Overview

Students use magnetic water molecules from 3D Molecular Designs to model properties of water. Teachers can choose one or more of the activities using the models and the Water Kit Booklet.

Learning Targets

All activities: To use models as a representations of natural phenomena.

Activity 1: To compare the relative strengths of a covalent bond, ionic bond and a hydrogen bond.

Activity 2: To understand the difference between polar and nonpolar molecules.

Activity 3: To understand the differences of water as solid, liquid and gas.

Activity 4: To understand the differences of solubility between nonpolar molecules and ionic compounds when dissolved in a polar solvent.

Activity 5: To understand the difference between cohesion and adhesion of water.

Activity 6: To understand how cohesion of water molecules causes surface tension.

Activity 7: To understand how cohesion and adhesion of water molecule cause capillary action.

Introduction

We recommend engaging students with properties of water using the formative assessment demonstration Walking the Tightrope and the Water Olympics activities as described in the accompanying lesson before introducing students to the magnetic models. These activities will likely require one class period. If putting on the Water Olympics is not practical, we recommend conducting the formative assessment and/or demonstrating some of the properties of water. At minimum, use slides 2 - 3 from the PowerPoint slide set to discuss the unique properties of water before proceeding with the Water Kit Booklet.
Lesson Outline

1. **Engage:** Demonstrate *Walking the Tightrope* and have students compete in the *Water Olympics*.

2. **Explain:** Introduce *Representations of Water Molecules* to show students different ways in which water is represented, and tell students that they will use the magnetic models for a number of activities.

3. **Explore:** Use the *Water Kit Booklet* in class with the water molecule models
   a. Have students complete selected activities in class by following the procedures
   b. Then answer analysis questions from selected activities. The answers to these questions are necessary for completing the *Student Assessment*.
   c. Things to watch for:
      i. In Activity 4, sodium and chloride should be separated by 1+ water molecules. Have student repeat if this does not occur.
      ii. In Activity 6, water molecules should form a small tower. Have students repeat if water molecules are all touching the table and flat.

4. **Evaluate:** Have students complete the Student Assessment. This can be completed as homework.

Each activity is accompanied by visuals found in the slide set:

- **A1. Bond Types**
- **A2. Polar and Nonpolar**
- **A3. Solid, Liquid, Gas**
- **A4. Solubility**
- **A5. Cohesion vs Adhesion**
- **A6. Surface Tension**
- **A7. Capillary Action Animation**
Prep Procedures

- Read and select relevant student activities for your class
- Fill water cups with necessary models EXCLUDING unnecessary models to prevent confusion and loss.

Lab Station Inventory

For each group of 2 students:
- Water Kit Booklet
- Water cup and lid containing
  - 12 water
  - 1 sodium
  - 1 chlorine
  - 1 ethane

Extension Materials:
- Hydroxyl (-OH) group in separate bag (might look broken but it is not)

Follow up

Share with students the quote by mathematician and statistician George E.P. Box:

“Essentially, all models are wrong, but some are useful.”

Have students discuss, in a large or small groups, in what ways the water molecules were useful in understanding properties of water, and in what ways the models were wrong. Did the model work better to show some properties more than others?

Students should understand that no matter how useful a model is, models are simplified representations of real-world events. These events are much more complicated than what can be shown by using a model.

Recommended Student Pre-Knowledge & Skills

- Basic understanding of the states of matter
- Basic understanding of the concept of volume
- Basic understanding of the difference between ions, atoms, and molecules.

Clean Up

Return neatly organized water cups, Activity Booklets, and chocolate. Lots of it. The dark stuff, no Hershey.
Teacher Notes

Reassembling hydrogens:
If unattached hydrogens are found, check the following guide to reassemble properly.

Building Ethanol
To build ethanol, remove hydrogen marked with a black dot from an ethane molecule. Insert hydroxyl group.

Extension Activities
These models can be used to teach the following concepts:

- Transpiration
- Solubility of partially polar molecules such as ethanol and methanol (see teacher background for assembling alcohols)
- Hydrophobic/hydrophilic properties (see Magic Sand materials included in Water Kit)
- Osmosis (see http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/Osmosis-Lesson.htm)
- pH (see http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/pH-Lesson.htm)

The models used in this lesson are made by 3-D Molecular Design. Additional sets, information, and lesson plans can be found at www.3dmoleculardesigns.com.
Connections to NGSS

This lesson supports:

Science and Engineering Practices

**Developing and Using Models.** Using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

**Analyzing and interpreting data.** Introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

Crosscutting Concepts

**Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Disciplinary Core Ideas

**PS2.B:** Attraction and repulsion between electric charges at the atomic scale explain contact forces between material objects

Performance Expectations:

**HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-PS3-5:** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**HS-PS2-6:** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Online Resources

States of Matter simulation


Effects of Temperature on Charged and Neutral Atoms

[http://lab.concord.org/embeddable.html#interactives/samples/3-100-atoms.json](http://lab.concord.org/embeddable.html#interactives/samples/3-100-atoms.json)

Surface Tension by Khan Academy

[https://youtu.be/pmagWO-kQ0M](https://youtu.be/pmagWO-kQ0M)

SEP Capillary Action with Water Molecules PowerPoint

[https://youtu.be/EBfGcTAJF4o](https://youtu.be/EBfGcTAJF4o)
Water Model Booklet
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Water Model Key

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Ethane ($\text{C}_2\text{H}_6$)
- Water ($\text{H}_2\text{O}$)
- Sodium (Na)
- Chloride (Cl)
- Salt ($\text{NaCl}$)
- Ethanol ($\text{C}_2\text{H}_6\text{O}$)
- Hydroxyl Group (-OH)
- 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 (within molecules)</strong></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>
</tr>
<tr>
<td><strong>Salt (NaCl)</strong></td>
<td>An <strong>ionic bond</strong> is the complete transfer of an electron between two atoms resulting in one positively and one negatively charged atom. Ionic bonds are <em>intramolecular</em> bonds within one molecule. <strong>Ions</strong> are charged atoms that have gained or lost electrons as a result of an ionic bond.</td>
</tr>
<tr>
<td><strong>Intermolecular Bonds (between molecules)</strong></td>
<td></td>
</tr>
<tr>
<td>Hydrogen bonds between $H_2O$</td>
<td>A <strong>hydrogen bond</strong> is an <em>intermolecular</em> 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.</td>
</tr>
</tbody>
</table>
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.
Activity 3: States of Matter

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.

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. [Image of hexagonal structure]
2. [Image of hexagonal structure]
3. [Image of hexagonal structure]
4. [Image of hexagonal structure]
5. [Image of hexagonal structure]

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 exists 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.
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. In this extension activity we will demonstrate capillary action.

Materials

- Paper Clip
- Rubber band
- Petri dish
- 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 you paper clip between the slides. This will create a variable width for your “capillary” across the slides.
3. Fill your petri dish will colored solution.
4. Carefully place one end of the slides into the solution on the petri dish.
5. Record your observations including how to 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. 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.

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STUDENT ASSESSMENT

Water Lab

Magnetic Water Molecules

Activity 1- Bonding

1. The bond broken when separating two grey carbon atoms of an ethane molecule is a **covalent bond**. The bond broken when separating blue sodium from the green chloride is an **ionic bond**. The bond broken when separating two water molecules is a **hydrogen bond**. Which bond is easiest to break? Relate this to **intra-** or **intermolecular** bonds.

Activity 2- Polarity

2. The image below represents an ethanol molecule. Draw the interaction between a water molecule and the ethanol.

   ![Ethanol molecule and water interaction](image)

Activity 3- States of Matter

3. Mass is the amount of matter in an object. Each step in this activity involved the same mass (exactly 12 water molecules). Describe solid, liquid, and gaseous water using relative density where, \( Density = \frac{mass}{volume} \).

4. Describe the effect of energy on the bonds when water changes from a liquid to gas.

Activity 4- Solubility

5. Explain why sodium chloride dissolves well in water using the properties of both substances.
6. Explain why ethane dissolves poorly in water using the properties of both substances.

7. Carbon dioxide dissolves poorly in water. Identify whether carbon dioxide is an ionic compound or a nonpolar molecule.

   Explain your reasoning.

Activity 5- Cohesion and Adhesion

8. Ethane does not exhibit cohesion but water does even though both have hydrogen atoms. Explain why this difference occurs.

Activity 6- Surface Tension

9. A paper clip can sit on the surface of water in a cup. It cannot sit on the surface of corn oil in a cup. Explain why this difference occurs.

10. A cup is filled with water so that the water is above the rim of the cup. Explain why this can occur.

Activity 7- Capillary Action

11. Capillary action is the ability of a liquid to move upward in a narrow tube or space. Describe the role of cohesion and adhesion in capillary action.

Online Resources


Effects of Temperature on Charged and Neutral Atoms
http://lab.concord.org/interactives/samples/3-100-atoms.json

Dissociation of Salt: https://youtu.be/EBfGcTAJF4o

Surface Tension by Khan Academy: https://youtu.be/pmagWO-kQ0M

Extension Activities:

Osmosis: http://www.3dmodel.com/Teacher-Resources/Water-Kit/Osmosis-Lesson.htm

pH: http://www.3dmodel.com/Teacher-Resources/Water-Kit/pH-Lesson.htm
STUDENT ASSESSMENT

Water Lab

Magnetic Water Molecules

Activity 1- Bonding

1. The bond broken when separating two grey carbon atoms of an ethane molecule is a **covalent bond**. The bond broken when separating blue sodium from the green chloride is an **ionic bond**. The bond broken when separating two water molecules is a **hydrogen bond**. Which bond is easiest to break? Relate this to **intra-** or **intermolecular** bonds.

   *The hydrogen bond is easier to break than either the ionic or covalent bond. Intramolecular bonds between different molecules are not as strong as the intramolecular bonds that hold a molecule together.*

Activity 2- Polarity

2. The image below represents an ethanol molecule. Ethanol is made when one of the carbon atoms in ethane is replaced with an -OH group from water. Draw the interaction between a water molecule and an ethanol.

   ![interaction between water and ethanol](image)

   *The slight negative charge of the water molecule will be attracted to the positive charge on the end of the ethanol. The other end of the ethanol will not attract or repel water.*

Activity 3- States of Matter

3. Mass is the amount of matter in an object. Each step in this activity involved the same mass (exactly 12 water molecules). Describe solid, liquid, and gaseous water using relative density where, **Density = mass/volume**.

   Since 12 water molecules (an equivalent mass) take up a large volume for gas, a medium volume for liquid and a smaller volume for solid states, density should be lowest for the gas state, in the middle for the liquid, and highest for the solid state. HOWEVER, while this holds true most substances on Earth, it is not true of water. Due to the unique structure of water and the angle of the bonds, the density of the solid state (ice) is slightly lower than the density of the liquid state. Therefore, ice floats.

4. Describe the effect of energy on the bonds when water changes from a liquid to gas.

   *Energy is required to break bonds. An input of energy (in the form of heat, for example) breaks the hydrogen bonds that hold water molecules together. When water molecules are no longer held together by hydrogen bonds, gas is formed.*

Activity 4- Solubility

5. Explain why sodium chloride dissolves well in water using the properties of both substances.

   Sodium chloride is made up of positive sodium and negative chloride ions, and water is a charged (polar) molecule. The positive parts of water attract the negative chloride, and the negative parts of water attract the positive sodium, thus pulling them apart.
6. Explain why ethane dissolves poorly in water using the properties of both substances.

   Ethane is not a charged (polar) molecule. Because it is non-polar, the positive and negative charges in water do not interact with ethane.

7. Carbon dioxide dissolves poorly in water. Identify whether carbon dioxide is a polar or a nonpolar molecule.

   Carbon dioxide must be nonpolar since it does not dissolve well in water.

   Explain your reasoning.

   Water is polar, and the positive and negative poles of water molecules work to dissolve other molecules with positive and negative charges.

Activity 5 - Cohesion and Adhesion

8. Ethane does not exhibit cohesion but water does even though both have hydrogen atoms. Explain why this difference occurs.

   The hydrogen atoms in ethane are arranged symmetrically around the carbon atoms at the core, balancing the charges around the molecule and making it nonpolar. In water, the hydrogen atoms are not arranged evenly around the oxygen atom which makes water lopsided and polar, with positive and negative charges grouped unevenly. Cohesion is due to the positive charges in one molecule being attracted to the negative charges in another, which cause the molecules to stick together. It is this “stickiness” due to polarity which causes cohesion.

Activity 6 - Surface Tension

9. A paper clip can sit on the surface of water in a cup. It cannot sit on the surface of corn oil in a cup. Explain why this difference occurs.

   Water is polar which causes the molecules to be cohesive and “stick together.” This stickiness creates a network or web which can support the paper clip. Corn oil is nonpolar, and the molecules don’t interact or stick together. A paperclip therefore falls in between the molecules to the bottom.

10. A cup is filled with water so that the water is above the rim of the cup. Explain why this can occur.

   Water molecules not only stick to each other due to their polarity (cohesion) but to other substances such as the cup (adhesion). Up to a certain point, the forces of adhesion and cohesion that create the dome are stronger than the force of gravity, which would destroy the dome.

Activity 7 - Capillary Action

11. Capillary action is the ability of a liquid to move upward in a narrow tube or space. Describe the role of cohesion and adhesion in capillary action.

   The ability of polar water molecules to stick to each other through hydrogen bonds (cohesion) and stick to the tube (adhesion) allows water to move upward in a narrow tube. The forces of adhesion and cohesion are strong enough to move the liquid up the tube when capillary action occurs, counteracting the force of gravity which would pull the liquid down the tube.

Online Resources
Effects of Temperature on Charged and Neutral Atoms: http://lab.concord.org/interactives/samples/3-100-atoms.json
Dissociation of Salt: https://youtu.be/EBfGcTAJF4o
Surface Tension by Khan Academy: https://youtu.be/pmagWOkQOM
Extension Activities:
Osmosis: http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/Osmosis-Lesson.htm
pH: http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/pH-Lesson.htm