Subject Area(s) **Chemistry, physical science, problem solving**

Associated Unit

Associated Lesson

Activity Title **Water Powered Boats**

Grade Level 11 (9-12)

Time Required **30 minutes**

Group Size 28

Expendable Cost per Group US$1

Summary

In this activity students learn about properties of water using boats that they design from an index card. When an index card is placed in a basin of water and a drop of liquid soap is placed near the card it moves away from the drop. This demonstrates hydrogen bonding and the activity allows students to examine many different parameters of the system to test their own ideas about why the boat moves. Soap is a surfactant and breaks down the surface tension of the water. When there is an imbalance of forces as stated by Newton's Laws there must be motion. Students design boats test hypothesis and learn about very fundamental chemistry.

Engineering Connection

The properties of water are integral to many engineering problems. Fluid dynamics are incorporated into every chemical plant and how water behaves on the macro scale can be predicted based on its molecular behavior. Surfactants and lubricants are essential tools in engineering and soap is a very basic introduction to this chemical tool.

Engineering Category

Choose the category that best describes this activity's amount/depth of engineering content: (#1) relates science concept to engineering, (#3) provides engineering analysis or partial design

Keywords

hydrogen bonding, properties of water, surface tension, surfactant

Educational Standards

State science: Chapter 112. Texas Essential Knowledge and Skills for Science, Amended 2009. Subchapter C. High School. Chemistry. (10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to: (A) describe the unique role of water in chemical and biological systems.

Pre-Requisite Knowledge

Previous study of elements and the periodic table specifically electronegativity of oxygen and hydrogen, as well as a discussion of bonding is useful, but with brief explanation not entirely necessary.

Learning Objectives

After this activity, students should be able to:

- **Define: hydrogen bond, surface tension, surfactant, electronegativity, covalent bond**
- **Relate behavior of water in bulk to its molecular properties**

- **Describe the importance of water's unique characteristics**

Materials List

To share with the entire class:

- 1 basin for holding water, preferably clear so that students can observe from multiple angles.
- 1 package of notecards
- 1 pair of scissors
- 1 bottle of liquid soap (Dawn)

Introduction / Motivation

What is so special about water? The human body is about 60% water. It covers almost 70% of the earth's surface. We hear in the news when ice is discovered on Mars or possible signs of water are seen on distant planets because it is so integral to life as we know it we think it must be integral to life that we don't know. You drink it, cook with it, pour it on plants, we even put boats in it and float on it for fun. So we have a 'boat' here (show them an example boat). I cut this from a regular note card. What will happen when I put it in the water? (Possible answers: sink, float. Ask them why. Place it gently in the basin. The boat should sit on top of the water and not move very much) Why isn't the boat sinking? (Possible answers: it is less dense than water. Push it down and once it breaks the surface it should sink) Why does it sink? (Answer: you pushed it) It isn't any more dense now than before I didn't change the density by pushing on it I just pushed it under the surface. Let's get a new boat. (Put the new boat in gently. Brandish a bottle of liquid soap) What is this? (Answer: soap) What do we use soap for? (Answers will vary) What will happen if I place a drop of soap in the hole in the boat? (Answers will vary, ask why they think what they do. Place a drop of soap in the hole in the boat. Ask students to tell you what they see). Why did the boat move forward? What did the soap do? We are going to make our own boats to try and figure out what is going on.

Vocabulary / Definitions

Word	Definition
hydrogen bond	The attraction of a hydrogen covalently bonded to on electronegative atom (F,O,N,Cl) to another electronegative atom which it is not covalently bound.
surface tension	The attraction of molecules on the surface to each other.
electronegativity	The ability of an atom to attract electrons.
covalent bond	A bond between two elements in which electrons are shared.
Surfactant	Surface active agent that reduces surface tension.

Procedure

Background

Hydrogen bonding is the cause of many properties of water. It increases surface tension, heat capacity, viscosity, cohesion, and density. Because of water's large dipole moment (imbalance in electronegativity within the molecule) it can solvate other polar compounds as well as ionic compounds. Soap is a surfactant that has a hydrophilic (water loving) head and a hydrophobic (water fearing) tail. This means soap cannot only mix with water, but also non-polar compounds such as oil and dirt. This is the reason we use soap, to attach to the dirt so that the water can carry it away. Without soap to break up the surface tension, the water would bead up on our skin and roll off without picking up any dirt. Soap hydrogen bonds to water molecules preventing them from hydrogen bonding to each other causing them to be more disordered and no longer able to

maintain surface tension. When the surface tension is removed from one side of the boat the force is still acting on the opposite side of the boat. This imbalance of forces causes the boat to move. Hydrogen bonding is responsible for more than holding the boat above water. The surface tension of water is very strong because of these hydrogen bonds allowing the boat to float. The high surface tension is also visible in the very low vapor pressure of water. Because the hydrogen bonds hold the water molecules together it is not nearly as volatile as other molecules of similar size and weight. The heat capacity of water (amount of temperature change for amount of energy absorbed) is also very high because of hydrogen bonds because all the bonds must be broken before any physical change can occur which takes energy.

Before the Activity

- Cut up several note cards in the shape shown.
- Fill the basin with water
- Test 1 of your boats by placing it in the water and putting 1 drop of soap behind it

With the Students

1. Have students now cut up their own boats and encourage any design changes.
2. Once all the students have been allowed to test their designs ask if they think the shape of the boat matters.
3. Have them record their observations and make a decision about how the shape effects the motion of the boat
4. Ask for suggestions on what is happening to the boat when the soap is added.
5. Lead a discussion on the forces pulling on the boat. Students should rationalize that the soap is disrupting these forces.
6. Present the image of how water hydrogen bonds. Also give students the structure of sodium lauryl sulfate and ask how this may prevent the 2 water molecules from hydrogen bonding.
7. Have students draw how they think soap disrupts hydrogen bond and have students present their ideas to the class.
8. Ask students to give examples of how hydrogen bonding affects their every-day life and emphasize the most important after they have brainstormed.
9. Explain how hydrogen bonding affects all properties of water such as density, specific heat, and vapor pressure. And how these must be considered when designing chemical plants and how surfactants can be used to change these properties.

Image #1 centered; #2 centered; #3 centered

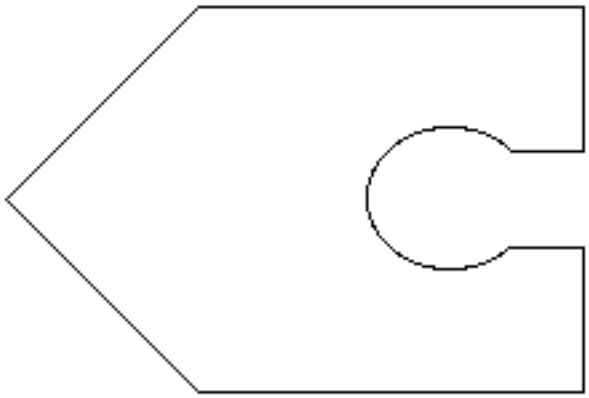

Figure 1

ADA Description: Image shows example shape for boat design

Caption: Figure 1: Example shape for note card boat.

Image file name: boat_shape.jpg

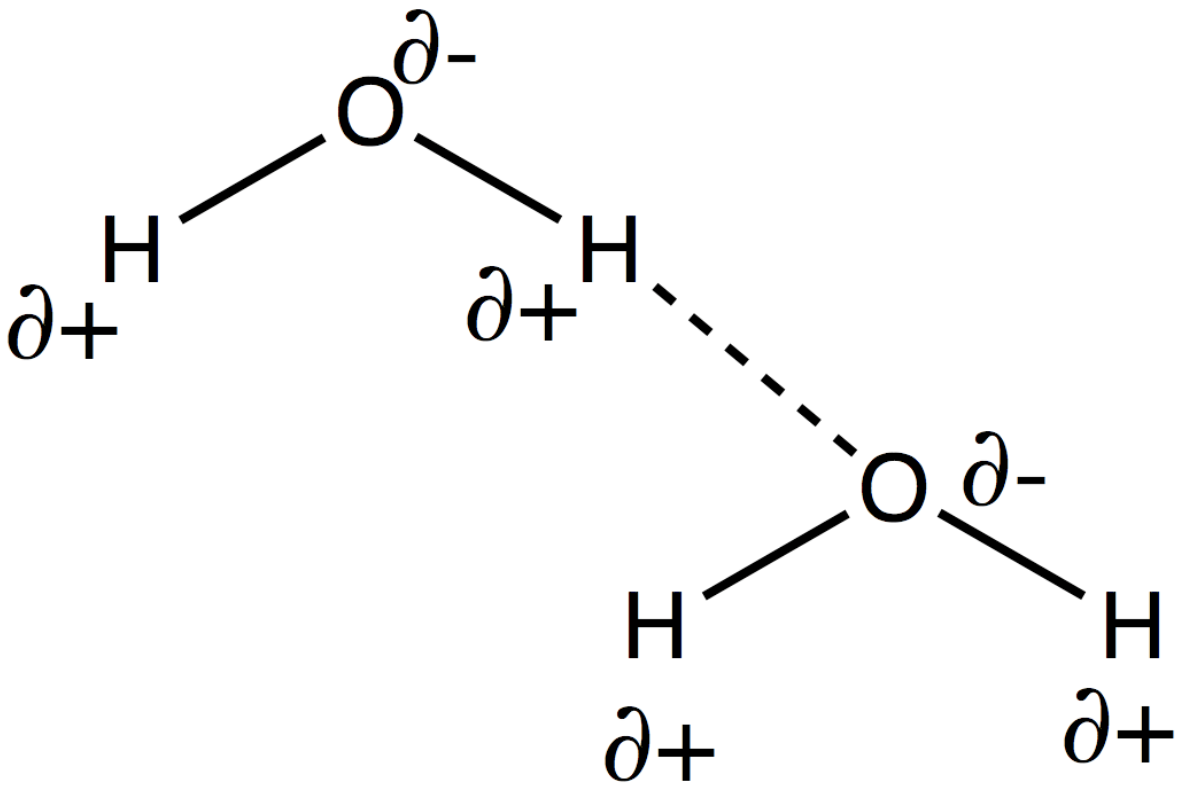

Figure 2

ADA Description: Image shows two molecules of water and the attraction between the partially negatively charged oxygen and the partially positively charged hydrogen of another molecule

Caption: Figure 2 shows how two molecules of water hydrogen bond to each other.

Image file name: hydrogen_bond.jpg

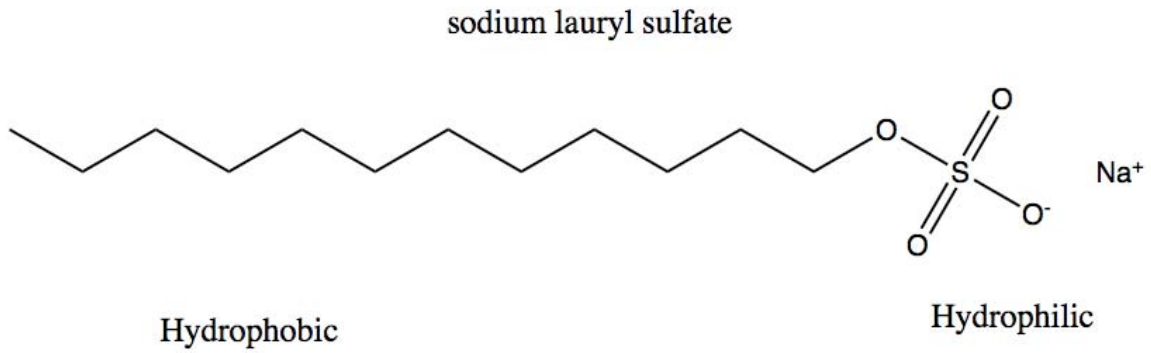

Figure 3

ADA Description: Image shows the structure of sodium lauryl sulfate and labels the hydrophilic and hydrophobic regions.

Caption: Figure 3: Sodium lauryl sulfate the surfactant present in many soaps.

Image file name: soap.jpg

Troubleshooting Tips

If the boat no longer moves upon addition of soap it is possible that you must change the water. The soap will diffuse through the water and reduce the surface tension of the whole system after being added. It is important to thoroughly rinse the container to remove any residual soap. Boats may curl or sink, just have several precut to save time.

Investigating Questions

How would life be different without hydrogen bonding?

Assessment

Pre-Activity Assessment

Pre-activity assessment comes from their response to questions before the activity. If they are struggling with those questions the concepts must be explained more thoroughly before moving on to the activity.

Activity Embedded Assessment

Activity embedded assessment comes from the students themselves. They lead the discussion and only their progress will move the activity along.

Post-Activity Assessment

Collecting their observations and conclusions from the activity to check for understanding will allow you to gauge what they have learned from the activity.

Activity Extensions

A heat capacity lab would be a good extension to teach energy transfer as well as support your statements that water has a high heat capacity.

Supporting Program

GK-12 Program, College of Engineering University of Houston

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