Microscale Demonstration of the Paramagnetism of Liquid Oxygen with a Neodymium Magnet.

Bruce Mattson*, Creighton University, Omaha, Nebraska 68178 *xenon@creighton.edu

Abstract:

When a neodymium magnet is brought near a suspended small glass tube (2.5 mL) containing 2 mmol (64 mg) liquid oxygen, the tube is attracted to the magnet demonstrating oxygen's paramagnetism. Larger amounts of liquid oxygen can be produced in a similar fashion using a sandwich bag filled with oxygen in place of a 60-mL syringe used to condense 2 mmol oxygen. On the larger scale, the blue color of liquid oxygen is readily observable by students.

Audience: First-Year Undergraduate / General, Upper-Division Undergraduate

Keywords: Inorganic chemistry, Oxygen, Descriptive chemistry, Molecular properties and structure, Free radicals, Gases, Magnetic properties, MO Theory

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Many teachers have seen the impressive photograph of liquid oxygen suspended between the poles of a large magnet. The photograph is commonly found in general chemistry books.[1] In conjunction with a discussion of how molecular orbital theory correctly predicts oxygen's paramagnetism, those of us who make use of classroom demonstrations are left with relatively few options to show the class an actual example. In this Journal, one article has appeared that describes how soap bubbles of oxygen gas are attracted to a powerful (1800 gauss) magnet *(1)*. A similar demonstration, simple, yet poignant, can be viewed on the web *(2)*. We describe here a truly microscale classroom demonstration of the paramagnetic behavior of samples as small as 60 mg liquid oxygen and the apparatus shown in Figure 1.

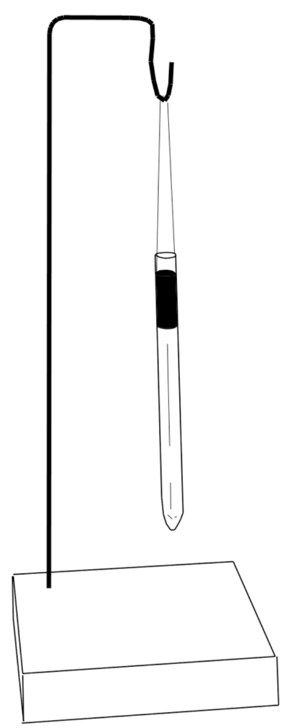

Figure 1. Paramagnetism of Liquid Oxygen device

A similar technique was reported earlier as a Tested Demonstration in which relative molar magnetic susceptibilities are tested using a neodymium magnet *(3)*.

Apparatus.

The apparatus shown in Figure 1 is constructed from a glass Pasteur pipet, a 20 cm length of sewing thread, a 25 cm length of heavy (e.g. 12 gauge) copper wire, 3 cm electricians' tape, and a wooden base (approximately 10 cm x 10 cm x 2 cm.) Use a Bunsen burner to seal the bottom of a glass pipet at the point there the diameter changes between the tip and the body. This will create a small test tube with a capacity of approximately 2.5 mL. Tape both ends of a 15 cm length of sewing thread at opposite sides of the pipet's open end to form a pail-like handle. The loop of thread will hang from the support hook. The vessel must be suspended above the base.

Materials[2]

- glass Pasteur pipet
- 20 cm length of sewing thread
- 25 cm length of heavy (e.g. 12 gauge) copper wire
- 3 cm electricians' tape
- wooden base (approximately 10 cm x 10 cm x 2 cm.)
- 60 mL plastic syringe, with a LuerLok fitting
- syringe cap fitting, Latex LuerLok
- Latex tubing, 1/8-inch (3.175 mm) ID, 2-cm length
- pinch clamp such as a hemostat
- Neodymium magnet
- plastic beverage cup, clear PETE (9 oz, 250 mL)
- Optional: freezer-quality quart (1 L) size food storage bag and a 10 cm length of Latex tubing (1/8-inch (3.175 mm) ID)

Chemicals required for demonstration

- supply of oxygen (CAS Number 7782-44-7)
- liquid nitrogen (in a dewar flask) (CAS Number 7727-37-9)

Optional projection system.

This is a small scale demonstration. Using it in a large classroom will require some sort of projection. We created a pipet vessel with a longer string (90 – 100 cm) that we hung from the lens head of an Elmo® document camera. This projected well while providing a "top view" of the pipet. Motion caused by the magnet was easily observed by the class. Using this approach, one does not need the wire support shown in Figure 1.

Instructions:

Fill the syringe with oxygen as follows. Connect the syringe and the 3-cm length of tubing. The tubing fits snugly over the inner part of the LuerLok fitting. If oxygen is being used from a compressed gas cylinder, run some oxygen out in order to purge the regulator of air. The regulator should have a fine-control-knob. Adjust the pressure to 100 kPa (1 atm, 15 psi) using the gas regulator knob. Connect the syringe/tubing syringe (plunger fully inserted) to the regulator and ***slowly*** fill the syringe with oxygen. **Caution:** If too much gas is discharged, the plunger could become a flying projectile! Hold the syringe so that the plunger will hit the floor if this happens. Once the syringe contains 60 mL oxygen, disconnect the syringe/tubing and seal the tubing shut with the pinch clamp. Oxygen can also be generated inside the syringe from 6% hydrogen peroxide and solid potassium iodide *(4 – 6).*

Remove the pipet/thread device from the apparatus and connect the pipet to the syringe of oxygen using the Latex tubing (Figure 2). Note: The tubing makes a snug fit *inside* the opening of the open end of the glass pipet; do not attempt to stretch it over the pipet.

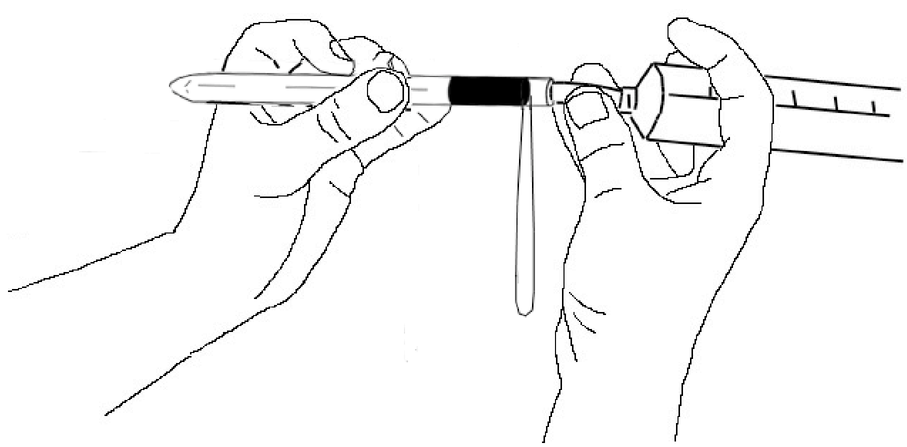

Figure 2. Connecting pipet to syringe with tubing: tubing fits inside the pipet.

Review the safety precautions regarding liquid nitrogen and liquid oxygen. Position the neodymium magnet close to the apparatus so it will be available when needed. The demonstration is now ready!

Pour liquid nitrogen into the plastic cup. Hold the bottom third of the pipet in the liquid nitrogen. Within a few seconds the syringe plunger will move inward as the oxygen gas condenses in the pipet. After the oxygen has condensed and the syringe is empty, remove the tubing from the pipet and immediately suspend the pipet from the wire hook of the apparatus. Quell any random movement that the pipet may be making by touching a finger to the pipet above the cold region. The liquid oxygen is initially about 5 mm deep inside the pipet but vaporizes rapidly. Some liquid should remain present for at least 30 s, so the demonstration must be completed quickly. Hold the neodymium magnet near the side and bottom of the pipet. Once the magnet is within a few mm of the pipet, it will swing towards the magnet and possibly hit it with a small, but audible ping.

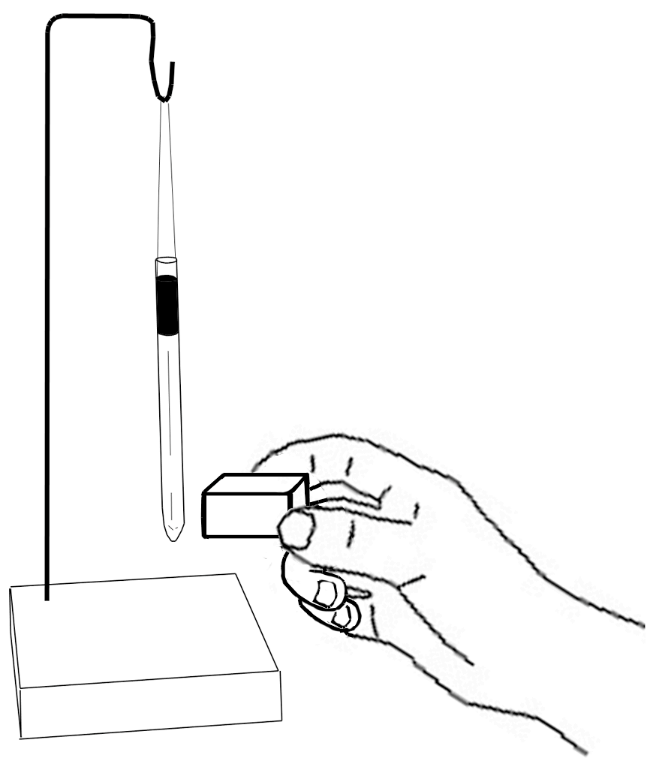

Figure 3. Conducting the experiment: Liquid oxygen is attracted to the neodymium magnet.

Gas bag option.

The demonstration can be scaled up in terms of the quantity of oxygen used, but using the same apparatus. Instead of a 60-mL syringe, a 1-L freezer-quality plastic, sealable, food storage bag is used. Instructions for construction of this gas bag *(5 – 7)* can be summarized as follows. Seal a new food storage bag with some air inside. Press in the bag to insure that the bag is airtight. With a pencil, poke a hole through the bag. The hole should be slightly smaller in diameter than the tubing. Moisten the tubing and work it through the hole in the bag. The gas bag in now ready for use. Follow the same instructions as given above for filling the bag (do not overfill) and conducting the experiment. There are several advantages with this option. Some individuals may find gas bags easier to use than the syringe method. Considerably more liquid oxygen will be produced so the demonstrator can allow students to see the blue color of the liquid oxygen. The color is best observed while keeping the pipet immersed in the liquid nitrogen. This prevents frost from forming and obscuring the view. Another advantage of working on this larger scale is that the demonstrator has more time to work with the magnet and the apparatus containing the liquid oxygen. After the demonstration, allow the liquid oxygen to vaporize in the pipet apparatus.

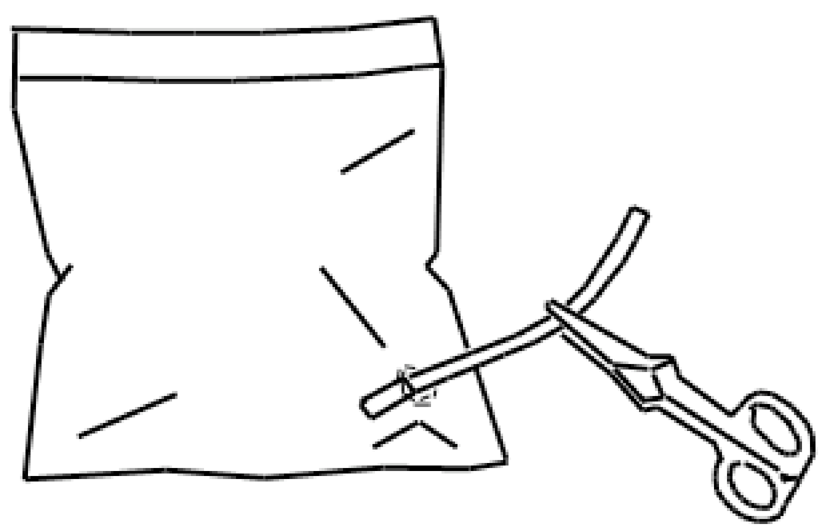

Figure 4. The 1-L "gas bag" made from a freezer food storage bag

Safety Concerns and Hazards.

Always wear safety glasses!

Liquefied gases must never be stored in a closed system. Note: None of the equipment described in this article would create such a situation.

Liquefied gases cause cryoscopic burns. Avoid dermal contact.

Liquid oxygen can react violently with organic matter. Do not use oxygen near open flames or where sparks are generated. Interested readers can learn more about liquid oxygen hazards from this Journal *(8)*.

Supplemental Material

A Quicktime movie of this demonstration is available at *JCE Online* and at http://mattson.creighton.edu/~jiro/liquid_oxygen.html. The movie was produced by Jiro Fujita of Creighton University.

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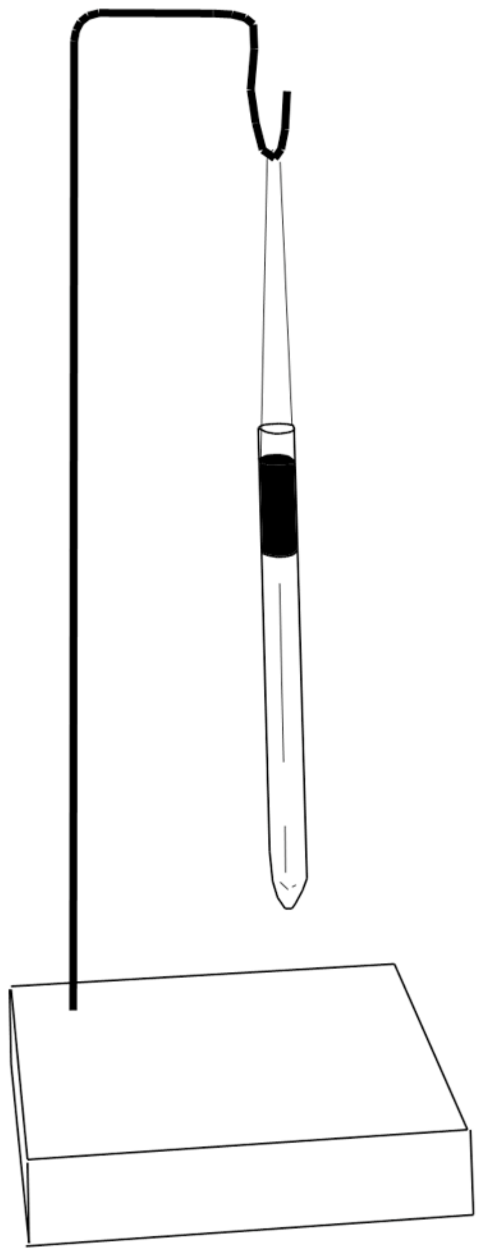
Endnotes:

[1] The first four general chemistry texts I checked had such a photograph. Texts checked were: *Chemistry*, McMurrey & Fay; *Chemistry and Chemical Activity;* Kotz and Treichel*, Chemistry, Molecules, matter and Change*; Jones and Atkins and *Chemistry*, Zumdahl and Zumdahl.

[2] Syringes and related equipment can be ordered from a variety of vendors including Educational Innovations, Flinn Scientific (US sales only), Micromole and Fisher Scientific. Part numbers and links to their websites are provided at our microscale gas website [5].



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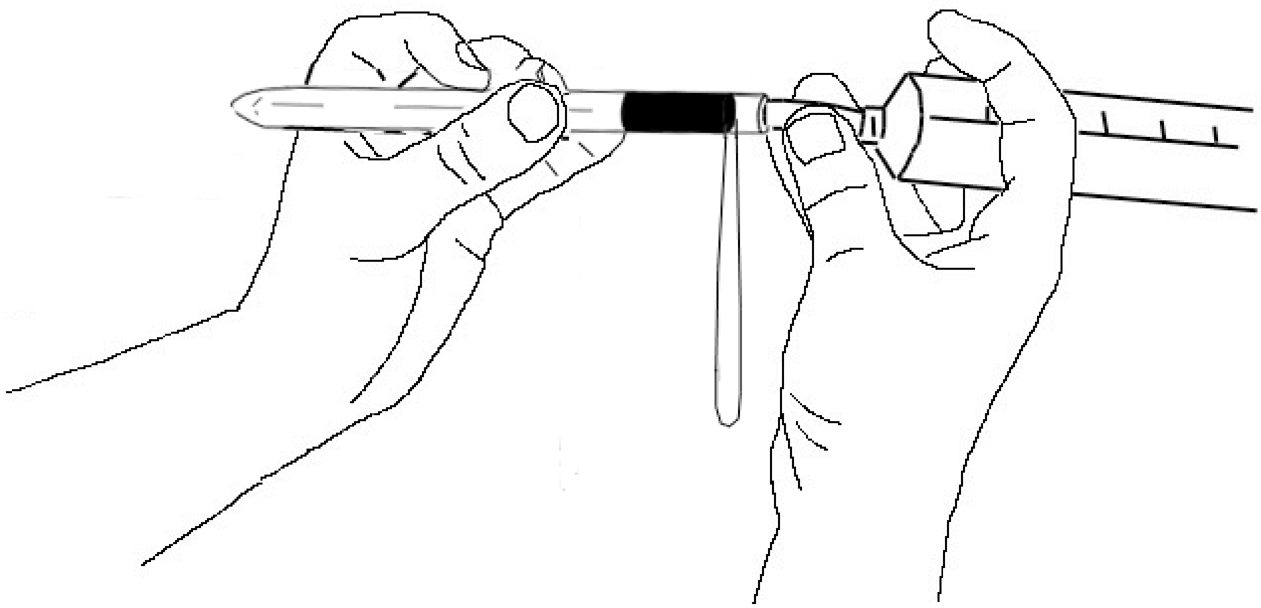

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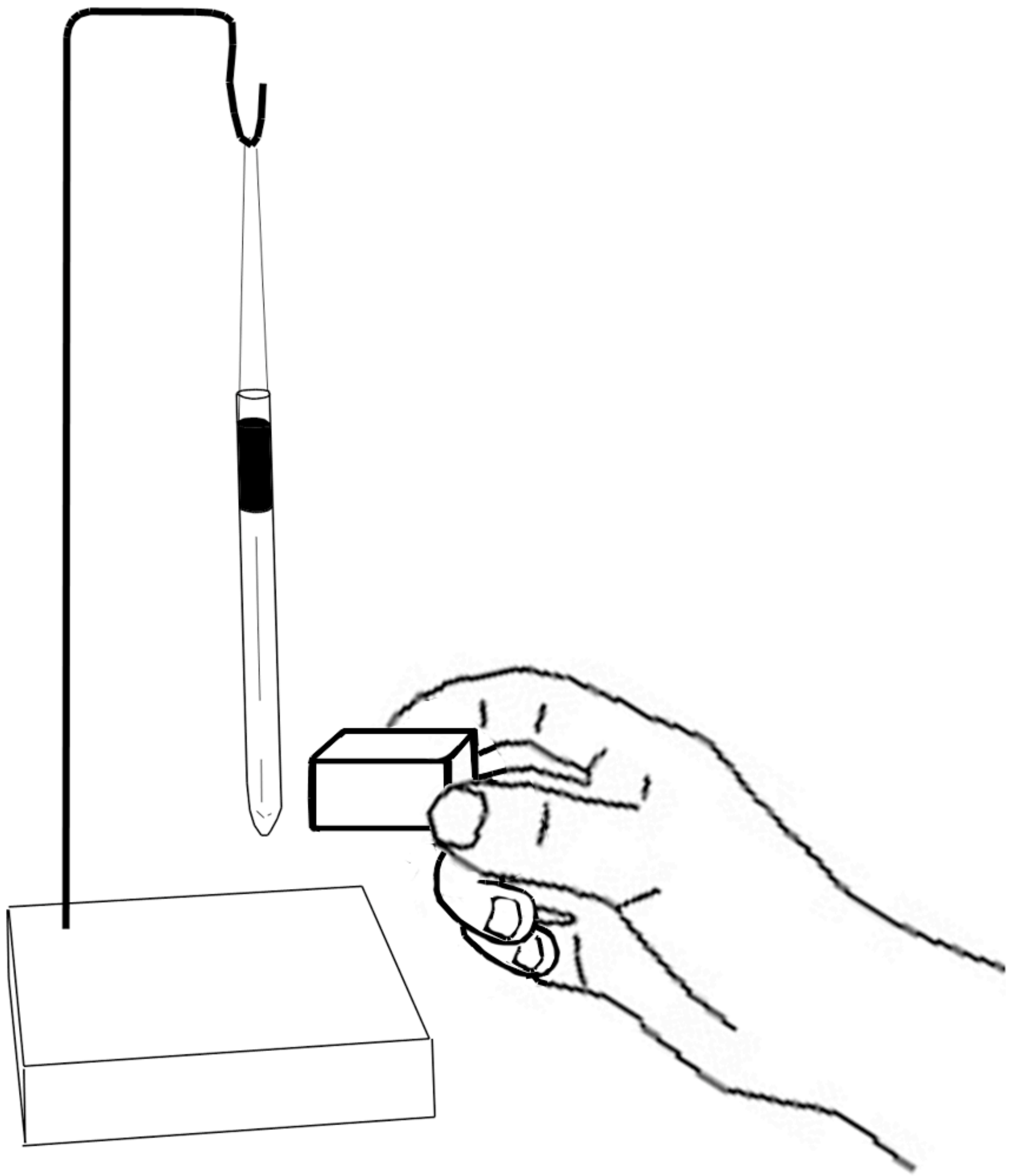

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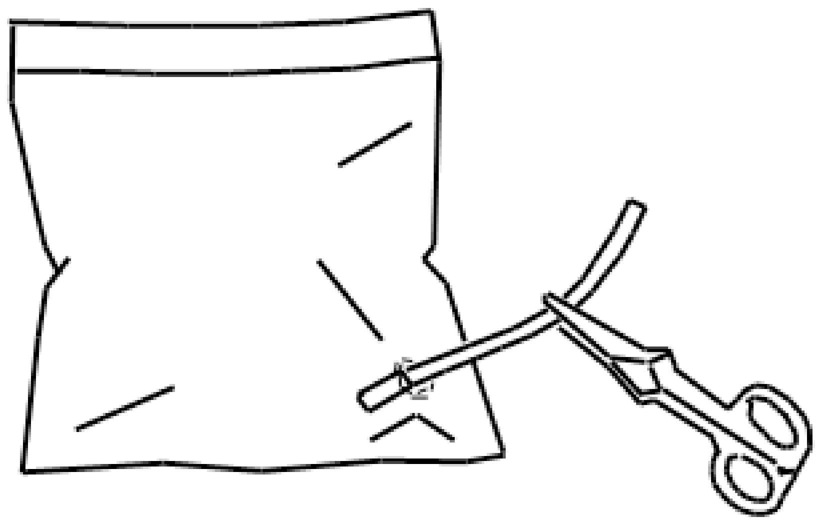

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