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Safe Handling of Cannulas and Needles in Chemistry Laboratories

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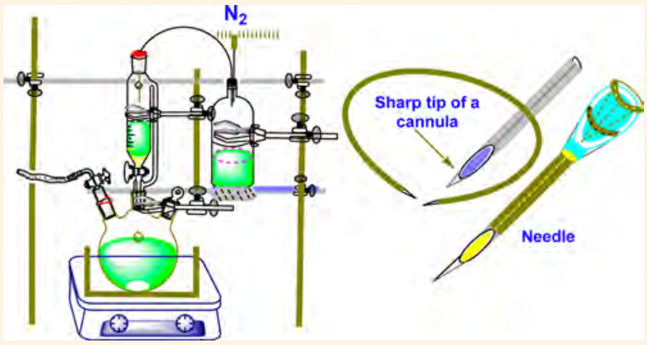

ABSTRACT: Cannulas and needles (sharps) are frequently used for chemical manipulations involving air- and moisture-sensitive chemicals. When using these devices, the presence of sharp tips poses a risk of puncture wounds and increases the likelihood of chemical exposure. While these devices are regularly used in chemistry, facts on their proper usage, as well as the prevention of injuries, are scarce in the literature. Needle injuries often reflect inadequate hands-on training in their use during chemical transfer procedures, incorrect recapping, and improper storage and disposal procedures. Preventing needle injuries in the lab requires having situational awareness which is achieved by using proper techniques and a proper reaction set up, performing a risk assessment, and having group discussions about the procedure. As in all chemical manipulations, it is critical to be familiar with the reaction setup, to receive the necessary training for the chemicals being used, and to have reviewed all associated standard operating procedures (SOPs). Thorough planning can reduce injuries and exposures incurred by students and other researchers. This paper will discuss safe techniques for the use of needles and cannulas in chemistry laboratories.

KEYWORDS: *air-sensitive, cannula, complacency, hazard assessment, hazard analysis, hazard controls, high-hazard operations, needles, pyrophoric, risk assessment, risk analysis, safety education, Schlenk line techniques, standard operating procedures (SOPs), syringes, toxic, training, vacuum*

■ INTRODUCTION

Many minor laboratory incidents are caused by needle stabbing and cuts from broken glass. Cuts from glass and needle punctures are also common in teaching laboratories. The bulk of these minor incidents occur due to inadequate hands-on training and incorrect handling of these devices. A recent study[1] on lab injuries found that lacerations and punctures from sharp items are more widespread in academic laboratories in comparison to other laboratory injuries such as chemical spills, exposures, explosions, and implosions. Lately, a serious injury (necrosis) was reported after a student accidentally stabbed his finger with a dichloromethane-contaminated needle.[2] Improper removal of the needle from its cap, removal of a septum from a flask with an attached needle, inappropriate application, wrongly attaching a Schlenk line port, improper storage and disposal, and the incorrect capping of needles are a few causes of injuries from cannulas and needles, CNs.[3−6] Proper training, hazard assessments,[7−13] and safe management of these devices[14] are critical to protect laboratory personnel from a puncture wound injury.

The use of cannulas and needles is common in organic and inorganic syntheses and nanomaterial chemistry. Typically, stainless-steel (SS) cannulas and needles provide an enclosed system for the safe manipulation of air-sensitive,[15,16] pyrophoric,[17−20] and toxic chemicals.[21−24] Small quantities of pyrophoric liquids are generally handled inside a glovebox. When a glovebox is not available, the transfer of such liquids is generally performed by either a syringe or double-tipped cannula under a nitrogen atmosphere. Due to the reactivity of these reagents in air, pyrophoric chemicals are typically supplied under an inert atmosphere in Sure/Seal bottles[25,26] for safe storage and manipulations using a needle or a cannula. Having a Sure/Seal bottle preserves reagent integrity. Most small-scale organic and inorganic syntheses are accomplished by applying Schlenk Line techniques (Figures 1 and 2).[27,28] Needles and cannulas are also used in gas chromatography (GC) and high-performance liquid chromatography (HPLC) applications.[29]

In addition to the applications, cannulas are also used for air-sensitive salt formation and isolation to prevent the oxidation and decomposition of the synthesized material.[30] Similarly, these techniques are used for the transfer of anhydrous solvents, substrates, and reagents from original containers into reaction

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Figure 1. Synthesis of compound **2** using a Schlenk line technique.

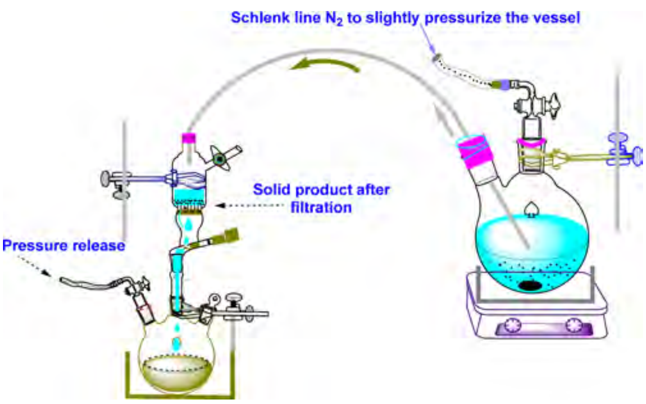

Figure 2. Isolation of an air-sensitive solid using an SS cannula and the Schlenk line technique.

vessels and in air-free filtration of the synthesized material when desired (Figure 2). Controlled addition of the substrate to the reaction mixture is also achieved by using cannulas, and needles are used for purging reagents and reaction vessels with inert gases for storage purposes and to maintain moisture-free vessels.

A needle-syringe mediated transfer (Figure 3) of air-sensitive reagents works very well for a small-scale manipulation, while a

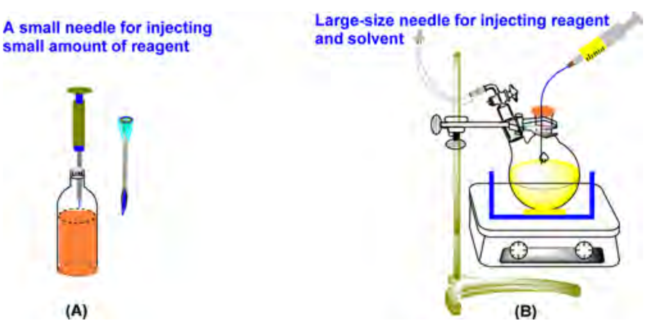

Figure 3. Use of a small and large needle for the transfer of reagent and solvent.

double-tipped SS cannula works especially well for a large-scale transfer of reagents (>50 mL), particularly for alkyllithiums[31−33] and Grignard reagents.[34−39] Having a sharp tip on a needle or a cannula provides an easy insert into the septum for the safe transfer of the reagents or the purging of nitrogen gas.

MATERIALS AND METHODS

Types of Needles Used in Chemical Manipulations. Generally, two types of needles are used in research laboratories for reagent and solvent transfer:[40] plastic, disposable needles and reusable stainless-steel needles (Figures 4 and 5).[41]

Disposable Needles (with Polypropylene Luer Lock Hubs). The key advantage of disposable needles is convenience. They

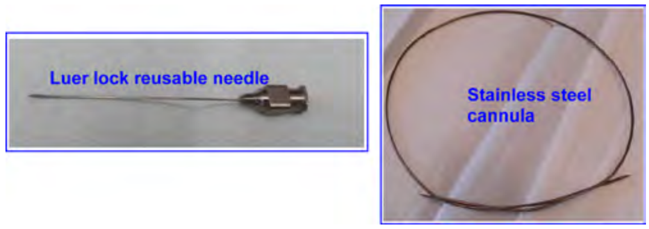

Figure 4. Needles and cannulas used in chemistry laboratories.

are always clean, sharp, and available in various lengths and gauges.

Because the connector is polypropylene, they cannot be heated in an oven; however, they do not contain glass, and water will not absorb significantly to the surface.

Reusable Stainless-Steel Needles. Reusable stainless-steel needles are available in various lengths and bore sizes (Figure 5).

Figure 5. Various reusable stainless-steel needles.

Because they are reusable, they require cleaning between uses, especially when used for reactive reagent transfers. Although reusable, these needles can become kinked or blunted over time, requiring disposal and replacement. Because they are completely made of metal, they can be heated in an oven to remove any surface moisture. While generally less sharp than disposable needles, reusable needles are still quite sharp and must be handled and disposed of as sharps.

Stainless-Steel Cannulas. Stainless-steel (SS) cannulas (double-tipped needles) are useful for transferring moisture-sensitive and pyrophoric (PP) chemicals at higher scales (Figure 6). A cannula is a long, thin metal tube with a needle on both

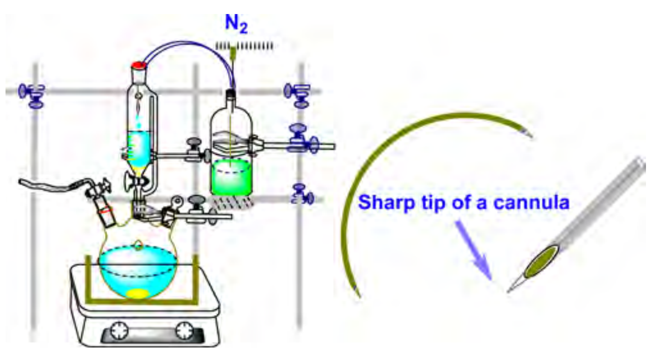

Figure 6. Use of a cannula for transferring pyrophoric reagents.

ends. They are also called double-tipped needles. The needle ends are available in different types, depending on the application. Both ends of the cannulas are often sharp so they can be easily inserted through septa. When the reagent is in a suspension, use a correct bore size cannula for reagent transfer to prevent clogging.

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The cannula used for the chemical transfer should be long enough to make a connection between the reagent container and a reaction vessel. Avoid excess bending of cannulas; however, slight bending will not cause breakage. Stabbing can occur from cannulas while inserting into septa and while cleaning and storing them.

Safe Handling of Cannula and Needles. A well-crafted documented safety plan could eliminate most needle pricks and stabbings. Safety plans should include appropriate hands-on training, a standard operating procedure (SOP), and information about the engineering controls. Having an SOP[42,43] prior to performing a chemical manipulation will reduce the hazards associated with the process. The following information will assist researchers in the safe handling of CNs and should be included in the documented safety plan.

- Assemble glassware and other items inside a properly working and uncluttered chemical fume hood before transferring any chemicals using a needle or a cannula.
- Only use new disposable syringes, clean reusable syringes, and/or clean cannulas for chemical manipulations.
- Inspect syringes and needles thoroughly before use to make sure they are not leaking or clogged. Use a properly sized syringe and needle for chemical or solvent transfer. Avoid using needles that are bent. Be attentive when using needles and syringes in the glovebox to avoid puncturing the gloves.
- Avoid using plastic syringes for chlorinated solvents; plastic generally reacts with chlorinated solvents.
- Use syringes only for small-scale transfers (<50 mL), and use special precautions when transferring pyrophoric chemicals using syringes. Syringes should not be filled at or more than half capacity so the plunger does not accidentally come out.
- When transferring chemicals that are air- or moisture-reactive, it is advisable to use a cannula or syringe only once for a single transfer. Multiple transfers should use fresh transfer equipment. Failure to follow this can result in clogged needles and frozen syringes.
- Special precautions are needed while manipulating pyrophoric chemicals using needles and cannulas.

Uncapping Needles. Never apply excess force while uncapping a needle; it may stab your fingers (Figure 7), and

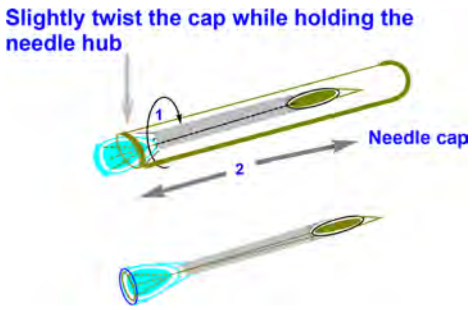

Figure 7. Uncapping a needle.

you could hit other objects with your hands. Do not pull the cap off directly. When the cap rapidly comes free, you reflexively push your hands back together, which often results in accidental stabbing. Instead, gently twist the cap and then slide the cap carefully. This will loosen the cap so that it can then be removed without causing the reflexive action.

Take extra precautions when uncapping needles inside a glovebox to prevent stabbing and damage to the gloves because dexterity is generally poor due to the thickness of the gloves.

Recapping Needles. Needles should not be recapped, bent, removed, or otherwise manipulated by hand. It is very easy to stick your hand while recapping needles, and the needle being recapped may be contaminated with hazardous chemicals. Recapping injuries can be very serious. However, if a needle must be recapped due to the nature of the work, the use of a mechanical device or the one-handed scoop method must be used.

When using the one-handed scoop technique (Figure 8), place the needle cap on a flat surface. Hold the syringe with one

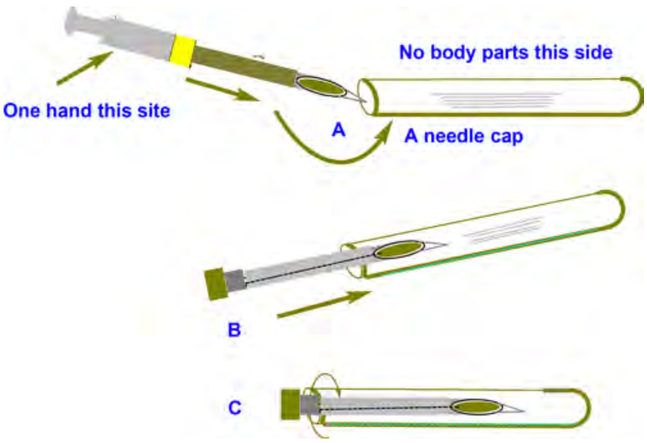

Figure 8. One-handed scoop method for the capping of a needle.

hand. Keep the other hand clear of the work area. Carefully lower the needle tip toward and into the needle cap. When the needle is mostly in the cap, scoop upward to lift the needle cap onto the needle. Once the needle cap is on the needle, use your second hand to secure the cap to the needle or tap it on the ledge of the benchtop.[44,45]

Decontamination/Cleaning of Cannulas and Needles. Proper cleaning of glass syringes and nondisposable needles is necessary when the experiment is over. Generally, methanol, acid water, deionized (DI) water, or acetone work well for cannula and needle cleaning. Dilute acid such as hydrochloric acid will help to dissolve blockage consisting of inorganic salts and catalyst particles. Strong acids such as nitric acid and sulfuric acid will damage SS cannulas. Store needles in their appropriate lab drawer. Only syringes that do not have any Teflon seals should be stored in high-temperature ovens. Gas-tight syringes with Teflon seals become damaged from intense and prolonged exposure to heat.

When a cannula is used for air- and moisture-sensitive chemical transfer, draw the cannula out of the reagent layer, ensure that enough nitrogen is purged through it, and ensure that no significant residue is left on the side of the cannula. Otherwise, the pyrophoric reagent will hydrolyze inside the cannula, causing a clog. Generally, cannulas are cleaned using a vacuum or nitrogen pressure (Figure 9). Cannulas used for homogeneous materials can simply be washed with acetone, then water, and finally with acetone before drying in an oven. A contaminated cannula can ruin a reaction, and rust can cause a cannula to become clogged, leading to a potential pressure build-up and unwanted events. When unable to remove the residue

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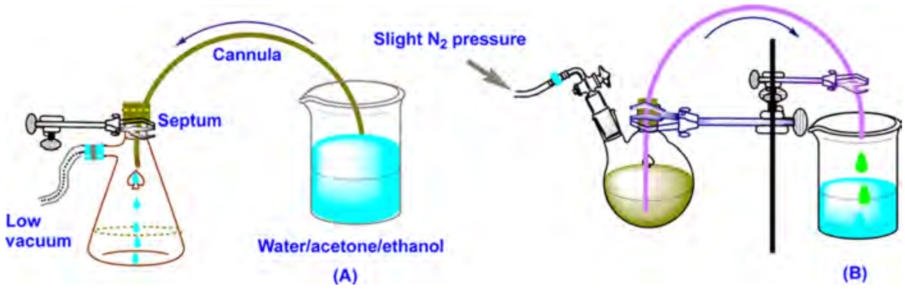

Figure 9. Cleaning cannulas using a vacuum (A) or nitrogen (B).

from the needle or cannula, try sonication to help loosen the solid particles.

The cleaning of reusable needles can be tricky and should be performed using proper safety precautions. Needles used for the transfer of anhydrous solvents do not need to be cleaned and only require drying in an oven before reuse. Cleaning can be achieved by connecting the needle to a syringe and then filling the syringe with appropriate solvent to rinse the needle multiple times. In case the needle is blocked with solid residue, do not push the plunger hard; instead, submerge the needle in an appropriate solvent to clear the solid particles. Sometimes sonication of needles can work by breaking or loosening the particles inside the needles.

Cannula and Needle Drying Procedure. All needles and cannulas should be dried before use with any water-reactive and pyrophoric chemicals. Never dry plastic syringes and needles with a plastic hub inside an oven. Avoid leaving small needles inside an oven without a secondary container (tray) to prevent any needle punctures. While drying metallic needles and cannulas inside an oven, use a glass dish, and keep them separate from other glass items. Small needles placed with other items are difficult to locate inside an oven and can puncture your hand.

Storage and Disposal. The storage of uncapped needles and unprotected cannulas inside a drawer or on a benchtop should be avoided. Styrofoam can be used to temporarily hold your needles and make them readily accessible for when needed for the experiment (Figure 10).

Figure 10. A soft and thick Styrofoam box for holding small needles inside a chemical fume hood.

Needles should not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated before disposal. Uncapped needles should not be left on laboratory benches or inside a chemical fume hood. Using a sturdy plastic or a stainless-steel container/box works well to store nondisposable needles and cannulas. Always collect all disposable needles in a sharps container (heavy-duty plastic). Never overfill a container to avoid injury; see Figure 11. Dispose of the container when it is 2/3 full. One cause of accidental needle-stick injury is the overfilling of a sharps disposal container. An overfilled sharps disposal container will also pose a risk during transport. Before moving a needle inside a glovebox, slightly loosen the cap, and keep it in a small beaker. Never store needles inside the glovebox without using a secondary container.

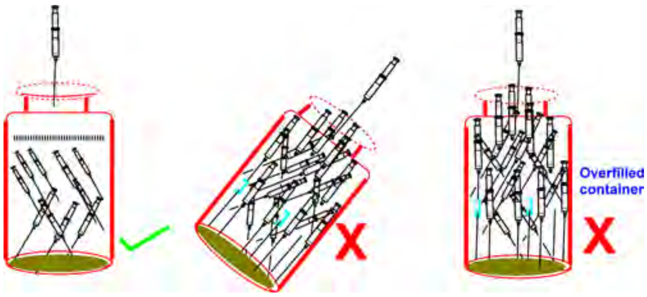

Figure 11. Correct use of sharp/needle containers for disposal.

PROCEDURE

Using Needles and Cannulas for Reactions/Manipulations. The use of a small-to-medium (16–20 gauge) needle is generally recommended for transferring water-reactive and pyrophoric chemicals from a Sure/Seal container to prevent damage to the Sure/Seal. Secure the container using a clamp to prevent dislodging during the reagent transfer.

Avoid insertion too close to the metal portion of the Sure/Seal cap (Figure 12) to prevent bending of the needle. Carefully pierce the cap without hitting your fingers. While transferring the reagent and solvent through septa, make sure to target the puncture area of the septa. Generally, the outer surface of septa is harder than the puncture area; see Figure 12.

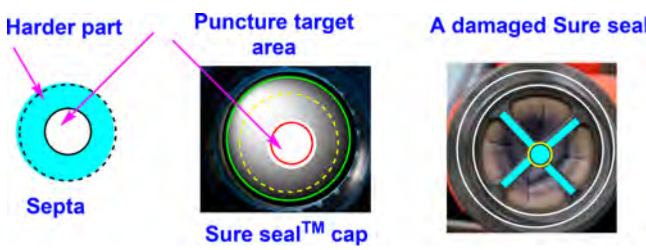

Figure 12. Puncture target area of a Sure/Seal container and a damaged Sure/Seal.

Insert a needle through septa only after it is placed on a reaction vessel; see the technique illustrated in Figure 13. Also, it is important to secure the reaction vessel by using a proper clamp. Needle puncture/injury can also occur when the septum is removed with a needle attached to it (Figure 13).

Many needle sticks have been reported from laboratories when the septum was removed from a reaction vessel with the

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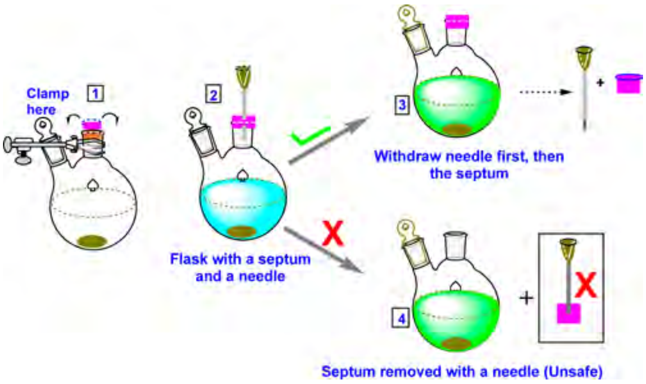

Figure 13. Correct use and removal of a septum and needle from a flask.

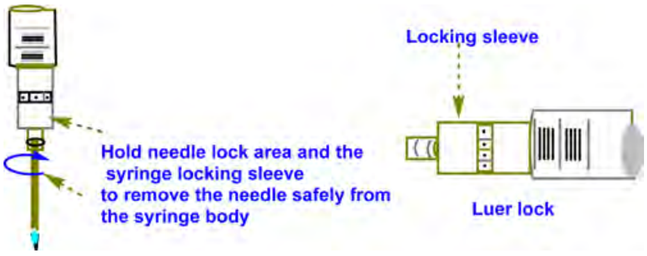

Figure 15. Removal of a needle from a glass syringe.

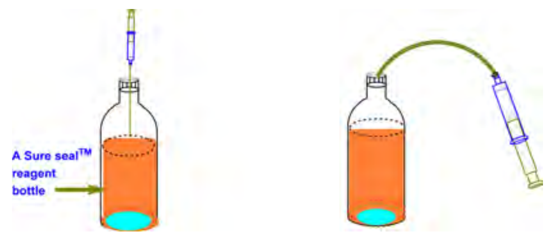

Figure 16. Use of a Luer lock needle to transfer pyrophoric and reactive liquids.

needle attached to it. Use precautions when removing a needle from a syringe. Hold the needle near the tip to puncture the septa, and carefully insert the needle inside the vessel. Avoid bending a needle during insertion into a septum or a reagent bottle. Holding the needle near the lock area will bend the needle (Figure 14). Before pushing the reagent or solvent from the syringe, make sure that the needle is inside the reaction vessel. If the needle is not fully inside the reaction vessel, pushing the plunger may inadvertently spray the solvent or reagent outside the reaction vessel.

When using nitrogen from a Schlenk line and when the diameter of the Schlenk line tubing is larger than the needle, use a smaller tubing connector that fits with the needle properly, otherwise the needle will slide inside the tubing. When a small quantity of reagent is left in any container, never tilt it for withdrawing reagent; instead use a large needle to touch the reagent at the bottom of the container (Figure 14a,b). Tilting a reagent container, especially a container of pyrophoric chemicals, can create additional safety hazards.

Always hold the needle lock area when removing the syringe from the needle; see Figure 15.

Method 1: Air- and Moisture-Sensitive Reagent Transfer with Syringe.[46,47] See refs 46 and 47.

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 (Figure 16). (Never overpressurize a reagent bottle containing AM reagents.)

II. Insert the 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 the syringe and needle with a nonreacting solvent after transferring reagent, and quench the residue under an inert atmosphere using isopropanol.

Method 2: Air- and Moisture-Sensitive Liquid Transfer with a Cannula. See refs 48 and 49. Premeasure the volume you require into an addition funnel, mark it correctly, and then dry the glassware thoroughly as your set up under inert gas or oven. Do not overpressurize the reagent bottle, and the use of Schlenk line nitrogen is recommended.

- Secure the bottle with a clamp, and 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 (Figure 17a).

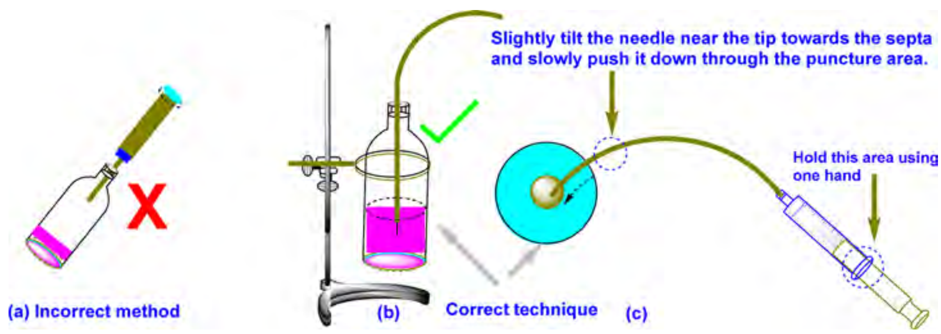

Figure 14. Use of a long needle and syringe for withdrawing the reagent/solvent.

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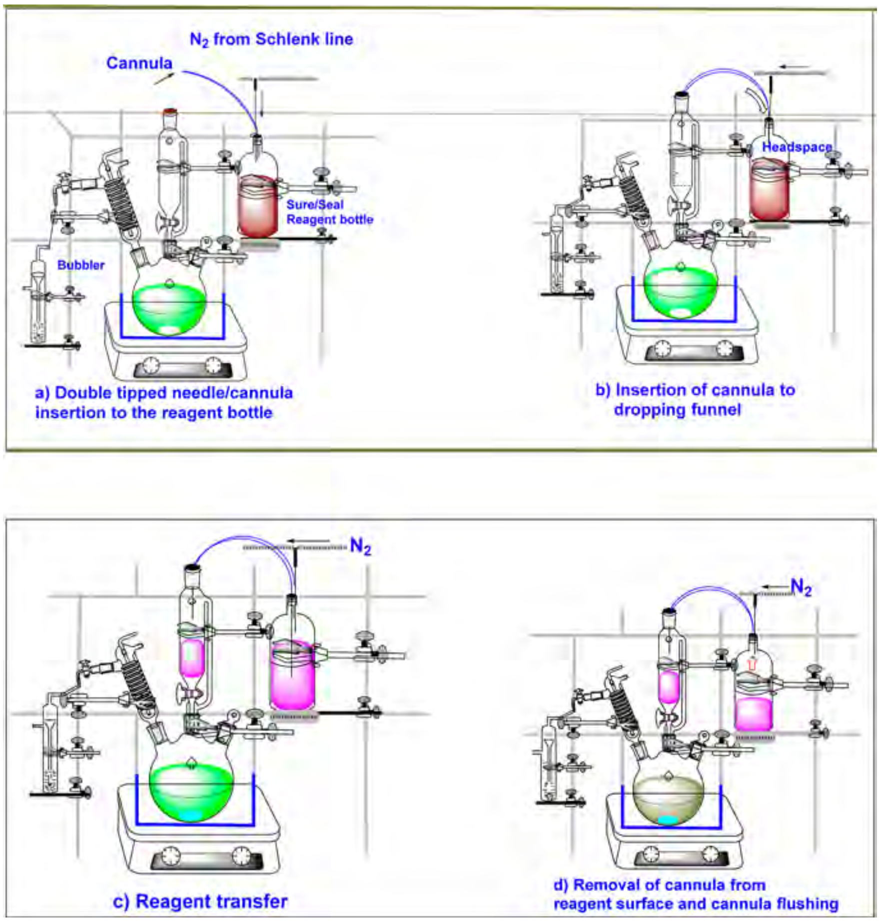

Figure 17. Use of a cannula to transfer pyrophoric and reactive liquids.

Table 1. Hazard Assessment: Handling Cannulas and Needles in Chemistry Labs

Department: Chemistry/Biochemistry	Description of Operation: Use of needle and cannula for organic syntheses			By: Tilak Chandra Review Team Date 11/25/2021
What if?	**Answer**	**Probability**	**Consequences**	**Recommendations**
The needle size is not long enough to withdraw the reagent from a Sure seal™ bottle	Difficulty in withdrawing the reagent	High	The possibility of chemical spills, and multiple punctures can deteriorate the septa	Use an appropriate-sized needle for withdrawing the reagent from the reagent bottle to avoid any difficulty with the reagent transfer.
The syringe method is used for a large-scale pyrophoric (PP) reagent transfer	Multiple syringe transfers will be needed	High	Possibility of fire and chemical spills	A cannula method is recommended for a large-scale PP reagent transfer
The Cannula is used without drying for moisture- sensitive liquid such as *tert*-BuLi	Introducing moisture to rxn or to reagent	High	Low yield or difficulty in product isolation	Always use dry cannulas for moisture sensitive-reagents and reactions.
The needle left inside a chemical fume hood without a cap	Possibility of needle sticks	High	Chemical exposures/injury	Never leave any uncapped needle inside a chemical fume hood or on a benchtop to prevent any injury.
The sharps container for disposal purpose is over-filled with used needles	Possibility of needle stick	High	Chemical exposures and needle injury	Never fill a sharp container above the 75% capacity to prevent needle injury.

- Insert the other end through the septum at the graduated dropping funnel (Figure 17b) of the reaction apparatus which must be equipped with a gas line to a bubbler or calcium chloride guard tube.
- Push the needle into the liquid in the Sure/Seal reagent bottle, and transfer the desired volume (Figure 17c). 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, Figure 17d). Allow nitrogen to flush the needle or cannula (Figure 17a,d). Take out the needle from the reaction apparatus first and then from the reagent bottle.

■ HAZARD AND RISK ASSESSMENT

Hazard Identification and Control. Proper hazard identification and mitigation strategies are critical to the safety of students and researchers.[50−60] Incidental punctures by contaminated needles can inject hazardous chemicals into the body. Sharps can create a cut in the skin, which allows contact between blood and fluids. Since needles and cannulas are

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regularly used for handling hazardous solvents and chemicals with variable reactivity, conducting a proper hazard assessment is critical to prevent unwanted events[61,62] and chemical exposures. Use the right-sized needles, syringes, and cannulas and proper techniques to prevent needle injuries in the lab. While this paper covers some of the basic safe handling procedures on needles and cannulas, the risk needs to be assessed within the context of the overall experimental procedure. A what-if analysis hazard assessment method works very well when manipulating chemicals for the first time (Table 1).

Generally, the use of safety goggles and a lab coat is recommended while using cannulas and needles for chemical manipulations to prevent chemical exposures. The cannula transfer method can spray chemicals when the nitrogen pressure is not controlled correctly. The risk assessment may also identify alternative transfer methods that are safer than the use of needles and cannulas.

Maintaining situational awareness[63,64] is also critical to reducing cannula and needle injuries in research laboratories. The researchers should be familiar with different situations such as the nature of the reagent, pressure build-up inside the container, cannula breakage, blockage, and good housekeeping inside the chemical fume hood. Situational awareness has mainly three components, awareness of your lab environment and surrounding, understanding of the experiment, and what can go wrong during the process. Missing or insufficient situational awareness has been identified as one of the primary aspects of accidents attributed to human error. The continuous use of cannulas and needles can cause complacency. In an industrial setting, most injuries occur during routine work. Similarly, in research laboratories, most near misses and incidents occur due to complacency.[65−70] Complacency is eliminated by reviewing administrative controls, using a what-if analysis, and updating the existing SOPs. Frequently reminding students and researchers during group meetings of attention when conducting routine tasks can help reduce injuries. However, over time, that message loses effect. Therefore, another method is to develop a well-written standard operating procedure and risk analysis. An SOP is detailed written instructions that inform the researchers about each task involving hazardous materials, equipment, or processes. SOPs are particularly useful for incoming students and researchers who, as we know, are much more likely to have an accident. Hazard analyses are also useful. They differ from SOPs in that they describe the potential hazards and advise one of the safest methods for completing a job.

Needle Injury/Needle Stick. Needle stick injuries[71,72] are cuts caused by needles and cannulas which unintentionally puncture the skin. Contaminated needle sticks can inject hazardous chemicals into the body through the skin, causing injuries and other health complications. The general recommendation for when you pierce or puncture the skin is to encourage the wound to bleed, ideally by holding it under running water. However, the specific chemicals used may require additional actions. As with all chemical operations, consult the SDS[73] for specific information related to exposures. Dry the wound and cover it with a bandage. Seek medical help immediately when exposed to highly toxic chemicals involving a needle stick.

■ CONCLUSION

Most reactive and toxic chemicals can be safely manipulated in chemistry laboratories by using stainless-steel cannulas and needles. Before using needles and cannulas, students and other researchers shall conduct a proper hazard assessment for the chemicals involved in the process. Special precautions are needed for handling pyrophoric and toxic chemicals when these devices are used in combination with a Schlenk line. The use of a proper reaction setup, safe techniques, and hands-on training is imperative to reduce needle injuries and chemical exposures. The incoming graduate students and undergraduate students should work under the supervision of staff, a senior student, or a researcher when hazardous chemicals are manipulated using these devices. Maintaining good laboratory housekeeping is also a key to prevent injuries. Unprotected needles and cannulas left on the benchtop or inside a chemical fume hood are a safety hazard. Proper precautions should be taken during the use, storage, and disposal of these devices. Whenever possible, the use of needles and cannulas shall be avoided. Any corroded, cranked, or damaged needles and cannulas shall be removed from service and disposed of properly. Frequently reviewing the administrative controls, using a what-if analysis, and updating the existing SOPs will reduce the complacency while using cannula and needles.

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Notes

The information provided in this manuscript is the authors' opinion and does not represent the opinion of organizations where we worked or that we are working with. We elucidated our arguments from experience and the available literature information. This manuscript serves only as a guideline and is in no way intended to serve as the sole training source for a procedure, method, or task. All references or mention of commercial products, trade names, trademarks, manufacturers, distributors or otherwise, are meant to be examples and do not represent an endorsement of a particular product or service. This article excludes safety information about needles and cannulas used in biological work.

The authors declare no competing financial interest.

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