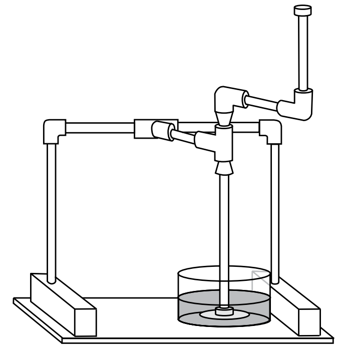
ICE Devices

Rod-climbing Liquid

This apparatus shows the chain-like structure of polymers. If used in combination with a setup of a rotating rod in a bowl of water and a second rotating rod in a bowl of cooked spaghetti, students will clearly see that the polymer behaves more like the spaghetti than the water—it climbs the rod. You may provoke discussion by asking what other substances your students might have seen climbing rods (bread or cake dough gunking up the shaft of a beater; long hair twisting up a nervous person's finger).



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1 hour plus 1 week of waiting

Rod-climbing Liquid

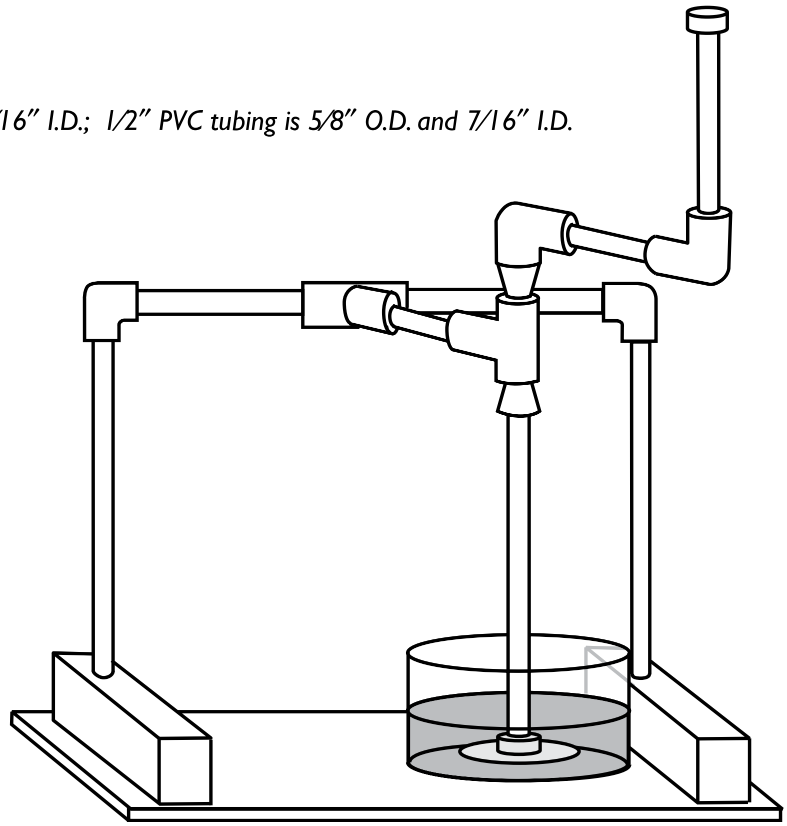
by Ron Perkins

This apparatus shows the chain-like structure of polymers. If used in combination with a setup of a rotating rod (e.g., the handle of a wooden spoon) in a bowl of water and a second rotating rod in a bowl of cooked spaghetti, students will clearly see that the polymer behaves more like the spaghetti than the water—it climbs up the rod. You may provoke discussion by asking what other substances your students might have seen climbing rods (bread or cake dough gunking up the shaft of a beater; long hair twisting up a nervous person's finger).

These instructions consist of two sections: making the sturdy stirring device and mixing up the polymer solution to use with it. The latter requires several days of stirring, with occasional adjustments of the stirrer speed. Stored in a clean, covered container, this solution should keep indefinitely.

Materials

Note: *3⁄4″PVC tubing is 7⁄8″ O.D. and 1 1/16″ I.D.; 1⁄2″ PVC tubing is 5⁄8″ O.D. and 7/16″ I.D.*



- __ *6′ PVC tubing, 3⁄4″ -dia.*
- __ *2.5″ piece PVC tubing, 1⁄2″-dia.*
- __ *PVC female fittings, 3⁄4″*
  - __ *2 tees*
  - __ *3 elbows*
  - __ *2 end caps*
- __ *PVC male/female fittings, 3⁄4″*
  - __ *1 elbow*
  - __ *2 reducers (3⁄4″-dia. tubing to 1⁄2″-dia. tubing)*
- __ *can of PVC solvent*
- __ *small paint brush*
- __ *16″ × 1″ × 12″ piece of wood*
- __ *2 ea. 2″ × 4″ × 10″ pieces of wood*
- __ *5″-dia. disk of rigid plastic (e.g., plastic plate or saucer, cut to size) or clear acrylic disk†*
- __ *190 mm dia. (minimum at bottom) 100 mm deep (minimum) transparent bowl* or crystallizing dish (colorless is best)*
- __ *2″ (or longer) screw, any diameter*

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† ***Rigid plastic disk:*** Several plastic plates can be glued together to make a disk of rigid plastic.

* ***Crystallizing dish:*** A plastic salad crisper can be an excellent alternative to the crystallizing dish. Provided it has a tight lid, it can be used to store the polymer solution indefinitely.

- __ *2 ea. hex nuts to fit the screw*
- __ *metal washer to fit the screw*
- __ *rubber washer to fit the screw*
- __ *epoxy*
- __ *4 ea. 2″-long nails*
- __ *hammer*
- __ *drill and 7⁄8″-dia. drill bit and drill bit to fit the screw*
- __ *screwdriver to fit the screw*
- __ *saw*
- __ *balance*
- __ *clean containers with caps to store 3 L of liquid (see footnote * previous page)*
- __ *75 g polyethylene oxide (ave. FW = 7×10^6).(e.g. Aldrich Cat. No. 372811)*
- __ *300 mL ethanol*
- __ *1.5 ml (~30 drops) 2% thymol in ethanol (used as preservative); [2% thymol in ethanol solution can be prepared by dissolving 0.5 g thymol (e.g. Aldrich Cat. No. 112097) in 24.5 g ethanol]*
- __ *food coloring*
- __ *3.0 L distilled water*
- __ *4 L beaker*
- __ *400 mL beaker*
- __ *glass stirring rod*
- __ *variable speed, mechanical (not magnetic) stirrer with 4″-diameter paddles (borrow a mechanical paddle stirrer from an organic chemist at a local college, or rent a paint stirrer that fits an electric drill from a hardware store)*
- __ *plastic funnel to fit over the shaft of the mechanical stirrer*

Procedure

Building the stirrer

1. In the two wooden pieces, drill 7/8″-dia. holes centered 2″ from the end of the 2″ side of the block.
2. Cut the 3/4″-dia. PVC tubing to the following lengths:

__ *2 pieces at 17.5″*	__ *1 piece at 15.5″*
__ *2 pieces at 5″*	__ *1 piece at 2.5″*
__ *1 piece at 1.25″*	__ *1 piece at 6″*

3. Drill or punch a hole in the 5″-dia. plastic disk to fit the screw. Drill or punch a hole in one of the end caps to fit the screw.

4. Attach the plastic disk to a PVC end cap: Insert the screw through the hole. Put on the metal washer, the end cap, the rubber washer, and both hex nuts. Tighten the screw down and epoxy the outer hex nut to the screw so that it is permanently attached (Figure 1).

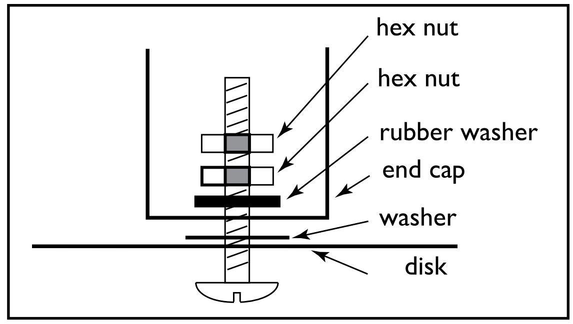

Figure 1: End cap

5. Assemble the tubing into the stirrer support and stirrer assemblies according to the diagrams in Figures 2 and 3 (below). Apply PVC solvent with the paint brush to the tubing at the joints, *except* where indicated. Note that the 1/2″-dia. tube is inserted into the tee of the stirrer, and held in place with reducers: this is the rotating piece of the stirrer—**do not use solvent on it!**

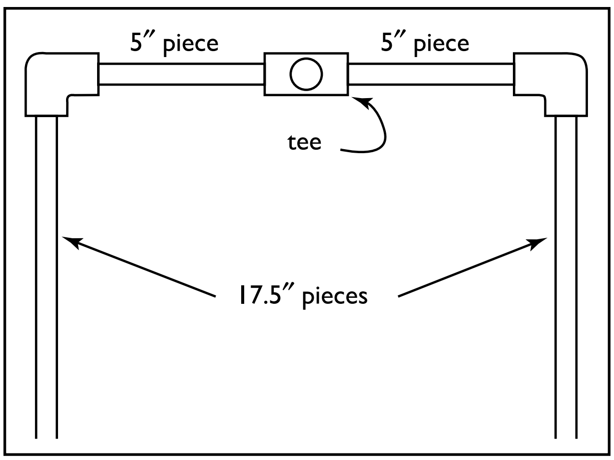

Figure 2: Stirrer support

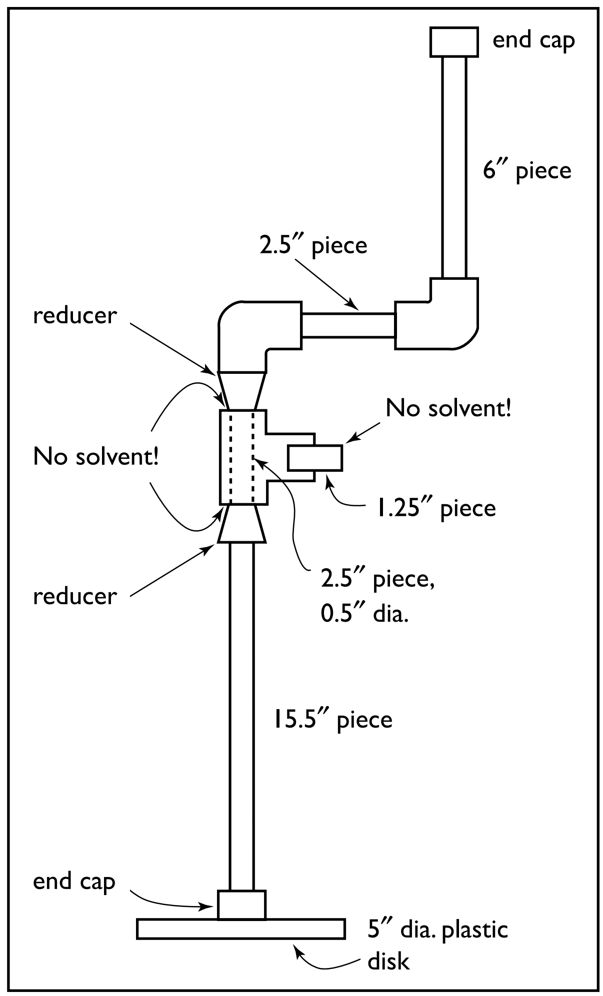

Figure 3: Stirrer assembly

6. Place the wood blocks onto the large wood board as indicated in Figure 4 at right. Insert the legs of the PVC support into the holes in the blocks and adjust their position on the board accordingly. Epoxy the blocks to the board. When the epoxy is dry, remove the PVC support, turn over the wood assembly, and attach the blocks more firmly to the board with the nails.

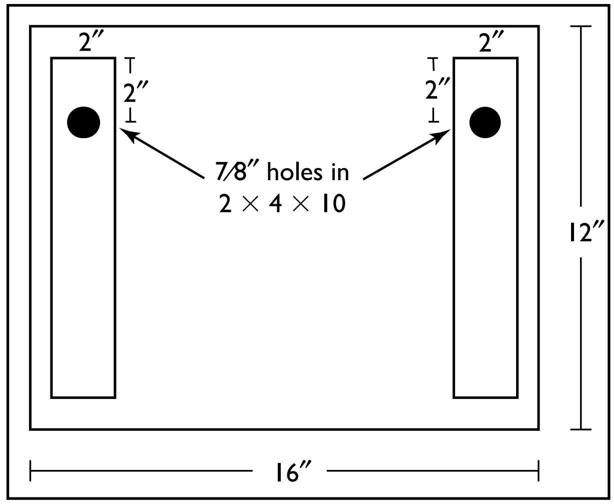

Figure 4: Wooden stand

*Preparing the 2.5% polyox solution**

1. Prepare a solution of 2% thymol (see Materials section).
2. Invert the funnel over the rod of the stirrer. This will prevent the polymer solution from climbing up the stirrer. Use tape to secure the funnel to the rod.
3. Pour 3.0 L of distilled water into a 4 L beaker and adjust a mechanical stirrer so that the stirring paddle is just above the bottom of the beaker.
4. Add 30 drops of 2% thymol in ethanol and any desired food coloring.
5. Place 75 g of polyethylene oxide into a 400 mL beaker and add enough ethanol to make a slurry, about 200 mL.
6. Adjust the stirrer speed to give a deep vortex in the large beaker and, while stirring the slurry, *quickly* pour it into the vortex.
7. Slow the speed of the mechanical stirrer to a crawl (say, 60 rpm) and readjust so that the paddle is just below the top surface of the solution. Adjust the angle of the stirrer to be 3° to 5° off the vertical. If the stirrer is set to move faster than a crawl, bubbles may develop in the polymer solution that will not disappear and that will make the solution opaque.
8. Stir for two days or longer.
9. Upon standing for a few hours, some undissolved polymer may float to the surface. Either continue the gentle stirring for a few more days or scoop off the undissolved polymer and gently stir the remaining solution a few hours longer.
10. Pour the polymer solution into the bowl or crystallizing dish and set onto the wooden stand.
11. Insert the tube of the stirrer assembly into the tee of the stirrer support. (Do *not* use PVC solvent for this joint!) Insert the support into the holes of the wooden stand and adjust the position of the bowl or crystallizing dish so that the plastic disk is centered in the polymer solution.

Presentation

Holding the stem and handle of the apparatus, rotate the rod. Observe the polymer creep up.

* The solution preparation procedure was suggested by members of the research group of Professor John L. Schrag, Department of Chemistry, University of Wisconsin–Madison, Madison, WI 53706.