**Getting a Grip on Hydrogen Bonds**

*Throughout this activity, one person will be in charge of “water” and one person will be in charge of “oil”. Be sure to keep the equipment used for each liquid separate. In other words, do not use the same pipette or capillary tube for both liquids.*

STEP 1. The “water” person should fill their small beaker about half full with the colored water solution provided by the instructor. The “oil” person should fill their small beaker about half full with vegetable oil provided by the instructor.

STEP 2. Place one or two drop of each liquid on the wax paper (drops not touching each other). OBSERVE. Do the drops of oil look the same as the drops of water? In particular, DESCRIBE the shape of each drop.

STEP 3. Place a capillary tube adjacent to one of the water drops. OBSERVE and DESCRIBE. Do the same with a second capillary tube and the oil drops. Again, OBSERVE and DESCRIBE.

STEP 4. Rip or cut the paper towel into two pieces of identical size. Use a permanent marker (such as a sharpie) to draw a line across the paper towel about 2 cm above the edge. Place the edge of the paper towels into each cup of liquid. OBSERVE and DESCRIBE what you see. Do both liquids behave in the same way? If not, DESCRIBE the difference.

 Paper towel🡪

 marker line 🡪

Put this end into the liquid 🡪

STEP 5. Pour the water into one of the small plastic cups until it comes very near the top. Do the same with the oil in a second plastic cup. Using the pipette, continue to add drops to the cups. Can you fill the cups “over” the edges without spilling? OBSERVE and DESCRIBE. Is there any way you can measure what you are seeing?

**Results:**

 This chart can be drawn on the board and completed as a class, or given to the students on paper to complete in their groups, or both. I have supplied examples of likely responses here in red.

|  |  |  |
| --- | --- | --- |
|  | **Water** | **Oil** |
| Drops of the liquid | Spherical, high relief | Some spherical but others irregular in shape, low relief |
| Capillary tubes | Water rose up tube higher | Oil rose up tube a little but not as high |
| Paper towel | Water climbed up higher and marker did not run | Oil did not climb as high and marker ran |
| Filling plastic cup | Water could be piled higher than oil above the lid | Oil could pile above the lid but not as high as the water |

**Discussion:**

Following the activity the instructor can now introduce the concepts of polarity, hydrogen bonds, cohesion, adhesion, and surface tension.

**Key Concepts:**

* Water molecules are ***polar***, that is each H2O molecule has a slight + and - charge. This is because the structure of a water molecule results in one end of the molecule having an excess negative charge and the other end having an excess negative charge.
* A special kind of bond, called a ***hydrogen bond***, exists between water molecules where the + side of one molecule is attracted to the – end of another molecule.
* ***Hydrogen bonds*** thus help to hold water molecules together. Each water molecule can form a maximum of four hydrogen bonds with other water molecules.
* As a result of the presence of hydrogen bonds, water has some unique properties when compared to most other liquids. These include cohesion, resistance to temperature change, and expansion during freezing. (Note that this activity only focuses on cohesive forces and related phenomena, but this is a good launching activity to then cover the unique heat capacity, density, etc. of water).

**Useful Vocabulary:**

 adhesion: electrical attraction between water molecules and other substances as the result of hydrogen bonds, such as on a glass or clinging to a spider web or leaf



 capillary action: ability of water to flow in a narrow spaces without gravity or other forces. It can be thought of as the result of both adhesion (water adheres to container and causes an upward force, creating a meniscus) and cohesion (water to water). **See diagram at right** (from hyperphysics.phy-astr.gsu.edu/hbase/surten2.html)

 cohesion: electrical attraction between water molecules as the result of hydrogen bonds; this causes water to bead up and gives water a *surface tension* that allows it to be filled above the brim of a container

 hydrogen bond: a type of chemical bond that forms *between* water molecules (perhaps contrast with covalent bonds) due the attraction between the positively and negatively charged sides of water molecules

 meniscus: the curving upwards of water at the walls of a container as a result of surface tension. Because surface tension acts to hold the surface intact, the entire liquid surface is dragged upwards. **Diagram at right** from crescentok.com/staff/jaskew/ isr/tigerchem/introduction/liquidkey.htm

 polarity: the separation of electrical charges; water molecules are polar, thus they have a slight excess negative (–) charge on one end and a slight excess positive (+) charge on the other

 surface tension: this is a property of water at its interface with air that gives water a thin “skin”. Water molecules below the surface form hydrogen bonds between other water molecules in all directions. The water molecules at the surface do not have neighboring water molecules above them. The result is a strong attractive force between the surface layer and the water molecules below the surface. It is the reason that water beads and also why some bugs can “walk” on water. **See diagram at right where arrows indicated attractive forces** (from craigssenseofwonder. wordpress.com/tag/phase-diagram/).

**Extensions:**

 You can nicely illustrate the concept of ***immiscible solutions*** by having students put one or two drops of food coloring into their plastic cup that holds the oil (have the cup only about half-filled with oil). The food coloring will sink and remain as spherical drops that do not mix with the oil. Student can then add a bit of water. The water will sink and, upon contact with the food coloring drops, change color as these two “miscible” liquids mix. They may need to stir with a toothpick or something to get the color drops into contact with the water. Another neat activity is to challenge them to “color” the oil with the food coloring. They will discover that despite their best efforts, the oil and coloring will not mix. The food coloring will simply be broken up into smaller and smaller immiscible droplets.

 The polarity of water can also be demonstrated if you are in a room where a stream of water can run from a faucet in clear view of the students. Rub an inflated balloon on your hair (doesn’t work on humid days) and hold the balloon close the water stream. The water stream will be deflected away from the balloon. The electrons that were transferred from your hair to the balloon are pushing away the negatively charged ends of the water molecules.