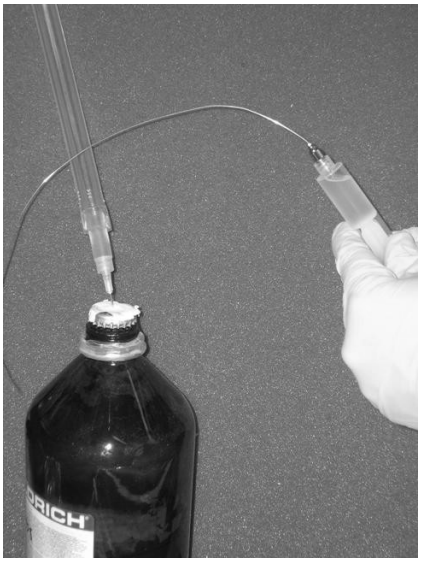


Fig. 5 Needle is carefully with-drawn from reagent bottle. Syringe is kept needle-up to prevent spilling

into a syringe. Insert an inert gas line with low positive pressure (1-2 psi). Ensure that excess pressure is released through the mineral oil bubbler that is attached to the gas line. Simply sticking a needle through the septum, or using a balloon to relieve pressure, is not safe for pyrophoric reagents.

Prior to starting the procedure, ensure that the reaction vessel you plan to deposit your reagent into has a mineral oil bubbler to relieve pressure (if a bubbler is not already on the gas line), and that it is thoroughly flushed with inert gas prior to use. Again, do not use a balloon, and do not simply stick a needle through the septum to relieve pressure.

Before beginning, set aside an Erlenmeyer flask with the same solvent in which your reagent is dissolved. If it is a neat reagent, use a solvent that is inert and unreactive towards that reagent. Aliquot slightly more than the volume you will be transferring with the syringe. This flask will need to be immediately available after the transfer for flushing out your syringe.

Draw slightly more than you need initially. Be careful to pull only very gently on the plunger as pulling too strongly can cause leaks and create air bubbles. Always keep a good grip on BOTH the needle and the plunger to ensure that neither comes off. If the plunger is ejected with its contents due to excess pressure, you will have a dangerous fire on your hands. (Fig. 1)

Flip the syringe needle-up, so that the inert gas bubbles rise to the top (a long needle is needed for this). It is best to avoid allowing the reagent in the bottle to come into contact with the septum to prevent degradation. Tap the syringe a couple of times and look to make sure all the air/gas has been collected at the tip. (Fig. 2)

Push the plunger down to eject the inert gas and excess reagent back into the reagent vessel, stopping once the volume you need for your experiment is reached. (Fig. 3)

Pull the needle into the headspace of the reagent bottle and draw a small amount of inert gas into the syringe. This prevents spilling, and very importantly protects the liquid from exposure to air during transfer. (Fig. 4)

The needle can now be removed from the bottle, keeping the inert gas layer at the syringe tip. If you see a small flame at the tip of the needle, do not panic. You can use a beaker of sand to extinguish this. (Fig. 5)

Insert the syringe into the septum of the reaction vessel, keeping the inert gas layer between the syringe and needle, if you have a long needle. Ensure that the vessel is equipped with an inert gas line to provide positive pressure, and a mineral oil bubbler to relieve excess pressure. Holding the plunger down, inject the inert gas cushion in your reaction first, and then inject your liquid into the flask.

Cannula/Double-Tipped Needle Transfer

Transfer of pyrophoric reagents via cannula is recommended for 20 mL or more.

Clamp your reagent container firmly. You will need to create a small amount of positive pressure in the reagent container in order to force the reagent through your double-tipped needle. Connect it to an inert gas line to provide low positive pressure (1-2 psi). Ensure that the line is equipped with a mineral oil bubbler to relieve excess pressure. Using a balloon or simply sticking a needle through the septum to relieve pressure is not safe for pyrophoric reagents.

Make sure, before starting, that the reaction vessel into which you plan to deposit your reagent has a pressure release mechanism such as a mineral oil bubbler on the inert gas line, and that it is thoroughly flushed with inert gas prior to use. Again, do not use a balloon or simply stick a needle through the septum to relieve pressure.

Insert one end of the double-tipped needle into the headspace of the reagent vessel and allow the positive pressure from your inert gas line to flush the needle free of air.

Insert the other end of the double-tipped needle through the septum of the reaction vessel. To allow for a measured transfer, you can use a sealed, measured funnel attached to the reaction flask, with the septum at the top of the funnel.

When ready to transfer, push the needle that is in the headspace of the reagent container down into the liquid. The pressure from the inert gas line will begin forcing the liquid through the double-tipped needle.

When the desired volume has been transferred, pull the end of the needle in the reagent container up into the inert gas headspace and allow it to be flushed with inert gas again. Remove the end of the needle from the reaction flask first, and then from the reagent container. If, upon removal, a flame is lit at either tip, extinguish it in a beaker of sand.

Equipment Cleanup

If you use a syringe transfer, the syringe will have a small amount of the reagent remaining. Fill an Erlenmeyer flask with a small amount of the same solvent in which the reagent was stored, using slightly more than the volume which the syringe was used to transfer. If the syringe was used for a neat reagent, use a solvent that is inert and unreactive toward the reagent. Ensure that any flame at the tip of the needle is extinguished first, and put the tip of the needle beneath the liquid in the flask, keeping it beneath the solvent. Carefully draw the solvent into the syringe and eject it to flush the syringe, and repeat for a total of three rinses. Afterwards, the syringe can be disposed of by putting it into a sharps container, if it is disposable. The solvent in the flask, with trace amounts of the pyrophoric compound, should be added to your solvent waste container. Be sure to list all of the components on the chemical/hazardous waste label.

For a cannula transfer, the double-tipped needle should have been purged with inert gas before you removed it. The needle can be place in a sink in the absence of any solvents or other combustible materials. Flush the needle with water, collecting the effluent for disposal with your aqueous waste. Making sure that there is no longer any reactivity, use a wash bottle to flush the needle with acetone, collecting the effluent with your solvent waste.

DISPOSAL

For any significant amount of reagent remaining in the reagent bottle, first ensure that the bottle is purged with inert gas. Place a secondary container such as a sealable plastic bag, or the manufacturer's can in which the bottle was shipped, into an inert atmosphere and purge it with inert gas. Put the reagent bottle into this purged secondary container and seal, then complete a chemical/hazardous waste label and submit an online chemical waste pickup request at http://vesta.cumc.columbia.edu/ehs/wastepickup/.

If only trace amounts of the reagent remain, use the solvent in which the reagent was originally stored to triple rinse the bottle (under positive pressure from an inert gas line when purging), collecting the rinse in your solvent waste container. If the bottle contained a neat reagent, perform this procedure with a solvent that is inert and unreactive toward the reagent. When finished, purge the bottle once more with inert gas and seal inside a secondary container, such as the metal can that came with the reagent. Complete the chemical/hazardous waste label and submit an online pickup request.

Sources

Aldrich Chemical Company, Inc.; *Handling Pyrophoric Reagents – Technical Bulletin AL-164*; May, 1995.

Aldrich Chemical Company, Inc.; *Handling Air-Sensitive Reagents – Technical Bulletin AL-134*; March, 1997.

Environmental Health and Safety, University of Nebraska at Lincoln; *Safe Operating Procedure – Pyrophoric Chemicals*; http://ehs.unl.edu/sop/s-pyrophoric.pdf; Revised July 2007.

Christensen, Kim; *Deadly UCLA Lab Fire Leaves Haunting Questions*; Los Angeles Times; March 1, 2009.

Department of Chemistry, University of Bath; *Risk Assessment – The use of small scale amounts of pyrophoric materials*; http://www.bath.ac.uk/chemistry/safety/pyrophoric.html; Revised November 18th, 2008.

Frontier, Alison, University of Rochester; *How to Syringe*; http://chem.chem.rochester.edu/~nvd/howtosyringe.html.

Thanks are due to Dr. Jack Norton, Professor of Chemistry at Columbia, Kathleen Kristian (his student) and Dr. Uttam Tambar.

Photos courtesy of Dr. Uttam Tambar.

Handling Pyrophoric Reagents

revised 6/95

Fig. 1 Pyrophoric reagents may be packed in a variety of containers.

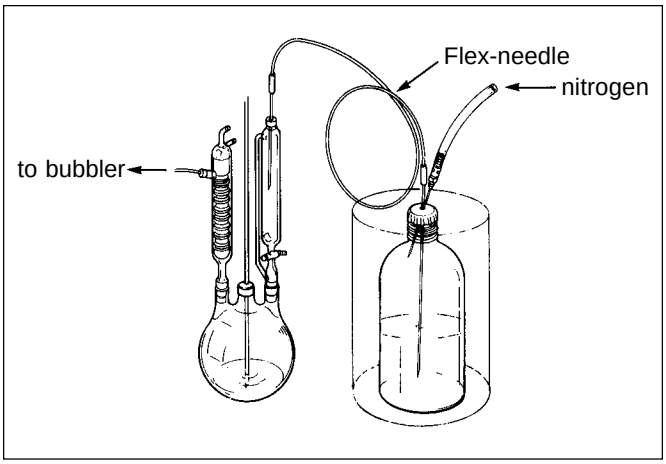


Fig. 2 Double-tipped needle transfer of pyrophoric liquid.

Fig. 3

Fig. 4

NOTE: The metal can in which each bottle is shipped should be retained as a protective container for transporting and storing the bottle of reagent.

I. INTRODUCTION AND PRECAUTION

Due to the hazardous nature of pyrophoric reagents, we strongly recommend that all users read this bulletin carefully and completely before starting any actual laboratory work. If you are unsure of any of these procedures or if you need assistance, please contact us prior to use.

All users of these reagents must be fully qualified and experienced laboratory workers to handle pyrophoric reagents without problems. All users must be made aware of the very hazardous nature of these products.

Users must have read and understood our Technical Information Bulletin No. AL-134 which describes standard syringe and double-tipped-needle transfer techniques before attempting to handle liquid pyrophoric reagents (see Fig. 2).

II. NATURE OF THE REAGENTS

Pyrophoric reagents are extremely reactive toward oxygen and in most cases, water, and must never be exposed to the atmosphere. Failure to follow proper handling techniques could result in serious injury. Exposure of these reagents to air could result in spontaneous combustion, which could cause serious burns or other injuries to the person handling the reagent or others in the immediate area.

In addition, all combustible materials, including paper products, should not be allowed to come in contact with any pyrophoric reagent at any time.

III. HANDLING

Pyrophoric reagents can be handled and stored safely as long as all exposure to atmospheric oxygen and moisture is avoided. Solids must be transferred under an inert atmosphere in an efficient glove box. Liquids may be safely transferred without the use of a glove box by employing techniques and equipment discussed in our Technical Information Bulletin AL-134.

Again, users must have read and understood the accompanying Technical Bulletin AL-134 (call us immediately for a copy if yours has been misplaced), before attempting to handle liquid pyrophoric reagents.

Glass bottles of pyrophoric reagents should not be handled or stored unprotected. The metal can shipped with each bottle should be retained as a protective container for each bottle for transporting and storage (see Fig. 3 and 4).

(OVER)

IV. SPILL

Powdered lime should be used to completely smother and cover any spill that occurs.

A container of powdered lime should be kept within arm's length when working with a pyrophoric material.

IV. DISPOSAL

We feel that the user of the reagent is the person most familiar with the contents and should accept the responsibility for safe disposal of the empty container.

A container with any residual material **MUST NEVER** be opened to the atmosphere. The last traces of reagent must be removed and should be used completely for a chemical reaction; however, if unused and unwanted material must be destroyed, it must be transferred to an appropriate reaction flask for hydrolysis and/or neutralization with adequate cooling.

The essentially empty container is then rinsed three times with an inert dry solvent; this rinse solvent must also be neutralized or hydrolyzed. The solvent must be added to and removed from the container under an inert atmosphere. After adding each rinse, the container is swirled or shaken. The best solvent to use is the same solvent used for the solution of the original reagent. If the container originally contained a **neat reagent, then use a solvent which is completely inert and unreactive toward the reagent.**

After the triple rinse is complete, the container is opened to the atmosphere at a safe location, preferably outdoors or, AT A MINIMUM, IN THE BACK OF A HOOD. After allowing the container to be exposed to the atmosphere for at least a week, the container must be triple-rinsed with water before disposal.

This hazard sheet must remain with the container at all times. If you have any questions, please contact us.

Aldrich Chemical Company, Inc.

1001 West Saint Paul Ave., Milwaukee, WI 53233

Telephone 414-273-3850 Fax 414-273-4979 Internet INFO@ALDRICH.COM

800-231-8327 800-962-9591 TWX 910-262-3052

SIGMA-ALDRICH®

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Technical Bulletin AL-134

Handling Air-Sensitive Reagents

The Aldrich® Sure/Seal™ system

Anhydrous solvents and air-sensitive reagents from Aldrich are packaged in our exclusive Sure/Seal bottles which provide a convenient method for storing and dispensing research quantities of these products. With this bottle, reactive materials can be handled and stored without exposure to atmospheric moisture or oxygen. The reagent comes in contact only with glass and a specially designed resin layer, yet it can be readily transferred using standard syringe techniques.

Fig. 1 Crown cap with hole

The polypropylene cap on a Sure/Seal bottle can be safely removed because the crown cap and liner are already crimped in place. The reagent can then be dispensed using a syringe or double-tipped needle inserted through the hole in the metal cap (**Fig.1**). We recommend only small-gauge needles (no larger than 18-gauge) be used and the polypropylene cap be replaced after each use. After the needle has been withdrawn from the bottle, the new elastomer liner provides outstanding resealing properties to protect the contents within from moisture and oxygen in the atmosphere.

Equipment Overview

Reactions involving our air-sensitive reagents can be carried out in common ground-glass apparatus. Other equipment required are a source of inert gas, a septum inlet, a bubbler, and syringes fitted with suitable needles.

Glassware preparation

Laboratory glassware contains a thin film of adsorbed moisture which can be easily removed by heating in an oven (125 °F/overnight or 140 °F/4 hrs). The hot glassware should be cooled in an inert atmosphere by assembling the glassware while hot and flushing with a stream of dry nitrogen or argon. A thin film of silicone or hydrocarbon grease must be used on all standard-taper joints to prevent seizure upon cooling. Alternatively, the apparatus may be assembled cold and then warmed with a heat gun while flushing with dry nitrogen. The oven-drying procedure is more efficient than using a heat gun because it removes moisture from inner surfaces of condensers and from other intricate parts.

Most of the techniques described in this bulletin were developed for handling various organoborane reagents. However, these methods are applicable to other air-sensitive solvents and reagents on a preparative laboratory scale.

Contents

The Aldrich Sure/Seal™ system
Equipment overview
Reagent transfer with syringes
Reagent transfer with double-tipped needles
Storage vessels
Equipment clean-up
Labware for handling air-sensitive solvents and reagents
Trademarks

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Inert gas supply and flushing equipment

Joint clips are required to secure joints during flushing since the nitrogen pressure may open the seals of unsecured standard-taper joints. Only high-purity, dry nitrogen from a cylinder with a pressure regulator (adjusted to 3-5 psi) should be used for flushing. Plastic tubing can be used to connect the nitrogen line to a tube connector adapter (equipped with a stopcock) on the reaction apparatus. Nitrogen may also be introduced through a rubber septum via a hypodermic needle connected to the end of the flexible tubing on the nitrogen line. The needle-tubing connector provides a simple method for attaching the needle to the tubing. When not in use, this nitrogen-flushing needle should be closed by inserting the needle into a solid rubber stopper or septa to prevent diffusion of air into the needle when the nitrogen is turned off (**Fig.2**).

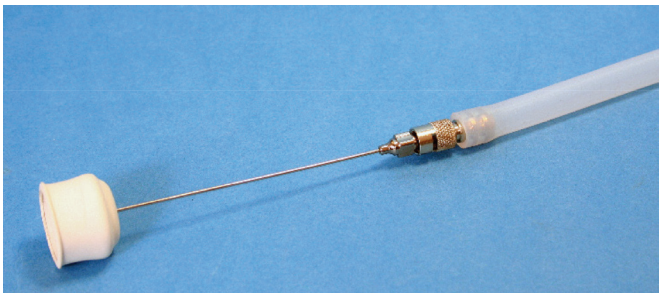


Fig. 2. Nitrogen-flushing needle

Septum inlet glassware

Large rubber septa may be used to cap female joints. However, the use of 6 mm septa and 9 mm o.d./6 mm i.d. medium-wall glass septum inlets is preferred. The small rubber septum provides a more positive reseal after puncture and allows less rubber to be in contact with organic vapors in the reaction vessel. With the recommended medium-wall tubing, the 6 mm septum not only fits the inside diameter of the glass tube but also fits snugly over the outside when the top is folded over (**Fig. 3**). The glass septum inlet can be built into the reaction flask (**Fig. 4**) or placed on an adapter (**Fig. 5**) for use with unmodified glassware. The rubber septum may be secured in place as shown in **Fig. 3**. with a nylon Wrap-it Tie. However, if the 6 mm septum is properly fitted to 9 mm medium-wall tubing, the ties may not be needed unless high pressures (>10 psi) are expected.

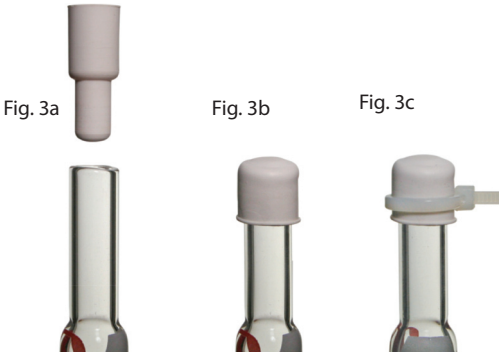


Fig. 3. Use of septum inlet

Bubblers for pressure equalization

To maintain an air-tight system the reaction vessel must be vented through a mercury or mineral oil bubbler. Drying tubes will not prevent oxygen from entering the system. At all times during the reaction, the system should be under a slight positive pressure of nitrogen as visually indicated by the bubbler. **Fig. 6** illustrates a suitable bubbler. A pressure reversal may cause the liquid in the bubbler to be drawn into the reaction vessel. The enlarged head space in the bubbler will minimize this danger. However, if a large pressure reversal occurs, air will be admitted into the reaction vessel. The T-tube bubbler shown can be used to prevent this problem because nitrogen pressure can be introduced intermittently through the septum inlet. The problem can be completely eliminated by a slow and continuous nitrogen flow.

Fig. 4. Flask with septum inlet

Syringe transfer tips

Small quantities (up to 50 mL) of air-sensitive reagents and dry solvents may be transferred with a syringe equipped with a 1-2 ft long needle. These needles are used to avoid having to tip reagent bottles and storage flasks. Tipping often causes the liquid to come in contact with the septum causing swelling and deterioration of the septa, and should therefore be avoided.

Fig. 5 Septum inlet adapter

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

A rubber septum provides a positive seal for only a limited number of punctures depending on the needle size. Therefore, always reinsert the needle through the existing hole. It is also advantageous to put a layer of silicone or hydrocarbon grease on a rubber septum to facilitate passage of the needle through the rubber and to minimize the size of the hole in the septum.

Syringe/needle preparation

Ideally, the syringe and needle should be dried in an oven prior to use. Naturally, the syringe body and plunger should not be assembled before being placed in the oven. The syringe should be flushed with nitrogen during the cooling. A syringe may also be flushed 10 or more times with dry nitrogen (**Fig. 7**) to remove the air and most of the water adsorbed on the glass. A dry syringe may be closed to the atmosphere by inserting the tip of the needle into a rubber stopper or septa. (**Fig 2**). The syringe-needle assembly should be tested for leaks prior to use. The syringe is half-filled with nitrogen and the needle tip is inserted in a rubber stopper. It should be possible to compress the gas to half its original volume without any evidence of a leak. A small amount of stopcock grease or a drop of silicone oil placed on the Luer lock tip will help ensure tightness.

Reagent transfer with syringe

The syringe transfer of liquid reagents (up to 100 mL) is readily accomplished by first pressurizing the Sure/Seal™ reagent bottle with dry, high-purity nitrogen followed by filling the syringe (**Fig. 8**).

1. The nitrogen pressure is used to slowly fill the syringe with the desired volume plus a slight excess (to compensate for gas bubbles) of the reagent. Note the nitrogen pressure pushes the plunger back as the reagent enters the syringe. The plunger should not be pulled back since this tends to cause leaks and create gas bubbles.
2. The excess reagent along with any gas bubbles is forced back into the reagent bottle (**Fig. 9**).
3. The accurately measured volume of reagent in the syringe is quickly transferred to the reaction apparatus by puncturing a rubber septum on the reaction flask or addition funnel (**Fig. 10**). **Note:** larger syringes are available but are awkward to handle when completely full.

Reagent transfer with a double-tipped needle

To conveniently transfer 50 mL or more of reagent, the double-tipped needle technique is recommended. **Fig. 11** illustrates liquid-reagent transfer under nitrogen pressure using this technique.

1. To accomplish the double-tipped needle transfer, the needle is first flushed with nitrogen.
2. The Sure/Seal bottle is pressurized with nitrogen using the nitrogen flushing needle.
3. The double-tipped needle is then inserted through the septum on the reagent bottle into the head space above the reagent. Nitrogen immediately passes through the needle. Finally, the

Fig. 6 Bubbler

Fig. 7 Flushing a syringe with nitrogen

Fig. 7a

Fig. 7b

Fig. 8 Filling syringe using nitrogen pressure

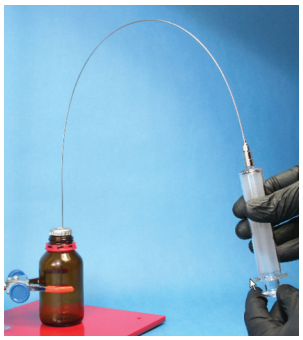


Fig. 9 Removing gas bubbles and returning excess reagent to the Sure/Seal bottle

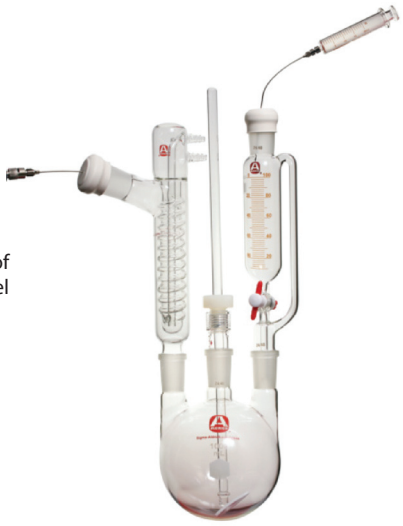


Fig. 10 Syringe transfer of reagent to reaction vessel

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

other end of the double-tipped needle is inserted through the septum on the reaction apparatus, and the end of the needle in the reagent bottle is pushed down into the liquid. The volume of liquid reagent transferred is measured by using a calibrated flask or addition funnel. When the desired volume has been transferred, the needle is immediately withdrawn to the head space above the liquid, flushed slightly with nitrogen, and removed. The needle is first removed from the reaction apparatus and then from the reagent bottle.

An alternative method

Transferring measured amounts of reagents (**Fig. 12**).

1. The reagent is first transferred via a double-ended needle from the Sure/Seal bottle to a dry, nitrogen-flushed graduated cylinder (**Fig. 13**) equipped with female joint and a double inlet adapter. Only the desired amount of reagent is transferred to the cylinder.
2. The needle is then removed from the Sure/Seal bottle and inserted through the septum on the reaction apparatus. By applying nitrogen pressure as before, the reagent is added to the reaction apparatus.

If it is necessary to add the reagent slowly, a modified transfer needle is constructed from two long standard needles and a male Luer lock to male Luer lock syringe valve. The valve may be opened slightly allowing only a very slow flow of reagent. Thus, the addition funnel is not needed and many reactions can be carried out in single-necked flasks (**Fig. 13**).

Storage vessels

The 12-gauge stainless steel needles on the Chem-*Flex*™ transfer line provide a rapid means of transferring air-sensitive reagents under nitrogen pressure. However, the needles are so large that once the crown cap liner on the Sure/Seal bottle is punctured, the liner may not self-seal. If only a portion of the contents is to be used, a needle no larger than 16-gauge should be utilized. By using small needles the reagent in a Sure/Seal bottle will not deteriorate even after numerous septum punctures.

However, if the reagent is to be used repeatedly for small scale reactions or if an unused portion is to be stored for an extended length of time, the material should be transferred from the Sure/Seal bottle to a suitable storage vessel.

One type of vessel is the Sure/Stor™ flask for air-sensitive reagents (**Fig. 14**). Alternatively, an appropriate adapter can be used to convert a round-bottomed flask into a storage vessel (**Fig. 15**).

The PTFE valve on the storage vessel keeps solvent vapors away from the septum, thereby minimizing swelling and deterioration of the septum. Furthermore, the valve allows for replacement of the septa. A change of septa is sometimes necessary because they tend to deteriorate on prolonged standing in a laboratory atmosphere.

Fig. 11 Double-tipped needle transfer of liquid reagent

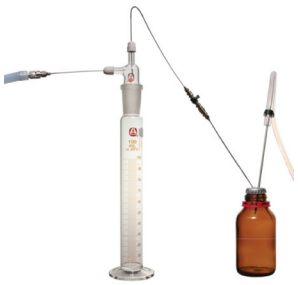


Fig. 12 Double-tipped needle transfer to graduated cylinder

Fig. 13 Double-ended needle transfer with syringe valve

Fig. 14 Aldrich Sure/Stor™ flask

Fig. 15 Aldrich Sure/Stor™ adapter

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Equipment cleanup

Clean-up of equipment that has been used to transfer air-sensitive reagents must not be taken lightly. Since many of these reagents react violently with water, fires are a potential hazard.

Empty Sure/Seal bottles - the crown cap and liner of an empty Sure/Seal bottle should be carefully removed and the open bottle left in the hood to allow the last traces of reactive reagent to be slowly air-hydrolyzed and oxidized. After at least a day, the inorganic residue can be rinsed out with water. Empty storage bottles and storage flasks should be treated similarly. Air-hydrolysis in a hood is appropriate only for the last traces of material that remain after a Sure/Seal bottle has been emptied as completely as possible via syringe or double-ended needle transfer. The Aldrich Catalog/Handbook or material safety data sheets should be consulted for the recommended disposal procedures for larger amounts of reactive chemicals.

Syringes and needles - Immediately clean all syringes and needles that have been used to transfer air-sensitive materials. Also, in general, a syringe should only be used for a single transfer. Failure to follow this practice can result in plugged needles and frozen syringes due to hydrolysis or oxidation of the reagents. The double-tipped needles are flushed free of reagent with nitrogen in the transfer system, and then immediately removed and placed in a clean sink. With water running in the sink and in the complete absence of flammable solvents and vapors, the double-tipped needles or Chem-Flex needle can be rinsed with water. When no activity in the rinse water is observed, acetone from a squeeze bottle can be flushed through the needle. Depending on the reagent transferred, it may be necessary to use dilute acid or base from a squeeze bottle to remove inorganic residue that is not water-soluble.

Following its use, a syringe contains a larger amount of residual reagent. It is advisable to rinse out the reactive reagent by first placing a few milliliters of the same solvent that was used for the reagent in a small Erlenmeyer flask in the hood. Keeping the needle tip under the solvent at all times, no more than half the solvent is then drawn into the syringe. The solvent plus dissolved residual reagent is ejected from the syringe back into the same Erlenmeyer flask. Repeat this rinse treatment at least three times. The wash solution can be safely combined with other waste solvents and the syringe may be further cleaned with water and acetone in the sink. Again, treatment with dilute aqueous acid or base may be necessary.

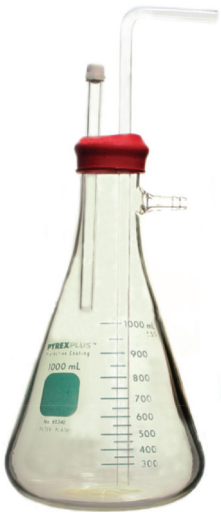


Fig. 16 Needle cleaning and drying technique

Once the syringe needles and double-tipped needles have been rinsed in a sink, they can be further cleaned and dried using a device similar to that shown in **Fig. 16**. Needles are cleaned by inserting them through the septum. Vacuum from a water aspirator is used to pull solvents from squeeze bottles through the needles. After pulling air through the system for a few minutes, the syringe plus needle or double-tipped needle will be dry. The syringe plunger should be replaced in the barrel for storage. If a syringe plunger and barrel are not assembled for storage, dust can settle on the plunger and in the barrel. Upon reassembly, these fine particles will occasionally scratch the barrel or cause seizure of the plunger on the barrel. However, the plunger and barrel must be disassembled before oven drying.

Summary

When handling air-sensitive materials, be prepared for the unexpected. For example, at least one extra set of clean, dry syringes and needles or double-tipped needles should always be available in case the first set of equipment becomes plugged. When working with these air-sensitive reagents keep in mind that these solutions should never be allowed to come in contact with the atmosphere.

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Labware for Handling Air-Sensitive Solvents and Reagents

A wide range of Labware products are available from Sigma-Aldrich for performing the techniques referenced in this technical bulletin. A sampling of these products are listed below. For additional products and ordering information, see the Sigma-Aldrich Labware Catalog or visit our website at sigma-aldrich.com/labware.

BUBBLERS

For safe pressure equalization during material transfers or reactions.

In-line bubbler

Use with oil or mercury, 5-7 mL. For monitoring gas evolution rate or rate of flow, or for closing off a reaction vessel from the atmosphere.
Cat. No. Z101214

In-line bubbler

SYRINGES, FITTINGS, AND NEEDLES

For transferring air-sensitive solvents and reagents.

Micro-Mate™ hypodermic syringes

Made from borosilicate glass with chrome-plated brass metal parts. Interchangeable barrels and plungers. All have needle-lock Luer tips. Additional sizes and tip styles are available.

Cat. No.	Capacity (mL)	Graduated (mL)
Z101052	5	0.2
Z101060	10	0.2
Z101079	20	1.0
Z101087	30	1.0
Z102342	50	2.0

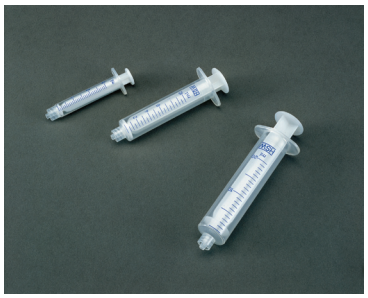
Micro-Mate hypodermic syringes

All polypropylene Luer lock syringes

Non-contaminating, sterile, disposable syringes with safety stop to prevent plunger separation. Individually peel-packed.

Cat. No.	Capacity (mL)	Graduated (mL)
Z248002	3	0.1
Z248010	5	0.2
Z248029	10	0.5
Z248037	20	1.0

Polypropylene Luer lock syringes



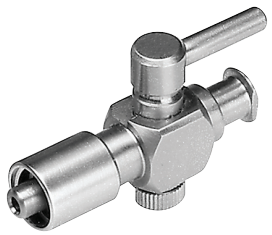
Perfektum® one-way compression-nut stopcock

Additional stopcock types are available.

Female Luer to male Luer lock, not unidirectional.
Cat. No. Z102350

Male Luer lock to male Luer lock, not unidirectional.
Cat. No. Z102377

Perfektum one-way compression-nut stopcock (female to male)



3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Syringe needles with noncoring point

304 stainless steel, chrome-plated brass Luer hub, 18 gauge. Additional lengths and gauges are available.

Cat. No.	L (in.)
Z102717	6
Z117102	10
Z101141	12
Z100862	24

Stainless steel
304 syringe needles

Double-tipped transfer needles

304 stainless steel with a noncoring point on both ends. Additional lengths and gauges are available.

Cat. No.	L (in.)	Gauge
Z175595	12	20
Z101095	24	20
Z100889	24	18
Z100897	24	16
Z185221	24	14
Z185213	24	12
Z100900	36	16
Z185205	36	12

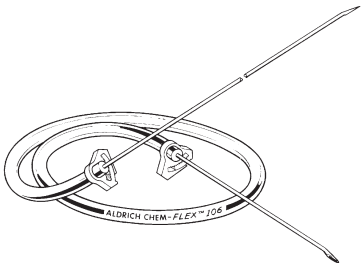
Double-tipped transfer needles

Chem-FLEX™ transfer lines

Two 12 gauge needles (6 and 18 in.) are connected to the Chem-FLEX 106 tubing with clamps. Liquids contact only PTFE and stainless steel during transfers.

Cat. No.	Tubing L (in.)
Z231029	30
Z281751	60
Z281778	120

Chem-FLEX transfer lines



INERT GAS SAFETY REGULATORS

For pressure transfer and purging operations.

The most compact laboratory regulator available. The bonnet is labeled "Inert Gas" to identify use. Outlet needle valve with ¼ inch NPTM connection. CGA 580 inlet.
Cat. No. Z569054

Inert gas regulator

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

RUBBER SEPTA

Additional septa sizes and types are available.

Red

Cat. No.	Size
Z565587	8 mm OD tubing
Z565709	9-10 mm OD tubing
Z554073	14/20 joints
Z554103	24/40 joints
Z554111	29/42 joints

White

Cat. No.	Size
Z565695	8 mm OD tubing
Z565717	9-10 mm OD tubing
Z553964	14/20 joints
Z553980	24/40 joints
Z553999	29/42 joints

Rubber septa

SCHLENK TYPE GLASSWARE

Designed specifically for air-sensitive chemical reactions.

Reaction tubes

2 mm glass stopcock with 14/20 joint.

Cat. No.	Capacity (mL)
Z409235	10
Z409243	25
Z409251	50
Z409278	100
Z409286	250

Reaction tube

SEPTUM INLET ADAPTERS AND FLASKS

Small bore inlets for syringe transfers.

Septum-inlet adapters

Additional adapter styles are available.

Cat. No.	Stopcock	Joint
Z107387	Glass	14/20
Z107409	Glass	24/40
Z102288	PTFE	14/20
Z101370	PTFE	24/40

Septum-inlet adapters

3050 Spruce Street, Saint Louis, MO 63103 USA
Tel: (800) 521-8956 (314) 771-5765 Fax: (800) 325-5052 (314) 771-5757

Septum-inlet flasks

Glass stopcock with 14/20 joint. Additional capacities and joint sizes are available.

Cat. No.	Capacity (mL)
Z515868	25
Z515876	50
Z515884	100
Z515914	250

Septum-inlet flasks

STORAGE BOTTLES AND FLASKS

For long-term storage of solvents and reagents.

Sure/Stor™ flasks

Designed for safe, reliable storage and dispensing of air-sensitive and odoriferous chemicals, pyrophorics, alkyl lithiums, Grignards, corrosives, and purified or deuterated solvents. High-vacuum PTFE valve. Additional flasks sizes, amberized, and plastic-coated glass are available.

Cat. No.	Capacity (mL)
Z404977	25
Z404985	50
Z404993	100
Z405000	250

Sure/Stor flasks

Storage bottles

Clear glass with PTFE stopcock and septum inlets.

Cat. No.	Capacity (mL)
Z103284	125
Z103292	250
Z101990	500
Z102482	1,000
Z103306	2,000

Storage bottles