Anti-Gravity Jars

You have probably spilled water from an open jar before. Do you think there is some way to prevent water from spilling from an inverted jar without permanently affixing a lid or other cover? How about employing what you know about the chemistry of water to meet this challenge? Any ideas? Try them and the following activity and see how successful you are.

Materials

- small-mouthed jar or bottle with lid
- wide-mouthed jar or bottle with lid
- several 3-inch x 5-inch index cards
- round sheet of Styrofoam™, larger than the mouths of the jars, with beveled edges (see Figure 1)
- several different gauges of screening, wide enough to cover the jar mouth (window screening works well)
- marker
- 1 of the following combinations:
    - 2 identical jars and epoxy glue
    - 2 identical canning jars with screw rings or wide-mouthed plastic vials with plastic snap type lids

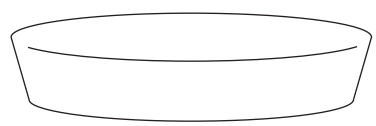

Figure 1: Make a round sheet of styrofoam with beveled edges.

Exploration

You may wish to do this activity over a sink.

Step 1 Completely fill the small-mouthed jar or bottle to the brim with water. Place an index card on top of the jar, making sure that there are no air bubbles between the card and the jar. While still holding the card in place, turn the jar completely over. Make sure that the jar is in a vertical position and not at an angle. Move your hand away from the card. What happens? Why do you think it happens?

Step 2 Repeat Step 1 using the top of the jar lid instead of the index card. No fair screwing or snapping on the lid. Remember to use the lid in the inverted position. Do the experiment starting with the lid completely dry and then again starting with the lid thoroughly wet. Can you do it either way? Why or why not? Now try the piece of thin Styrofoam instead of the jar lid. Does it work better?

Step 3 Repeat Step 1 with the jar 1/2 to 2/3 full of water. Compare your results with Step 1. Does the jar need to be full of water?

Step 4 Can you carry out Step 1 with the wide-mouthed jar? Try it and see. How does the wide-mouthed jar act differently than the small-mouthed jar?

Step 5 Use a sharpened pencil to make a small hole (2–4 mm in diameter) in the center of your piece of Styrofoam. Does this modified Styrofoam sheet hold the water back? Try a hole that is 4–8 mm in diameter. What happens? What's the largest hole that you can make that will hold the water back?

Step 6 Use one of the following methods to secure the screen to the jar or vial:

Jars and epoxy glue:

Cut out a piece of the smallest gauge screening so it is just larger than the mouth of one of the 2 identical jars. Glue the screen to the mouth of the jar. Try to make the screen as tight as possible. (See Figure 2.)

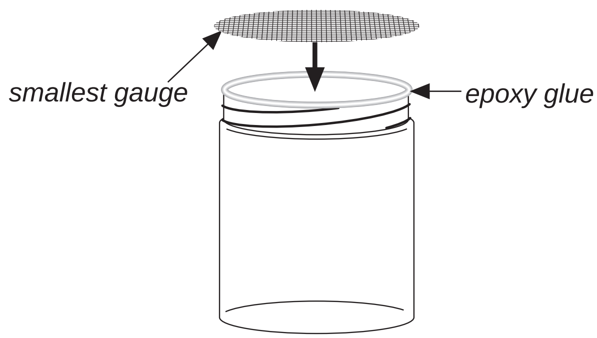

Figure 2: Place the smallest gauge screening onto the mouth of the jar.

Canning jars or plastic vials:

Cut out the top of the plastic lid, leaving enough lip around the edge to grip the screen. Use a marker to outline the screw ring or cut-out plastic lid on the screen. Carefully cut the screen so it is large enough to be held by the lip of the screw ring or cut-out plastic lid, but not so large that it buckles. Place the screen over the mouth of the jar or vial and secure it with the screw ring or cut-out lid.(See Figure 3.)

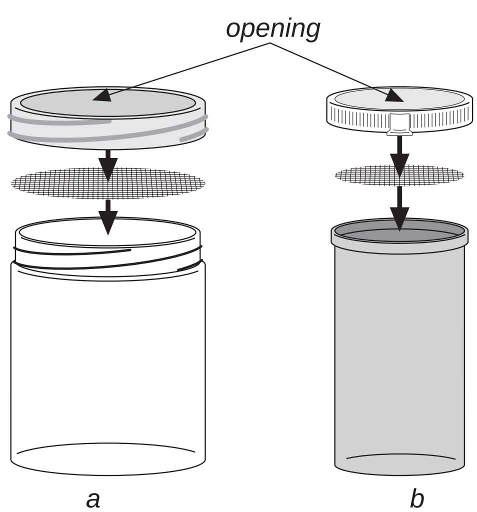

Figure 3: Sandwich the screen between the mouth of the jar or vial and the (a) screw ring or (b) cut-out lid.

Step 7 Pour water through the screen until the jar is completely full to the brim. Place an index card over the mouth and hold it with one hand while you invert the jar with the other. Make sure that the jar is in a vertical position, and not at an angle. Slide the card off the side of the screened lid. What happens? How can you explain it? How are the forces at work here different from the ones at work in Steps 1 and 2? Try tapping on the screen with your finger several times. What happens? Why?

Step 8 Repeat Steps 6 and 7 with the other identical jar and a larger gauge screening. How does the larger gauge screen behave differently from the smaller gauge screen? Why? What do you think is the largest gauge screen that would work in this experiment?

Step 9 (Optional) With an exacto-knife, cut a small hole in the screen of either jar that you assembled in Steps 6 and 8. (See Figure 4.) Try the experiment with this “larger gauge” screen that you have created. Does it hold the water back?

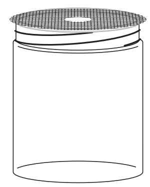

Figure 4: Cut a small hole out of the screen.

Challenge

To use jars of water to investigate the forces exerted by intermolecular attractions and air pressure.

Anti-Gravity Jars

This activity effectively demonstrates the forces that are at work both in and surrounding liquids.

Concepts

surface tension, air pressure, intermolecular forces of attraction, adhesion, cohesion, hydrogen bonding

Expected Student Responses to Exploration

Step 1 (a) The card will remain against the mouth of the jar or bottle and prevent the water from pouring out of the container until the card becomes soaked.

(b) The water stays inside because the air pressure outside is greater than the pressure of the water against the card.

Step 2 (a) The jar lid will work just as well as the index card. However, the lid needs to be wet first.

(b) Here we are applying the forces of adhesion (attraction of the water molecules to the jar lid), as well as air pressure.

(c) The Styrofoam should work even better. The sharp edges produce less adhesive force than the rounded jar lid. This adhesive force pulls the water in the direction of gravity. Thus, the less adhesion, the better the system should work.

Step 3 The jar does not need to be full of water. However, it is important to be sure that air bubbles are not trapped between the card and the mouth of the jar.

Step 4 (a) The results will be the same as those in Step 1.

(b) The wide-mouthed jar will not behave any differently because the air pressure will still be the same. The card may become soaked more quickly, however, and the jar will need to be perfectly vertical.

Step 5 (a) The Styrofoam will still hold the water.

(b) The Styrofoam will still hold the water.

(c) Theoretically, a hole of 1.4 cm would be able to hold back the water. However, it is very difficult to get this to work in practice.

Step 6 (No student question.)

Step 7 (a) The screen will hold the water inside the container.

(b) Several factors contribute to this phenomena:

- cohesion—the especially strong intermolecular attractions between water molecules because of hydrogen bonding. Because of cohesion, the water molecules behave as an elastic film at the surface, giving water a high surface tension.
- adhesion—the attraction of water molecules to other substances, such as the edges of the screening.
- air pressure—exerts an upward force, as it did in Steps 1 and 2.

These forces won't work to hold the water in an open jar, but when the openings are small enough, the combined strength of the forces is larger than the gravitational force.

(c) The primary force at work in Steps 1 and 2 is air pressure against the card.

(d) Tapping on the jar causes some of the water to run out of the jar. If the tapping is not too hard, the water flow will stop before the jar is emptied.

(e) The movement briefly breaks the attractive forces and allows some of the water to run out.

Step 8 (a) Whether or not the screen will hold water depends on the specific gauge of the screening. Success for the larger gauge screening probably has a lot to do with steadiness of hand!

(b) As the gauge of the screen becomes larger, there is less area for adhesion to occur. Thus, it is easier for gravity to overcome the attractive forces.

(c) Once again, theoretically, a hole of 1.4 cm would be able to hold back the water.

Step 9 (Same as Step 8.)

Acknowledgment

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