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Toys in the Classroom

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Since 1986, Miami University has been conducting teacher workshops for K–12 teachers and a course for pre-service teachers titled Teaching Science with TOYS. This includes physics and chemistry components, and since the theme of National Chemistry Week this year is toys, this is the perfect time to pass on a few of the chemistry activities that we have used with teachers over the years. In addition, many of these same activities can be explored in greater depth at the college level.

Toys are exceptional teaching tools because they are non-threatening to children of all ages; they present chemistry as a more friendly science than traditional references to chemistry; and many chemistry concepts can be easily illustrated with toys.

Shrinking Toys

Many young children have experienced the wonder of Shrinky Dinks (1). Plastic pieces with patterns can be colored and then placed into the oven. They shrink to one-third their original area and become nine times as thick as the original piece of plastic. This product has been on the market for more than 30 years and is made of biaxially-oriented polystyrene film (2, 3). You can make your own shrinking plastic toys from readily-available household containers. Transparent plastic deli containers (identified by the #6 recycle code stamped on them) made of polystyrene film exhibit similar shrinking. (See instructions opposite.)

The "magic" of Shrinky Dinks and the deli containers comes from the way the polystyrene film is manufactured. These polystyrene films are stretched at a temperature above the glassy transition point of about 100 °C and rapidly cooled, maintaining the stretched shape. But when heated, the polystyrene returns to its more random configuration. The polystyrene seems to "remember" its most stable random configuration even though it can be "frozen" into a less stable configuration by rapid cooling during manufacture.

The behavior of the biaxially-oriented polystyrene is unusual. Most objects will get soft or melt when heated, or decompose. The polystyrene shrinks dramatically, but its mass stays the same. The decrease in the area of the shape is compensated for by the increase in the thickness.

This activity can fit into the curriculum in several places. There is a strong connection to art; shrinking plastic can be used to make jewelry, ornaments, and name or luggage tags (punch any needed holes before shrinking the items). It can also be used to explore mathematical relationships by studying the shrink-



photo: Susan Geritz

Figure 1. A pattern before and after shrinking.

Instructions for Making Shrinking Toys

A. The Design

1. Gather transparent polystyrene containers (recycle code #6).
2. Use permanent markers to create a design on the polystyrene or use sandpaper to roughen the plastic and create designs with colored pencils.
3. Cut out the desired shape.
4. Measure and record the length and width of the polystyrene shape at the longest and widest parts.

B. The Experiment

1. Preheat an oven (a toaster oven will work well) to 350 °F (170 °C).
2. Cover a cookie sheet with aluminum foil.
3. Place the polystyrene shape on the foil and place the cookie sheet into the oven.
4. Watch the shape—typically it will first curl, then flatten out. When it is flat (usually in less than a minute), remove the cookie sheet from the oven and let it cool.
5. When the shape has cooled, measure it again at the longest and widest points and compare the thickness with that of an unheated sample.

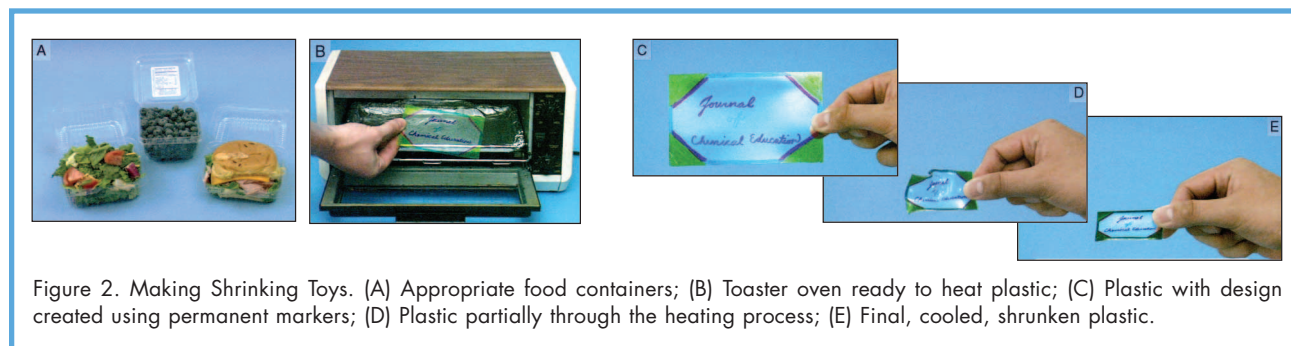


Figure 2. Making Shrinking Toys. (A) Appropriate food containers; (B) Toaster oven ready to heat plastic; (C) Plastic with design created using permanent markers; (D) Plastic partially through the heating process; (E) Final, cooled, shrunken plastic.

photo: J. J. Jacobsen, J. Harris, S. Kehoe

Report

make jewelry, ornaments, and name or luggage tags (punch any needed holes before shrinking the items). It can also be used to explore mathematical relationships by studying the shrinking behavior of different shapes and particularly the relationship between measures of area and volume. Finally, the re-use of deli containers, which would otherwise be discarded, ties in to recycling of materials. Other ideas for classroom activities have been published elsewhere (3–5).

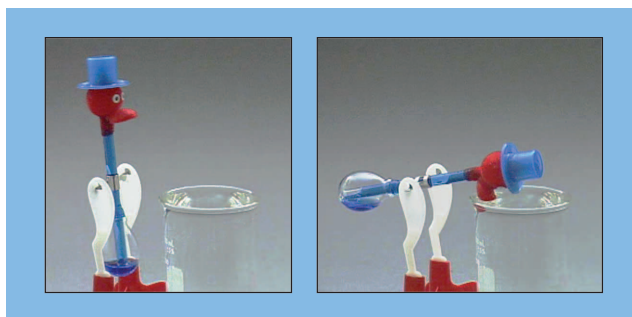


Figure 3. Drinking bird takes a sip. Note that the liquid runs back into the “tail” as it “drinks”. From *Chemistry Comes Alive!* Vol. 2.

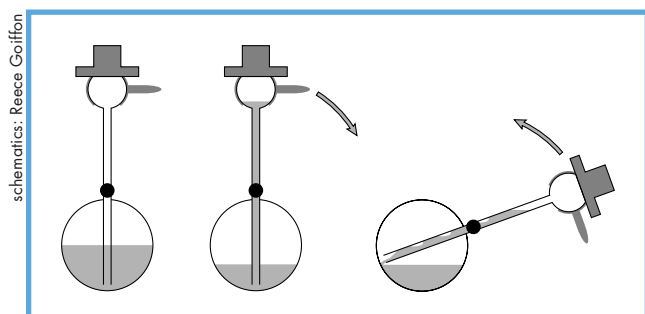


Figure 4. Drinking bird upright (left); as the top bulb cools (center) the pressure decreases and liquid is forced up the tube, causing the bird to tip; as the bird “drinks”, the pressures in the two bulbs equalize and the liquid drains back into the base (right), causing the bird to return to the upright position.

Questions To Investigate: The Drinking Bird

1. How long will the bird “drink” with and without its head dipping into water?
2. Will a “bald” bird (one with the absorbent material and beak removed from the head) drink?
3. Will the bird drink in a closed aquarium?
4. What will happen if the bird drinks rubbing alcohol? (Note that the alcohol will eventually loosen the adhesive holding the beak on the bird, and it will fall off.)
5. What will happen if the bottom of the bird is heated with a heat lamp?

Drinking Birds

Another favorite toy of chemistry teachers is the Drinking Bird (also called the Happy Drinking Bird, Dippy Bird, etc.). This novelty item, along with the hand “boiler” described in the final section, nicely illustrate vapor pressure and related concepts (6–10). Both need to be handled carefully since the glass is very thin and can break.

The Drinking Bird is filled with methylene chloride or a freon. The bird has two glass bulbs and a glass tube connecting the bulbs and extending into the lower bulb (Figure 3). The tube is under the liquid level in the bottom of the bird and the head contains vapor. The neck of the glass apparatus is mounted on an axis (the bird’s legs), so it can pivot.

When the head of the bird, which is coated with an absorbent material, is moistened, the bird begins to bob up and down. A glass of water is placed so the beak enters the water when the bird bobs down to “take a drink”. Then after “taking a sip”, the bird returns to the upright position, and shortly dips its head again to get another “drink”. The cycle repeats for a long time.

There are multiple stages in the process. First, the head of the bird is moistened with water. As the water evaporates, the head cools and the pressure of the vapor in the upper bulb is decreased relative to the pressure above the liquid in the lower bulb. Since there is a pressure differential, liquid from the bottom bulb is pushed into the neck and finally the head. As liquid enters the head, the bird pivots and the head lowers, with the beak coming in contact with the water. At the same time, the pressure in the head and tail is equalized and liquid runs back into the bottom bulb, which causes the bird to return to its upright position (Figure 4). When the head cools again (water is still evaporating), the liquid is once again pushed up the tube, into the head and the cycle repeats.

Hand “Boiler”

A related toy, the Hand “Boiler” (or “Love Meter”), resembles the drinking bird except it is not mounted on an axis and has a twisted tube connecting the two bulbs (Figures 5 and 6). Initially, the liquid—ethanol containing a dis-



Figure 5. Hand “boiler”. Warming the lower bulb increases pressure, forcing liquid (and eventually vapor) into the upper bulb.

photo: Susan Geritz

Report

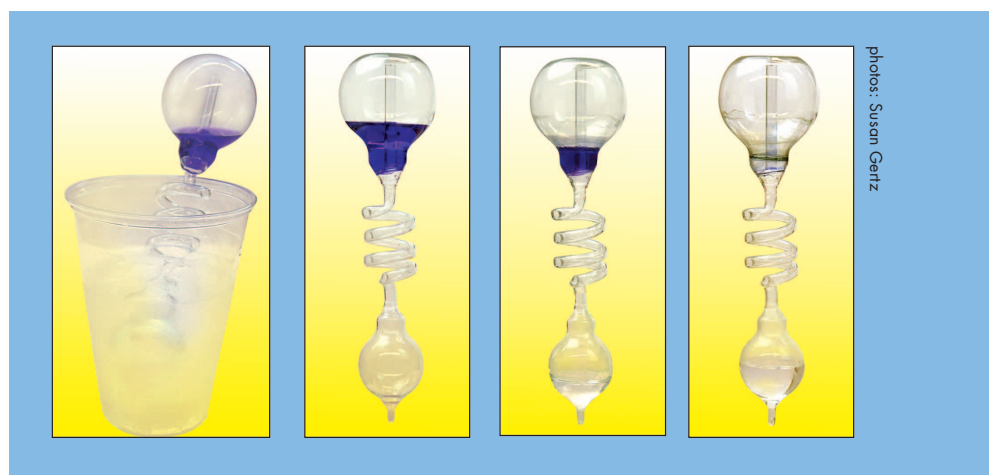


Figure 6. Cooling an inverted “hand boiler” causes the pure liquid to condense in the bottom bulb and the solid dye to remain in the top bulb.

Hand “Boiler” Distillation

A. Procedure

1. Force all of the liquid from the top bulb into the bottom bulb. Then, turn the boiler upside down so that the liquid is in the bulb with the tube (and at the top), and the bulb at the bottom contains only vapor.
2. Cool the bottom bulb of the *inverted* “boiler” containing just the vapor in a salt–ice water bath while holding the top bulb between your palms.

B. Questions

1. What condition is necessary for the distillation to take place?
2. What will happen when the two bulbs have the same volume of liquid, one with dye and the other without, and the “boiler” lies on its side so the liquids cannot run from one bulb to the other?
3. With the “boiler” on its side, will the solutions in the two bulbs ever attain the same color?

Questions to Investigate: The Hand “Boiler”

1. What does it take to get the liquid back from the top bulb into the lower bulb?
2. Can you get the liquid to rise using an ice cube? by using a heat lamp?
3. Is the color of the solid dye the same as the dissolved dye?

solved dye—is in the bottom bulb. When the bottom bulb is grasped between the palms of the hands, the liquid travels from the bottom bulb into the top bulb. After all of the liquid is pushed to the top, the expanding vapor bubbles rise through the liquid, thus giving it the appearance of “boiling”. (It really is not boiling. For the liquid to boil, its vapor pressure would have to equal the pressure of the vapor in the upper bulb. But the heat from hands is not sufficient to raise the vapor pressure that high.)

An interesting experiment comes from a serendipitous discovery by Jenna, daughter of high school chemistry teacher Bob Becker (10). She picked up a hand boiler that had fallen on its side next to a heat register and noticed that one bulb had a deeply colored liquid and the other was colorless. When she showed this surprising result to her father, they realized distillation had occurred and the pure vapor condensed in the cooler bulb to give colorless ethanol while the nonvolatile dye was concentrated in the warmer bulb. This experiment can be duplicated using the hand boiler as a closed, mini-distillation apparatus (see instructions opposite).

As vapor cools and condenses in the bottom bulb, the pressure decreases. This causes more liquid to vaporize in the top bulb, enter the bottom bulb, cool, and condense. The top bulb becomes cold to the touch since vaporization is endothermic. Since the dye is nonvolatile, it remains in the top bulb. Eventually, all of the vapor is condensed into the bottom bulb of the inverted boiler and the top bulb contains only the solid dye (Figure 6). The two components are separated and the distillation is complete! It is very hard to get all of the colored ethanol out of the connecting tube, so this may cause the condensed liquid to be slightly colored. But the difference in color will make it obvious that the concentration of dye in the two bulbs is different.

For younger children, sturdy hand boiler pens are recommended. They have two small bulbs mounted on top of

Report

a ball point pen. The glass bulbs are much sturdier and harder to break.

These are but a few ideas. From now on, when you visit the toy store, see if you can find other toys that illustrate chemistry principles in a non-threatening way.

^wSupplemental Material

QuickTime video of the process of making shrinking toys is available in this issue of *JCE Online*. The video shows a small rectangular piece of recycle code #6 plastic being cut from a small deli-style container. Designs were drawn on the piece with permanent markers before it was placed in a toaster oven preheated to 375 °F. After approximately 30–60 s, the plastic began to curl up and contract in length and width, while also getting thicker. At two min into the process, the shrinking of the plastic was complete; it was removed from the oven and placed in a container of cold water. The result was a thicker piece of plastic—both its length and width shrank but retained the same ratio between their measurements.

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