Tissue in a Cup: How Soggy?

Have you washed any cups or glasses recently? Have you ever tried to submerge an inverted glass, jar, or cup into water only to have it bob back to the surface without the inside getting wet? What does this have to do with chemistry? You will find out as you investigate several aspects of this phenomenon through this activity.

Materials

- clear plastic cup or clear glass
- paper cup
- several tissues or paper towels
- push pin or nail
- 2 containers large enough to completely submerge the cups (preferably with clear sides or a very large mouth to allow observation of the sides of the cup when submerged)
- ice-cold water
- very hot tap water

Safety

Be cautious of the sharp point on the push pin or nail. Use appropriate procedures to avoid burning yourself with hot tap water.

Exploration

Step 1 Fill one container with ice-cold water. Fill the second container with very hot tap water. Submerge an inverted clear cup or glass in the cold water for several minutes and observe from the side. Remove the cup from the cold water and, taking care not to burn yourself, submerge the inverted cup in the hot water for several minutes and observe as before. Repeat the submersion in cold and then hot water. Record your observations in a tabular format. Explain any differences in your observations of the cup in cold and hot water.

Step 2 Using any of the materials listed above, devise a way to submerge a tissue or paper towel under water without getting it wet. Briefly outline your procedure and draw a labeled picture to illustrate what you observed. What kept your tissue from becoming wet?

Step 3 Make a hole in the bottom of the paper cup with the push pin or nail. Repeat Step 2 with the paper cup. Record your observations of the water and tissues. Briefly explain your observations and draw a labeled picture to illustrate what occurred.

Challenge

What are some properties of air in an upside-down cup submerged in water?

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Concepts

properties of matter (volume), Charles' law

Expected Student Responses to Exploration

Step 1 When the inverted cup is submerged in cold water, the water usually rises less than 1 cm inside the cup. (See Figure 1). In hot water, a large bubble of air actually protrudes below the rim of the cup and some small bubbles may be seen escaping. Repeated submersions produce the same results until the cold water warms and the hot water cools to room temperature. The water will then remain level with the rim of the cup.

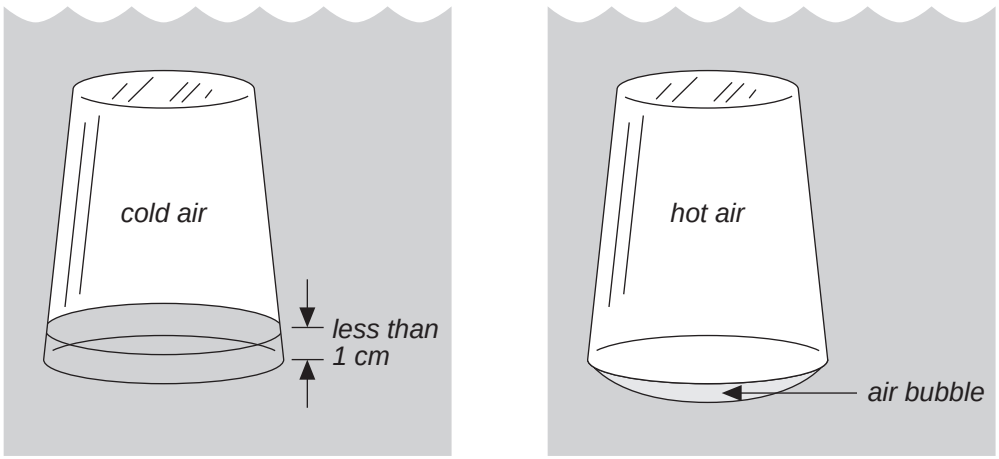

Figure 1: When air in the cup is cooled (a), water can enter around the rim. When the air is warmed (b), the air expands out of the cup in a bubble.

Because the air trapped inside the inverted cup is matter, it occupies volume. Thus, the water cannot enter the cup. Cooling the trapped air causes its volume to decrease (Charles' law), allowing space for the water to enter the cup. Conversely, heating the trapped air causes its volume to increase and the air to protrude from the cup.

Another factor to consider is the vapor pressure of the water. Although the water that is visible is in the liquid state, some water particles go into the gas state—the higher the temperature, the greater the number of particles. Thus, the greater number of gaseous water particles from hot water (becoming trapped in the cup) will "expand the bubble."

Step 2 (a) The suggested method involves pushing a crumpled tissue into the bottom of a cup so that the tissue does not fall out when the cup is inverted. Invert the cup containing the tissue and push it straight down into the container of water. (See Figure 2.)

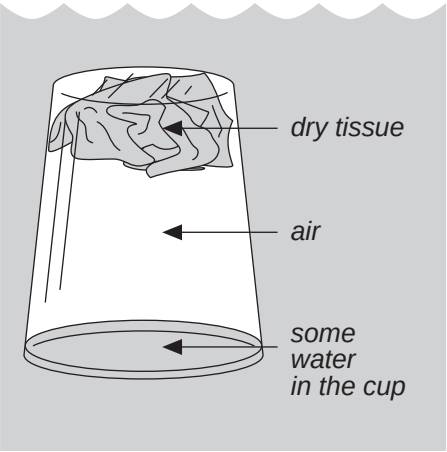

Figure 2: The tissue in the cup stays dry.

(b) The tissue does not get wet because the trapped air keeps the water out of the cup.

Step 3 (a) When the cup has a hole in the bottom, water fills the inverted cup and the tissue becomes wet.

(b) Since air is less dense than water, it is expected to rise above water; the hole allows it to do so. As the air escapes, water enters the cup from below, filling the space previously occupied by the air and wetting the tissue.

Expected Student Answer to Challenge

The air in an inverted cup submerged in water occupies volume, thus keeping out water. The air contracts when cooled and expands when heated.

Acknowledgment

This activity was developed as a part of the NSF-funded “General Chemistry: Discovery-Based Advances for the Two-Year College Chemistry Curriculum” project, grant #DUE-9354378.