Water Model Booklet
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Water Model Key

Carbon (C)

Ethane (C₂H₆)

Hydrogen (H)

Water (H₂O)

Oxygen (O)

Sodium (Na)

Salt (NaCl)

Chloride (Cl)

Hydroxyl Group (-OH)

Ethanol (C₂H₆O)

Water Cup
Activity 1: Bond Types

The magnets in these water molecule models simulate the intermolecular force of two polar water molecules forming a hydrogen bond. The bonds between the hydrogen atoms and the oxygen atom are covalent bonds. These are intramolecular bonds. Ionic bonds are formed between the sodium and chloride ions. This is an intramolecular bond.

Goal

Compare the relative strengths of a covalent bond, ionic bond, and a hydrogen bond using the models.

Procedure

In this activity you will identify the different bonds represented in this model and assess the model’s ability to imitate bond strengths.

1. Set the ethane, sodium chloride, and two connected water molecules on the table.
2. Carefully separate the two carbon atoms (grey) in the ethane molecule. Which bond does this represent?
3. Remove the sodium (blue) from the chlorine (green). Which type of bond does this represent?
4. Separate one water molecule from the other water molecule. Which bond does this represent?

Analysis

1. In your lab notebook or on a separate page, identify the different bond types being represented.
2. Rank the relative difficulty of separation for each bond type.

Conclusion

1. Summarize what you’ve learned about bond strength.
2. Describe whether you think this is a good model for bond types and why.
# Bonding Atoms and Molecules

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intramolecular Bonds</strong> (within molecules)</td>
<td></td>
</tr>
<tr>
<td>ethane ($C_2H_6$)</td>
<td>A <strong>covalent bond</strong> is formed when two atoms share two electrons. These shared electrons move around the nucleuses of both atoms. As a result, a covalent bond is an <em>intramolecular</em> bond, or a bond that occurs within one molecule. Covalent bonds can be either polar (which have partially charged atoms) or nonpolar (without charged atoms) depending on whether the electrons are shared equally between the two atoms.</td>
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</table>

| Salt (NaCl) | An **ionic bond** is the complete transfer of an electron between two atoms resulting in one positively and one negatively charged atom. Ionic bonds are *intramolecular* bonds within one molecule. **Ions** are charged atoms that have gained or lost electrons as a result of an ionic bond. |

| **Intermolecular** (between molecules) |
| Hydrogen bonds between H$_2$O | A **hydrogen bond** is an *intermolecular* bond, which occur between molecules. A hydrogen bond occurs when a positively charged hydrogen atom interacts with a negatively charged fluorine, nitrogen, or oxygen atom in a second molecule. A hydrogen bond is about 1/20 as strong as a covalent bond. |
Activity 2: Polarity

The water molecule models have been embedded with magnets to help simulate what the (+) and (-) charges feel like as they interact with other polar molecules. There are two magnets embedded in the oxygen at 105° apart. These represent the two partial negatives. Each hydrogen in the water model also has one magnet representing the partial positive.

Goal
Understand the difference between polar and non-polar molecules.

Procedure
In this activity you will demonstrate how these models represent interactions between polar and nonpolar molecules.

Polar Molecules
1. Set a water molecule on the table.
2. Bring the hydrogen of a second water molecule closer to the oxygen of the first water molecule and observe any interactions.
3. Set a water molecule on the table.
4. Bring the hydrogen of a second water molecule closer to the hydrogen of the first water molecule and observe any interactions.
5. Set a water molecule on the table.
6. Bring the oxygen of a second water molecule closer to the oxygen of the first water molecule and observe any interactions.

Non-polar Molecules
7. Set an ethane molecule on the table.
8. Bring a water molecule closer and closer to the ethane molecule and observe interactions.

Analysis
1. Compare the interactions between the following:
   a. Hydrogen and oxygen of different water molecules
   b. Hydrogen and hydrogen of different water molecules
   c. Oxygen and oxygen of different water molecules
2. Describe the difference in the interaction between water and water vs. ethane and water.

Conclusion
1. Summarize what you’ve learned about how polar and non-polar molecules interact.
2. Describe whether you think this is a good model for polar and non polar molecules and why.
3. Describe a real-world example of polarity.
**General Info on Polarity**

Polarity refers to the partial positive charge (+) and partial negative charge (-) that a molecule has when electrons are unequally shared between two or more atoms. Molecules that have partial charges are polar molecules. Water molecules are polar.

In a water molecule, each hydrogen atom has a partial positive charge and the oxygen atom has two partial negative charges.

Some molecules do not have unequal regions of charges and therefore do not interact with polar molecules. These are nonpolar molecules. Oil and ethane are examples of a liquid and a gas composed of nonpolar molecules.
Like other compounds, water can convert between solid, liquid, and gas phases. The remarkable property of water is that it is a liquid over a very large temperature range.

In this activity you will use the water molecule models to represent water in its various states of matter. You will also need a ruler to model how “volume” changes between each state. During the activity discuss with your partner the strengths and weaknesses of these models for each state.

**Goal**
To understand the differences between water in its various states (solid, liquid, gas).

**Procedure**
In this activity you will use the water molecule models to represent water in its various states of matter. You will also need a ruler to model how “volume” changes between each state. During the activity discuss with your partner the strengths and weaknesses of these models for each state.

**Gas Phase**
*In the gas state individual water molecules are moving too fast and are too far apart to form hydrogen bonds.*

1. Using your 12 water molecule models create a representation of water molecules in the gas phase (also known as water vapor).
2. Record the approximate “volume” of your water molecules in the gas phase by using a ruler to measure the height, length, and width.

**Liquid Phase**
*In liquid water, the hydrogen bonds between water molecules are very short-lived. They are constantly forming, breaking, and reforming between other molecules.*

3. Using your 12 water molecule models create a “snap-shot” of what water molecules might look like in liquid state.
4. Record the number of hydrogen bonds (represented by two water molecules held together by the magnets).
5. Record the approximate “volume” of your water molecules in the liquid phase by using a ruler to measure height, length, and width.
Activity 3: States of Matter Continued

**Solid Phase**

*In ice, the hydrogen bonds between water molecules are more stable and longer-lived. Scientists have described 12 different structures of ice. Using the pictures below as a guide, create the hexagonal structure of water molecules in ice.*

1.  
2.  
3.  
4.  
5.  

6. Create the hexagonal ice structure by joining 2 rings of 6-water molecular. Use the pictures above to help.

7. Record the number of hydrogen bonds (represented by two water molecules held together by the magnets).

8. Record the approximate “volume” of your water molecules in the solid phase by using a ruler to measure height, length, and width.

9. Test the resistance created by the hexagonal structure. Have you and your partner gently pull on a water molecule at opposite sides of the structure. Gently press the structure down on the table.

**Analysis**

1. Compare the volumes of the various states of matter represented by the models.

2. The wiggling and pressing of water molecules represents the addition of energy.
   a. Which step required the most energy?
   b. Which state of matter of water has the least number of hydrogen bonds?

**Conclusion**

1. Summarize what you’ve learned about water in different states of matter.

2. Describe whether you think this is a good model for showing the states of matter and why.

3. Earth is often referred to as being in the “Goldilocks zone” because the temperature is just right for water to exist naturally in all three states. Describe how this might be important to life.
Activity 4: Solubility

Water is often called the “universal solvent” because it dissolves more substances than any other liquid. This is an important aspect of life on earth. Whether in the ground or through our bodies, water is able to carry along many different valuable chemicals, minerals, and nutrients.

Because of their structure and composition, water molecules have a polar arrangement making water an excellent solvent. This allows water to be attracted to other polar molecules forming hydrogen bonds. This attraction can even disrupt the attractive forces in ionic compounds such as salt.

Goal Understand the difference of solubility between polar and nonpolar molecules, and ionic compounds.

Procedure
In this activity you will demonstrate the differences of solubility between nonpolar molecules and ionic compounds when dissolved in a polar solvent using the models provided in the water kit cup.

Nonpolar Molecules
1. Place ethane on the table.
2. Connect 3 water molecules to ethane, not to each other.
3. Flip the cup over the molecules.
4. Add 2 water molecules into the cup.
5. Slide the cup vigorously back and forth on the table to mix the molecules.
6. Lift the cup and make observations about the interaction between the water and ethane.

Ionic Compounds
1. Place sodium chloride on the table.
2. Connect 3 water molecules to sodium.
3. Connect 3 water molecules to chloride.
4. Hold the chloride on the table and push a water molecule between sodium and chloride. Leave the water molecule connected the sodium and chloride.
5. Flip the cup over the molecules.
6. Slide the cup vigorously back and forth on the table to mix the molecules.
7. Lift the cup and make observations about the interaction between the water, sodium and chloride.

Analysis
1. Describe the difference between connecting water to ethane and water to sodium chloride.
2. Describe which part of the water molecule is connected to sodium and which part to chloride.
3. Sodium chloride dissolves better in water than ethane dissolves in water. Give evidence from the activity that supports this statement.
4. Solubility is how well a solute dissolves in a solvent. Explain whether the ethane or sodium chloride (solutes) had better solubility in water (solvent).

Conclusion
1. Summarize what you’ve learned about solubility.
2. Describe whether you think this is a good model for dissolving salt.
Activity 5: Cohesion and Adhesion

Cohesion is the attraction between molecules of the same substance. Adhesion is the attraction between unlike molecules. Adhesion and cohesion are intermolecular forces between two molecules. These forces are only called hydrogen bonds when a hydrogen atom is attracted to a fluorine, nitrogen, or oxygen atom. These properties in water are essential for life on earth and is one of the forces that allows plants to pull water upward from their root to the leaves.

Goal
Understand the differences between cohesion and adhesion of water.

Procedure
Cohesion
1. Connect 5 water molecules to each other in a line. This represents cohesion.

Adhesion
2. Without pulling apart a water molecule, do the following:
   a. Find 3 surfaces in the classroom that the hydrogen will connect to. This represents adhesion.
   b. Find 3 surfaces in the classroom that the hydrogen will NOT connect to.

Analysis
1. In your lab notebook or on a separate page, identify the different bond types being represented.
2. Rank the relative difficulty of separation for each bond type.

Conclusion
1. Summarize what you’ve learned about cohesion and adhesion.
2. Describe whether you think this is a good model for cohesion and adhesion and why.
3. Describe a real-world example of adhesion and/or cohesion
Activity 6: Surface Tension

Surface tension is due to the cohesion between molecules at the surface of a liquid. In a liquid, molecules are pulled in all directions intermolecular forces. At the surface of a liquid, the molecules are only pulled downward and toward the sides. Surface tension is the amount of energy required to stretch or increase the surface of a liquid by a unit of measure.

Procedure
1. Flip the cup over 12 water molecules.
2. Slide the cup vigorously back and forth on the table to mix the molecules.
3. Then slowly remove the cup, leaving the water molecules on the table.
4. Carefully balance a pencil on the water molecules.

Analysis
1. What property of water allows the pencil to balance on top of the water molecules?
2. A pencil has a mass of 5 grams. Predict the outcome if a filled water bottle with a mass of 1000 grams was used in step 4. Explain your answer in terms of what happens to the hydrogen bonds.

Conclusion
1. Summarize what you’ve learned about surface tension.
2. Describe whether you think this is a good model for surface tension and describe areas in which it fails.
3. Describe a real-world example of surface tension.
Activity 7: Capillary Action

Capillary action is the spontaneous rising of a liquid in a capillary (small diameter) tube. Capillary action of water in plants is possible by forces like adhesion and cohesion. Capillary action is also responsible for moving liquid through your tear ducts to keep your eyes wet. Even the small pores of a sponge act as capillaries.

Procedure

1. Place three water molecules on a flat surface so that they can connect to something metallic, such as a file cabinet. Ensure that they are not connected to each other.
2. Attach two water molecules between the previous three so they form a chain. Not all must connect to the metallic surface.
3. Carefully connect all but one of the remaining water molecules to the chain so that they stick out from the surface as far as they can without falling.
4. Place the remaining water molecule on the lowest water molecule.
5. Remove the molecule that was connected in step 4 and connect it to the next closest molecule.
6. Repeat step 5 while moving the water molecule upwards until it reaches the highest point possible.

Analysis

1. Compare the location of the highest water molecule in step 4 to the highest water molecules in step 6.
2. Five more water molecules were added by following steps 4 to 6. Predict the location of the highest water molecule.

Conclusion

1. Summarize what you’ve learned about capillary action.
2. Describe whether you think this is a good model for capillary action and describe areas in which it fails.
3. Using the pictures below, label a point at which molecules are experiencing adhesion, and a point in which they are experiencing cohesion.
Extension 1: Testing Surface Tension

The surface tension of water is created by the hydrogen bonds between each molecule of water. Below is the ball-and-stick molecules for water and isopropyl alcohol. Predict how isopropyl alcohol’s surface tension may differ from water. Then test it.

Materials
- 70% Isopropyl Alcohol
- 35% Isopropyl Alcohol
- 4”x 2” piece of Parafilm
- Water
- Plastic Transfer Pipet

Procedure
1. Place a piece of Parafilm on your desk. Wetting the desk will help the Parafilm to lay flat.
2. Using your plastic transfer pipet place a 0.5mL drop of each liquid (water, 35% isopropyl alcohol, 70% isopropyl alcohol) on your Parafilm. Make sure you have three separate drops (no mixing).
3. Record the relative height of each liquid by drawing a profile of each drop in your lab journal.

1. Discuss with your partner what a drop of soapy water might look like. Consider what soap does, hydrogen bonding, and surface tension.
2. Test it! Place a 0.5mL drop of soapy water on your Parafilm. If you are out of room on your Parafilm, make sure you’ve recorded the heights and use a paper towel to clean it off.

A molecule of soap
Extension 2: Demonstrate Capillary Action

Capillary action is a force that occurs naturally in nature. However, new biotechnology is developing ways to harness capillary action to create cheap portable tools that don’t require electricity.¹ In this extension activity we will demonstrate capillary action.

Materials

- Paper Clip
- Petri dish
- Rubber band
- Colored solution
- 2 Glass slides
- Other liquids for testing

Procedure

1. Use the rubber band to hold together the 2 slides length-wise. The space between the 2 slides will work as a capillary.
2. Carefully place your paper clip between the slides. This will create a variable width for your “capillary” across the slides.
3. Fill your petri dish with colored solution.
4. Carefully place one end of the slides into the solution on the petri dish.
5. Record your observations including how the liquid moves up the “capillary”.
6. Consider how this would look with other liquids like alcohol, oil, or soapy water.

¹ http://www.medgadget.com/2015/04/colored-pencils-developed-easy-chemical-based-diagnostic-testing.html
http://www.arvindguptatoys.com/toys/Capillaryaction.html
Extension 3: Design Capillary Action

Capillary action is a force that occurs naturally in nature. However, new biotechnology is developing ways to harness capillary action to create cheap portable tools that don’t require electricity.¹ In this extension activity, use the materials available in the Capillary Action Tool Kit to demonstrate capillary action. Try to make a visual that shows how density, viscosity, and diameter affect capillary action. Be creative!

Materials

- Paper Clip
- Petri dishes
- Straws
- Rubber bands
- Colored solution
- Oil
- 2 Glass slides
- Blotting paper
- Other liquids for testing

Procedure

1. Use the materials provided to design your own visual resource for explaining capillary action.
2. Get creative!
3. Manipulate your design to show a variable like density, viscosity, and diameter.
4. Explain the forces involved.
5. Connect it to a common item that uses capillary action like a sponge. Be able to explain the connection.

¹ http://www.medgadget.com/2015/04/colored-pencils-developed-easy-chemical-based-diagnostic-testing.html
http://www.arvindguptatoys.com/toys/Capillaryaction.html