That's Polarizing: Chemical Properties of Water

Estimated Time: 60 minutes (or 20 minutes/activity)

SUMMARY
Water exhibits unique properties critical to life. These properties can be attributed to its polar nature and ability to form bonds. Throughout this activity you will see the various properties of water. Choose to do all three activities or select a few favorites!

WHAT YOU'LL LEARN

- Define polarity and consider its relevance to the properties of water.
- Compare the chemical structures of water and isopropyl (rubbing) alcohol through various experiments.
- Experimental design (including independent/dependent variables, hypotheses, data collection etc.)

Materials Used	**Resources Used**
• Tap water • Rubbing alcohol • Pennies • Pipettes or eye dropper • Dish soap • Paper towels • Solutes (such as sugar, baking soda, salt, and vegetable oil) • Ice cubes	• How Polarity Makes Water Behave Strangely by Christina Kleinberg (simplistic explanation) • Properties of Water - Crash Course (includes some important applications for life) • Wondrous Water • Properties of Water Lab

WHAT TO DO

1. Begin a conversation with your student on the chemical structure of water. Depending on their educational level, the conversation can be rich in chemical concepts or more simplistic. Ultimately, all of water's properties boil down (pun intended) to its polar nature and ability to form hydrogen bonds between water molecules. See TIPS below for ideas.
2. Continue the conversation as you begin experimenting with water's properties. This lab includes three different activities that display some of water's properties: cohesion, solvation, and density.

ACTIVITY 1: Droplets on a Penny
Useful chemical information:
Water is a **polar** molecule; the oxygen atom exhibits a **slight negative charge** while the hydrogen atoms exhibit **slight positive charges**. When many water molecules are together, as in a droplet of water, **hydrogen bonds** form. This **intermolecular force** (between molecules) occurs when the slightly positive hydrogens are temporarily attracted to the slightly negative oxygens of different water molecules. Although each bond is temporary, so

many of them are happening at once and collectively are a powerful force. In this activity, these hydrogen bonds explain **cohesion**, where water molecules "stick" together and resist overflowing the penny. The addition of soap inhibits the formation of hydrogen bonds by surrounding water molecules; the presence of soap prevents water molecules from interacting with each other and forming hydrogen bonds. Isopropyl alcohol molecules have a small polar region, but overall, they are a nonpolar molecule. Its intermolecular forces do not include hydrogen bonds and are much weaker than those of water, therefore isopropyl alcohol molecules cannot "stick" to each other as in cohesion.

1. Create a hypothesis to be tested by the experiment. Include the independent variables (liquid used) and dependent variables (number of drops). Which liquid will hold the most drops on a penny? The least?
2. Set up six pennies on a bed of paper towels. Label three small cups with tap water, tap water with 3 drops of dish soap, and rubbing alcohol; add the respective substances to each cup. Each cup will not need more than a ¼ cup of liquid. Remember to use pipettes/droppers designated for each liquid so no cross contamination occurs.
3. For each trial, the liquid will be administered to each penny and the number of drops that can be held by the penny before the liquid overflows is measured. When dropping liquid on top of each penny, ensure the dropper is upright and over the center of the penny (the logic behind this creates an opportunity to discuss controlled experiments and their importance to reliable and valid data!) Record the drops administered for two trials per liquid.
4. Conclude the experiment with a discussion of the results. Did they support or refute the hypothesis? How do the properties of water, soap, and isopropyl alcohol help explain the results? Were any of the results surprising?

ACTIVITY 2: Disappearing Solutes

Useful chemical information: Water is a polar molecule while isopropyl alcohol is nonpolar. When a solute (sugar, Kool-aid, etc.) dissolves in a solvent (such as water, coffee, etc.), it is because the solute and solvent have similar properties. The polarity of water is complementary to the properties of sugar, salt, and baking soda; on the other hand, it is much more difficult to dissolve the same amount of solute into isopropyl alcohol due to its nonpolar nature. However, oil, which is entirely nonpolar is not compatible with water, but can be in an alcohol solution. See these properties in action by investigating which solutes can dissolve and which will not.

1. Create a hypothesis to be tested by the experiment. Include the independent variables (solvent/solute combination) and dependent variables (did it dissolve?). Which solutes will water dissolve? Which solutes will alcohol dissolve?
2. Set up four glasses of water and four glasses of isopropyl alcohol; use approximately ½ cup of liquid for each trial. Test each solute (sugar, salt, baking soda, and oil) one at a time using a teaspoon of each solute. Record observations in an organized manner, including if the solute dissolved.
3. Conclude the experiment with a discussion of the results. Did they support or refute the hypothesis? How do the properties of water and isopropyl alcohol help explain the results? Were any of the results surprising?

ACTIVITY 3: Will it Float?

Useful chemical information: Objects float because they are less dense than the liquid they are submersed in. Density refers to the amount of mass per unit of volume. Humans float on water (generally!) because much of our body is full of air, fats, and other less dense matter. The water in a pool is below the air around the pool because air is less dense than water. Although ice cubes and water are the same substance, ice is less dense than liquid water. Why? The hydrogen bonds force water molecules to remain a specific distance apart near freezing temperature; thus, lattice structure leaves space between water molecules. As a result, the same mass of ice takes up more volume than liquid water and is described as less dense. On the other hand, isopropyl alcohol is less dense than ice. This means that while ice floats on liquid water, it will sink in a container of rubbing alcohol!

1. Create a hypothesis to be tested by the experiment. Include the independent variables (liquid) and dependent variables (did the ice float?).
2. Set up two glasses with relatively equal volumes each of water and isopropyl alcohol.
3. To each glass, add one to two ice cubes. Record observations of the ice cubes in each liquid; which liquid allowed ice to float?
4. Conclude the experiment with a discussion of the results. Did they support or refute the hypothesis? How do the properties of water and isopropyl alcohol help explain the results? Were any of the results surprising?

TIPS

- A more basic explanation of water's chemical properties would include the three atoms that make it up, the little electrons floating around the molecule, and oxygen's strong pull on the electrons which causes polarity. See the TED-Ed and Crash Course videos to gauge the parent/student understanding on the properties of water. Also consider the "useful chemical information" sections for each activity.