Contents

Discover Nature Schools 5
Unit Overview 6
Activity Components 7
Outdoor Learning 7
Wrap-up/Formative Assessment Strategies 8
Correlations to the Next Generation Science Standards and the Missouri Learning Standards 9
Student Science Notebooks 14
Field Investigations in Your Schoolyard 16
Discover Nature — Fishing 18
Unhooked in Action — Project Based Learning 19
Diving In: The Science Notebook 25
1 The Structure and Properties of Water 31
1.1 Modeling a Water Molecule 32
1.2 Cohesion and Adhesion 39
1.3 The Universal Solvent 46
1.4 Density of Water 49
2 The Incredible Journey 55
2.1 Search for Water Cycle Evidence 57
2.2 Transpiration in a Bag 60
2.3 Water Evidence Hike 65
2.4 Schoolyard Topography and Mapping 69
2.5 Runoff in the Schoolyard 73
2.6 Erosion in a Stream Table 80
2.7 Turbidity 84
3 Matter and Energy 87
3.1 Physical and Chemical Hike 89
3.2 Photosynthesis Investigation 92
3.3 Aquatic Food Chains and Food Webs 95
3.4 Go with the Flow — Energy Flow in Food Chains 98
3.5 Classroom Composting 103
3.6 Photosynthesis Model Relay 107
4 Interactions 113
4.1 Interaction Patterns 115
4.2 Population Limiting Factors 125
4.3 Identifying Specialized Structures 129
4.4 Fishing for Specialized Structures 136
4.5 Mussel Lures 138
5 Biodiversity 145
5.1 Biodiversity in the Schoolyard 147
5.2 Aquatic Invertebrate Sampling 155
6 People and the Environment 169
6.1 Using Chemical Tests to Measure Water Quality 170
6.2 Water Purification Engineering 176

Appendices . . . 179
Unit Assessment Strategies . . . 181
End-of-Chapter Assessments . . . 182
Unit Pre- and Post-test . . . 192
Unhooked in Action — Project Based Learning Guide Sheets . . . 195
Possible Solution Criteria Master Guide . . . 196
Current Event Guide . . . 197
School and Community Venn Diagram . . . 198
What Do We Know? . . . 199
Mapping Solutions Guide . . . 200
Possible Solution Criteria Guides . . . 201
Solution Evaluation Guide . . . 205
Persuasive Argument Guide . . . 206
Project Scope Guide . . . 207
Project Calendar . . . 210
Field Experience . . . 211

1 the STRUCTURE and PROPERTIES of Water

Estimated Time

(5) 50-minute class periods

Vocabulary

Adhesion
Atom
Cohesion
Density
Electron
Gas
Heat capacity
Hydrogen bond
Liquid
Molecule
Polar molecule
Proton
Solid
Solute
Solution
Solvent
Temperature

Activities

1.1 Modeling a Water Molecule
1.2 Cohesion and Adhesion
1.3 The Universal Solvent
1.4 Density of Water

Missouri Learning Standards

6-8.PS1.A.1 Develop models to describe the atomic composition of simple molecules and extended structures.
6-8.PS1.A.2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)

Crosscutting Concepts

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

Activity 1.1 Modeling a Water Molecule

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: PS1.A.4
NGSS: PS1-1

Objectives

Students will be able to:

1. Create a model of a water molecule.
2. Identify the properties of a water molecule.
3. Demonstrate that water is a pure substance made of three atoms.

Teacher Preparation

In this activity, students will create a model of a water molecule. Before class, cut out and assemble the *Teacher's Water Molecule Model Template*. This template will be used to help guide the students during the lesson. Have students work in small groups. Each student will create six water molecule models, and each group will work together to create ice crystal maps using the water molecule models.

Materials

- Student science notebooks
- Pencils
- *Teacher's Water Molecule Model Template* (2 pages)
- *Student's Water Molecule Model Templates* (one per student)
- *Ice Crystal Map* (one per group)
- Colored pencils or crayons
- Scissors
- Double-sided sticky dots, double-sided tape, or glue

Procedure

1. Have students prepare headings in their science notebooks. (This is an indoor activity; therefore, temperature and weather factors may be left blank.)
2. Explain to the students that they are going to make a model of a water molecule. Holding up the *Teacher's Water Molecule Model Template*, explain that they are going to make six water molecules that look like the one you are holding, except smaller. Use this opportunity to talk about the properties of a water molecule.

   Q: What atoms make up a single molecule of water?
   A: Three atoms make up a single molecule of water. There are two atoms of hydrogen and one atom of oxygen in each molecule of water.

   Q: If you separate the atoms of a water molecule, is it still water?
   A: If you break the molecule apart, it stops being water and becomes individual atoms of hydrogen and oxygen — two substances with properties that are quite different from those of water.

Q: What are the properties of a hydrogen atom? (Hold up one of the hydrogen atoms from the *Teacher's Water Molecule Model Template* for the class to see.)
A: Hydrogen atoms only have 1 proton, 1 electron, and 0 neutrons.

Q: What are the properties of an oxygen atom? (Hold up the oxygen atom from the *Teacher's Water Molecule Model Template* for the class to see.)
A: Oxygen atoms have 8 protons, 8 electrons, and 8 neutrons.

Q: When two hydrogen molecules bond with an oxygen atom and make one water molecule, how many protons, electrons, and neutrons does it have?
A: Each molecule of water has 10 protons, 10 electrons, and 8 neutrons.

Q: Why does a single water molecule only have 8 neutrons?
A: The two hydrogen atoms of a water molecule do not have neutrons, and the only available neutrons come from the oxygen atoms.

Q: What is the shape of a water molecule?
A: Water atoms are arranged in such a way that they look like a teddybear's head.

Q: What are some other facts about a water molecule? (List the student answers on the board for them to reference later in the activity. Students may refer to pages 3–4 of the student book.)
A: Answers may vary but should include some of the following:

- The chemical formula for water is H_2O.
- Water is the universal solvent because many substances dissolve in water.
- Water is a pure substance because it has a definite and constant composition. Its composition does not vary.
- Many compounds contain hydrogen and oxygen, but water is the only one that has that special 2:1 ratio.
- Water is a polar molecule because its positive and negative charges are unevenly distributed.
- Polarity gives H_2O many of its distinct properties.

3. After the students have finished discussing the properties of water, hand out *Water Molecule Model Templates* and have the students:
   - Color the oxygen atoms red and the hydrogen atoms yellow.
   - Label (for each individual atom) the number of protons, electrons, and neutrons in the spaces provided for each.
   - Cut out each atom. To make six molecules of water, each student should have six oxygen atoms and twelve hydrogen atoms. While students color atoms, watch Water Polarity (time 3:51) **ed.ted.com/lessons/how-polarity-makes-water-behave-strangely-christina-kleinberg**
4. Using the *Teacher's Water Molecule Model Template,* demonstrate where to attach the hydrogen atoms to the oxygen atom. Explain that on the oxygen atom, there are eight dots, representing eight electrons, and on the hydrogen atom, there is one dot, representing one electron. Have students glue the hydrogen atoms to the top of the oxygen atom by placing one hydrogen atom on the top left dot of the oxygen electron and the other hydrogen atom on the top right dot of the oxygen electron.

Q: If each dot represents an electron, how many electrons can you count on this model? Is it correct?
A: There are only 8 visible electrons on this model because when the hydrogen atoms were glued to the oxygen atom, the dots representing the electrons on the oxygen atom were covered up. This model does not correctly demonstrate the total number of electrons represented in a water molecule.

Q: How can we fix our water molecule models to reflect the correct total number of electrons in a water molecule?
A: To reflect the correct total number of electrons in a water molecule, students should add a dot (electron) next to the dot on each of the hydrogen atoms. (Use the *Teacher's Water Molecule Model Template* to demonstrate where to place the dot/electron.)

Q: What do you notice about the number of hydrogen atoms and the number of oxygen atoms?
A: There is a 2:1 ratio of hydrogen to oxygen atoms.

5. On the back of the water molecule models, have students write their initials and one fact about a water molecule. Have them use the list created earlier in the lesson to complete this step. Students can use these water molecule models as flash cards to study water facts alone or in groups.
6. Break students into small groups and provide a copy of the *Ice Crystal Map*. Explain that this is a map of what water molecules look like when they are in a frozen state.
7. Have students:
   - Combine their water molecules with other group members to build an ice crystal similar to the ice crystal on the map.
   - Start with six molecules and build the structure out from those six molecules.

Wrap-up

Have students retrieve and save their original six water molecule models. These will serve as flash cards/study guides for future reference/assessments.

Extension

View the following videos:

- Water Polarity
  ed.ted.com/lessons/how-polarity-makes-water-behave-strangely-christina-kleinberg
- Why Does Ice Float?
  ed.ted.com/lessons/why-does-ice-float-in-water-george-zaidan-and-charles-morton

Cross-Curricular

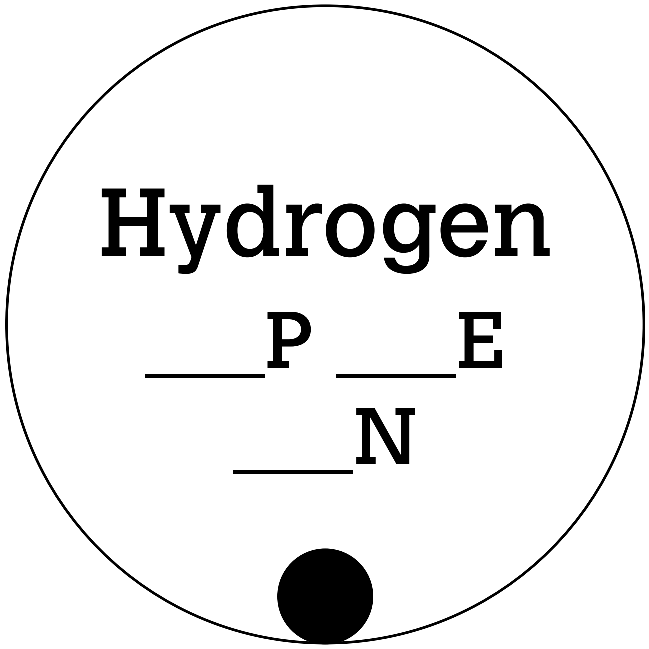
Using modeling clay, have students create a 3-D model of a water molecule, identifying the three atoms, and labeling parts.

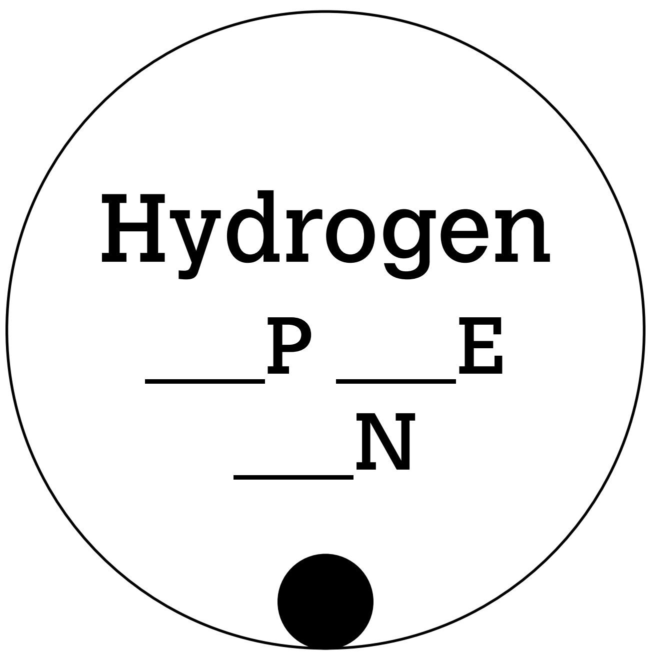
Fine Arts Connection — Divide students into small groups. Have each group produce a play acting out the formation of a water molecule. "Actors" will represent hydrogen and oxygen atoms. Have students create a script depicting the formation of a molecule and, if time allows, a script showing the separation. Students should be able to answer the question "If a water molecule is broken apart and separated, is it still water?"

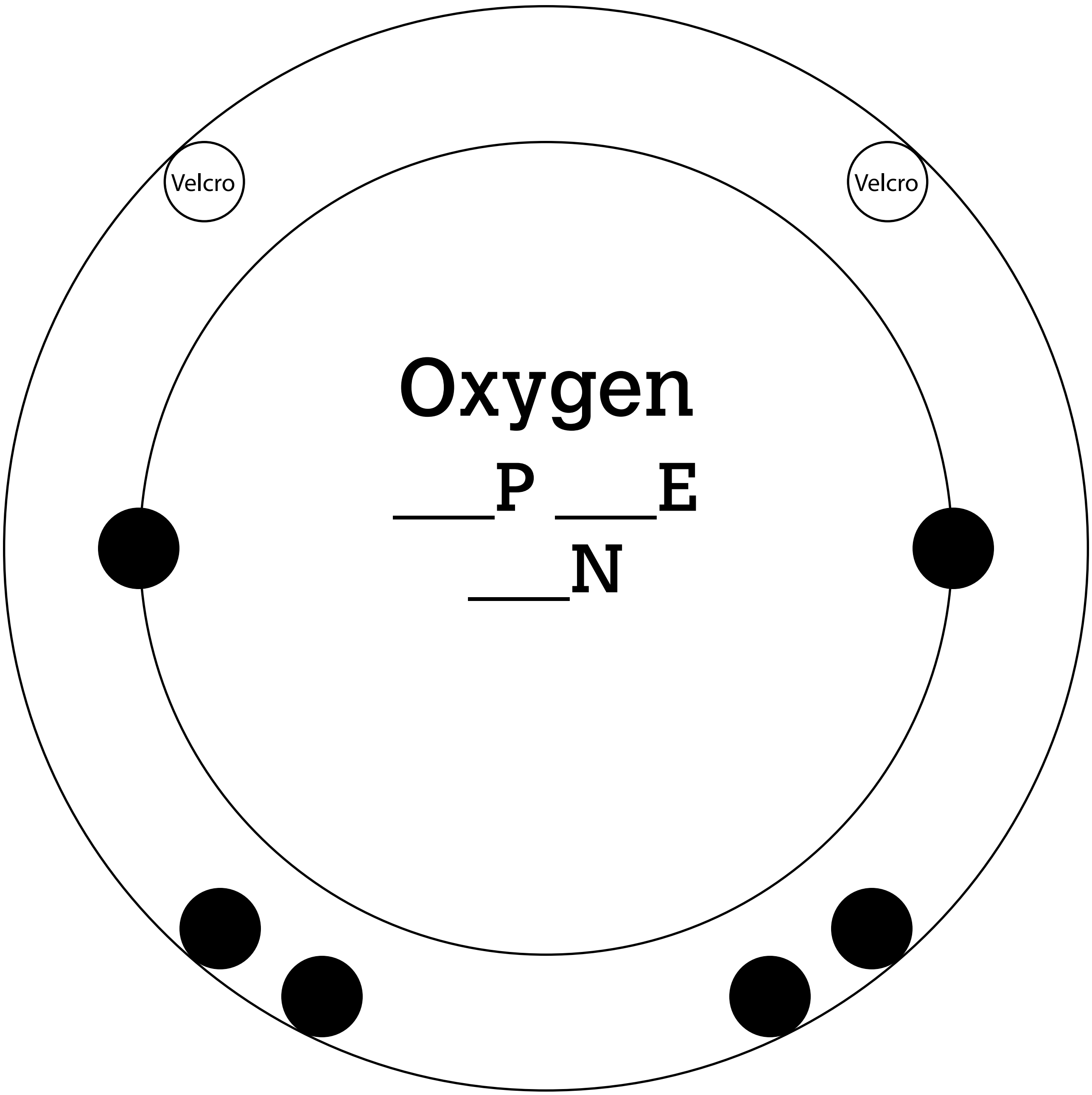
Teacher's Water Molecule Model Template

Directions:

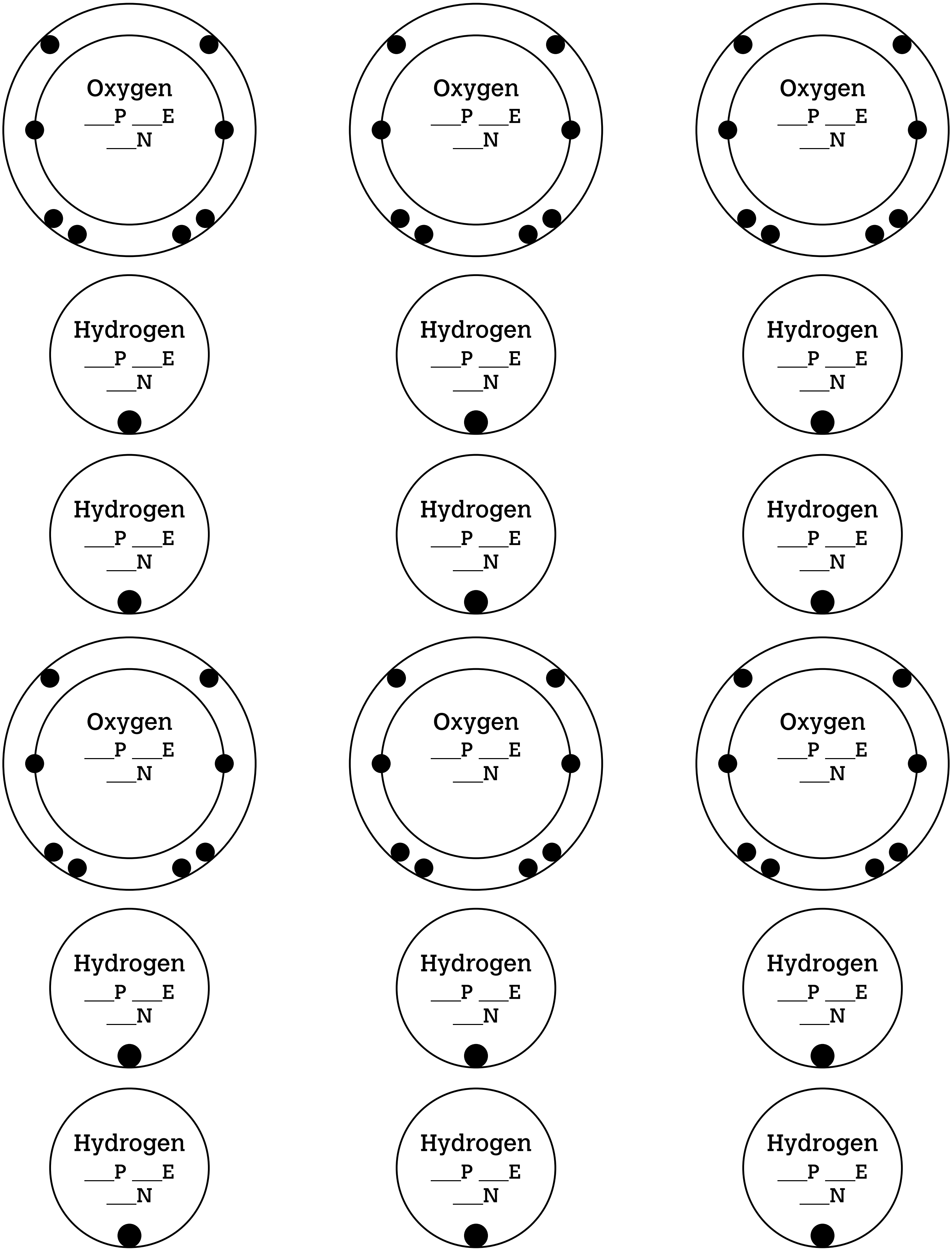
- Cut out and laminate each atom, 2 hydrogen atoms and 1 oxygen atom.
- Place Velcro behind the electron dot on both of the hydrogen atoms.
- Place Velcro on the electron dots marked "Velcro" on the oxygen atom.



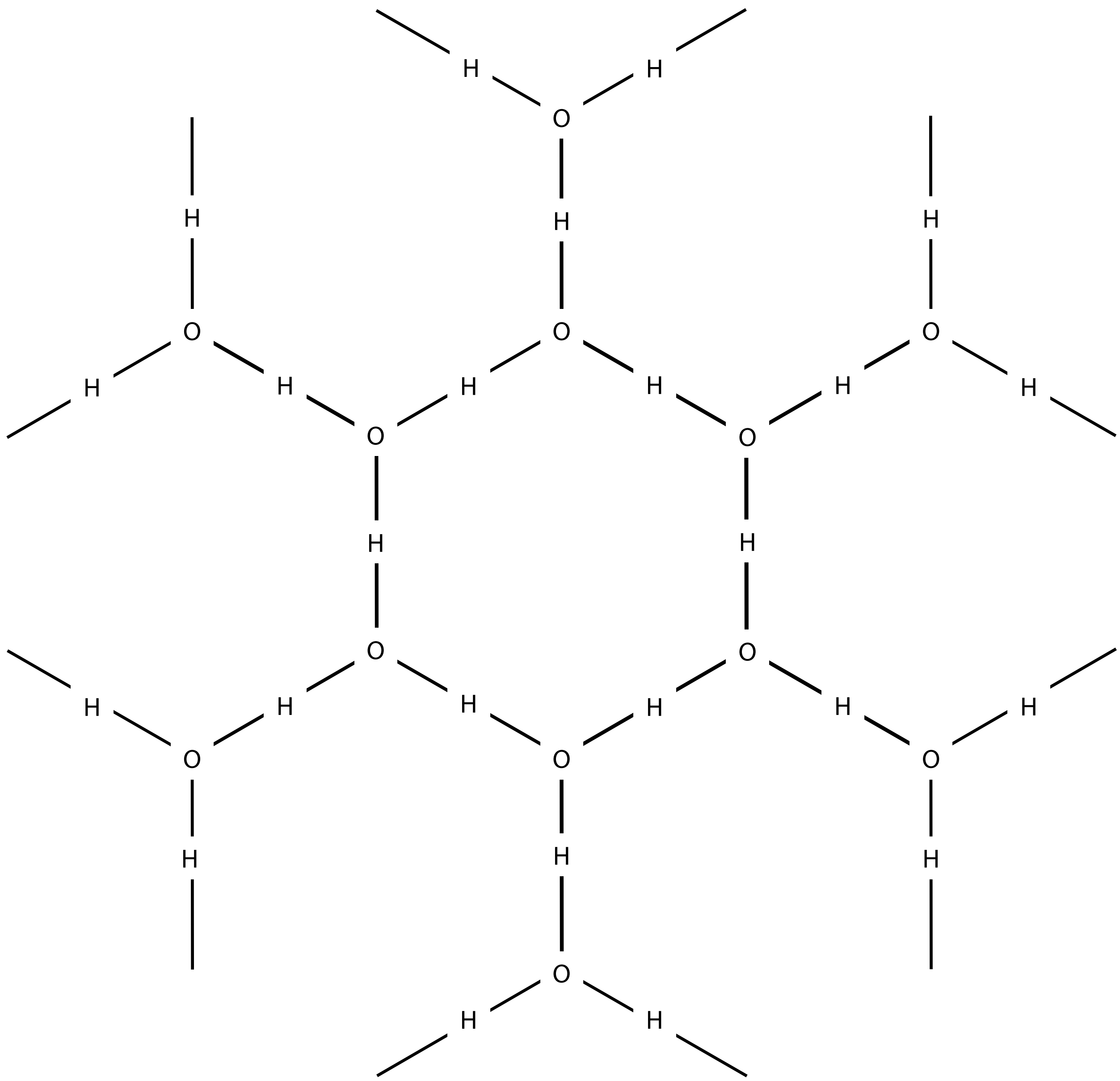



Velcro
Velcro
Oxygen
___P ___E
___N

Student's Water Molecule Model Templates



Ice Crystal Map



Activity 1.2 Cohesion and Adhesion

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: PS1.A.2
NGSS: PS1-2

Objectives

Students will be able to:

1. Observe and describe two distinct properties of water (cohesion and adhesion).
2. Gather, analyze, and interpret data.
3. Explain how cohesion and adhesion may work together.
4. Explain how cohesion and adhesion are important for plants, animals, and people.

Teacher Preparation

This activity can be done in the classroom or science lab, if available. However, it can also take place outdoors in the schoolyard ecosystem using plastic containers and cups rather than glass. If outdoors, a flip chart or small white board and markers will be necessary. The first part of this activity will require a stable, flat surface and one penny per group. The second part of this activity will require a stable, flat surface and up to a roll of pennies per group. Both parts will require easy access to water.

Materials

- Student science notebooks
- Pencils
- *Activity 1.2 Number of Drops on a Penny* (included in student science notebook)
- *Activity 1.2 Number of Pennies* (included in student science notebook)
- Large containers to hold water
- 5–6 small glasses (or clear plastic cups if outdoors), all the same size
- 30–50 pennies per group (depending on the size of the glasses or cups)
- Dish soap (enough for 10 drops per group)
- 10–12 eyedroppers (two per group: one for pure water use and one for use with soap and water)
- Air thermometer (if outdoors)
- Flip chart or white board and markers (if outdoors)

Procedure

1. Have students complete their science notebook headings. Include air temperature and weather data if outdoors.
2. Divide students into 5–6 groups, assign numbers to each group, and provide each group a glass or cup, an eyedropper, and one penny.
3. Have students:
   - Open their science notebooks to *Activity 1.2 Number of Drops on a Penny*.
   - Predict how many drops of water can be dropped on the penny before the water runs off the penny.
   - Record their personal predictions.

4. Have groups:
   - Place one penny on a flat, stable surface.
   - Fill the eyedropper with water and begin slowly squeezing one drop at a time directly on the top of the penny.
   - Count each drop and record on the table in their science notebooks the total number of drops added to their penny before water began running off the penny.
5. Have groups discuss and record responses in their science notebooks:
   - How close were their predictions to the actual number?
   - How might they show their Actual Number of Drops compared to their Predicted Number of Drops? (Different graphic organizers)

Q: What did you notice about the surface of the water on your pennies?
A: A dome formed. Refer students to the photo on Page 4 of the student book.

Q: What property of water made the actual number of drops possible?
A: Cohesion, the attraction of one water molecule to another water molecule (positively charged hydrogen ends of a water molecule attracted to negatively charged oxygen ends of nearby water molecules) allowed water to form a dome over the penny. Cohesion produces surface tension.

6. Have groups:
   - Open their science notebooks to *Activity 1.2 Number of Pennies* table.
   - Place their glass or plastic cup on a stable, flat surface.
   - Get water from the large containers and fill their group's glass or cup with as much water as possible (at least to the rim).
7. Have groups:
   - Take turns gently slipping pennies, one at a time, into the glass or cup.
   - Count the number of pennies added until surface tension at the top of the glass or cup breaks and water runs down the side of the container.
   - Record in the "Pure Water" column of their table the number of pennies added before the surface tension broke.

Q: What happened to the surface of the water in your container as you added pennies?
A: The surface bulged up over the top.

Q: What properties of water are demonstrated by this bulge?
A: Cohesion, the attraction of one molecule to another of the same kind. Adhesion, the attraction between two different kinds of molecules.

Q: What causes the water to form a bulge?
A: Water molecules have an uneven distribution of charges, which explains why water molecules stick together (cohesion). Water molecules are also attracted to the sides of the container (adhesion), which anchors the sides of the bulge to the rim of the container.

8. Instruct groups to:
   - Dump half the water in their glass or cup back into the large containers of water.
   - Observe and sketch the shape of the surface of the water remaining in their glass or cup.

Q: What do you observe about the surface of the water remaining in your glass or cup?
A: There is a slight downward curve in the middle of the surface.

Q: What caused this curve? Why?
A: Adhesion is responsible for the slight curve you see. The water is attracted to the sides of the glass or cup because of the attraction between the two different kinds of molecules (water molecules and glass or plastic molecules.)

Q: Based on this observation, how should you always read the volume measurement in a graduated cylinder?
A: Because of adhesion, you should always read the volume measurement at the bottom of the curve.

9. Ask students to consider how the experiment might work using soapy water. Instruct them to individually predict whether they will be able to add more pennies, the same number of pennies, or fewer pennies after adding soap.
10. On the flip chart or white board, create the following chart titled "Predictions," and record students' general predictions for the 3 categories.

Predictions

More Pennies	Same Number of Pennies	Fewer Pennies

11. Have each group add 5 drops of soap to their half-filled glasses or cups. From the larger container of water, SLOWLY add water to the glasses or cups to the same level it was the first time. The water should be added slowly to avoid creating any bubbles. **Note:** larger glasses or cups may require more drops of soap.
12. Have groups:
    - Take turns gently slipping pennies, one at a time, into the glass or cup.
    - Count the number of pennies added until surface tension at the top of the glass or cup breaks and water runs down the side of the container.
13. Have students record in the "Water and Soap" column the actual number of pennies added before the surface tension broke and water ran down the side of the container.
14. On the flip chart/white board, create the following chart titled "Predictions."
15. After all students have finished recording their data, survey the class about their predictions. Record the number of students who made predictions for the three categories of the table.
16. On the flip chart/white board, create a table similar to *Activity 1.2 Number of Pennies* students used in their science notebooks with the addition of a column labeled "Group No."

Number of Pennies

Group No.	Pure Water	Water and Soap
	Actual No.	Predicted No. Actual No.
	Actual No.	Predicted No. Actual No.
	Actual No.	Predicted No. Actual No.

17. Have a member of each group record their data on the "Number of Pennies" chart on the flip chart/white board.
18. Discuss the data charts with the class and guide students to analyze and interpret the data. Compare the results of each group's penny activities.

    Q: What do you notice about the results for each group?
    A: Answers may vary depending on the results. Some numbers may possibly be the same for both pure and soapy water. Some may have added more or fewer pennies to the soapy water.

    Q: Why do you think the results among groups are different?
    A: Amounts of water may not have been equal between the two trials; surface tension may have broken before students noticed; measurements were not accurate; etc.

Q: Looking at all the results, what trend or pattern do you see?
A: More groups were able to slip more pennies into pure water than into water mixed with soap before the container overflowed.

Q: Using this class data, what can you infer about the properties of pure water compared to pure water mixed with soap?
A: Pure water exhibits properties of cohesion and adhesion more than water mixed with soap. Soap or other substances mixed in water can change the distribution of positive and negative charges in water molecules. This change in the distribution of positive and negative charges in water molecules reduces the water molecules' polarity, changes the physical properties, and breaks surface tension.

Q: How does your "Prediction" chart match the "Number of Pennies" chart?
A: Answers may vary. Discuss reasons behind student predictions, misconceptions students may have had, and reasons for expected or surprising results.

Q: Does the number of drops of soap make a difference in terms of how many pennies could be added before water flows over the side? How could we find out?
A: Design and conduct an experiment involving glasses/cups with different amounts of soap added. Discuss what evidence could be used to defend their answers.

Wrap-up

Allow time for groups to discuss:

- Examples of cohesion and adhesion in nature
- Ways cohesion and adhesion work together
- How cohesion and adhesion are important for plants, animals, and people

Assessment

Have students respond to the following in their science notebooks:

- Define cohesion and adhesion.
- Explain why pure water exhibits these properties.
- Give an example in nature of how cohesion and adhesion may work together.

Extension

Some items sink in water because they are denser than water. However, some of these same items may be able to be placed on top of the water's surface, allowing the surface tension to prevent the items from sinking.

1. Ask groups of students to consider items that are small and that normally sink, but that might rest on top or water due to surface tension. Have them make a prediction about one or more objects. (Suggestions might include paper clips, straight pins, and rubber bands.) Have students design and test an experiment and record their results and conclusions in their science notebooks.
2. Assuming that students are successful in "floating" an object, have students predict how they might cause a successfully floating object to sink without touching that object in any way. Groups should design and test an experiment and record their results and conclusions in their science notebooks.
3. Have groups discuss why their results did or did not support their predictions. For groups with results that did not support their predictions, students can redesign their experiment and test it.
4. Repeat the Number of Drops on a Penny activity using water mixed with soap. Have groups of students make predictions, and gather, analyze, and interpret data as described in the activity.

Cross-Curricular

Trees have internal plumbing that relies upon the properties of cohesion and adhesion. Have students create an illustration showing how cohesion and adhesion work together in a tree's internal plumbing, from roots to branches. (Students could label adhesion as the water drawing up and cohesion where molecules attach.)

Activity 1.2 Number of Drops on a Penny

	Predicted Number of Drops	**Actual Number of Drops**
1.		
2.		
3.		

1. How close were your predictions to the actual number?

2. How might you show the actual number of drops compared to the predicted number of drops?

Activity 1.2 Number of Pennies

Pure Water	Water and Soap	
Actual Number of Pennies	**Predicted Number of Pennies**	**Actual Number of Pennies**
Sketch of water surface before water spills over the edge.		
Sketch of water surface when container is partially filled.		

1. Define *cohesion* and *adhesion*.

2. Explain why pure water exhibits these properties.

3. Give an example in nature of how cohesion and adhesion may work together.

Activity 1.3 The Universal Solvent

Estimated Time

(1) 50-minute class period with a brief check-back after a couple of days

Learning Standards

MLS: 6-8.PS1.A.2
NGSS: MS-PS1-2

Objectives

Students will be able to:

1. Observe and distinguish between physical changes and chemical changes.
2. Explain what distinguishes a physical change from a chemical change.
3. Observe that solubility of solids in water generally increases with increasing temperature.
4. Observe that the solubility of gases generally decreases with increasing temperature.

Teacher Preparation

This activity may be done as a teacher demonstration or as a lab activity with students working in small groups. If done as a lab, the materials list should be multiplied by the number of student groups. This activity helps to lay the conceptual groundwork for water quality testing and water purification activities in Chapter 6.

Materials

- Student science notebooks
- Pencils
- Sheet of 8.5 × 11 inch paper
- Scissors
- Matches or lighter
- Glass or metal tray for safely containing burning paper
- 1 clear glass 250 mL beaker
- 3 cups of sugar
- Teaspoon
- Magnetic stirrer and stirring hotplate or hotplate and manual stirring rod
- 2 clear bottles of seltzer or other clear soda — one warm, one cold
- Pencil with a few inches of string tied around the middle

Procedure

1. Show the class an ordinary sheet of copy paper. Cut the paper into a few large pieces.

    Q: Have I made a physical change or a chemical change to the sheet of paper?
    A: Physical. It is still paper, just smaller pieces.

2. Cut one of the pieces into tiny pieces.

    Q: How about now? Have I made a physical change or a chemical change?
    A: Physical. It is still paper, just smaller pieces. Even if you could grind the paper up into a powder, it would still be paper. You would only have changed its physical appearance. With some effort you could still turn it back into a sheet of paper. Whether a sheet of paper, a smaller piece, a tiny piece, or even a powder, it is the same substance, which is really a plant material called cellulose.

3. Now take another piece of paper and light it on fire (carefully!).

Q: Have I made a physical change or a chemical change?
A: Chemical.

Q: How do you know?
A: What you are left with is not paper (not cellulose). It is not possible to turn it back into a piece of paper. The reaction (burning) gave off heat, light, and gas (smoke).

Q: What is the difference between a physical change and a chemical change?
A: A physical change may alter the state (solid, liquid, gas) or appearance (shape or form) of substances, but it does not change the fundamental identity of the substances. They are still made up of the same atoms arranged in the same way. In other words, they are still made of the same molecules. Physical changes can be reversed because all of the original substances are still there. A chemical change breaks the molecular bonds of the original substances and rearranges the atoms to form different molecules. Chemical changes cannot be reversed because the original substances no longer exist.

Q: How do the cellulose molecules in a piece of paper change when the paper burns?
A: They break apart and combine with oxygen from the air to form carbon dioxide, carbon (ash, soot, and smoke), and water. In the process, the breaking and reforming of molecular bonds releases energy in the form of light and heat.

4. Pour some water into a glass beaker.

Q: If I heat this water, will I be making a chemical change or a physical change?
A: Physical. Heating is not the same as burning. No chemical change takes place.

Q: How do you know?
A: You can let the water cool back down (or condense, if you boil it) and get all the water back.

5. Take a spoonful of sugar and hold it up to the class.

Q: What if I add this sugar to the water in the beaker? Will the change be physical or chemical?
A: Allow the class to offer varying hypotheses as to whether the change will be physical or chemical. Ask each respondent to explain why they believe the change is physical or chemical. Make notes on the board of their responses.

Q: If the change is physical, I should be able to get the original substances back, right?
A: Yes.

Q: How much sugar do you think will dissolve in this cup of water?
A: Allow responses, then say "Let's see."

6. Count as you add spoonfuls of sugar to the water, stirring as you go, until undissolved sugar begins to accumulate in the bottom of the beaker. Announce your result to the class.

Q: What if I heat the water? Will more sugar dissolve?
A: Yes.

7. Add the remainder of the sugar to the water, set it on the hotplate, and leave it heating.
8. Take the clear bottle of clear soda from the cooler and show it to the class.

Q: What will happen when I open this bottle of soda?
A: It will fizz.

9. Open the bottle, noting the hiss of gas escaping and the bubbles that form inside the bottle.

Q: What caused the hissing sound? Where did these bubbles come from?
A: Carbon dioxide gas is dissolved in the water of the soda under pressure. When you open the bottle, you relieve the pressure and allow gas to escape. Some of the gas comes out of solution.

10. Now take the bottle of the same soda from the window ledge where it has been warming in the sun.

Q: What about this bottle of soda, which I left sitting on the window ledge in the sun? What will happen when I open it?
A: It will explode/erupt with bubbles.

11. Open the bottle over the sink.

Q: Why did so many more bubbles come out and with so much force?
A: The gas is dissolved in the soda water under pressure, like before. But more gas comes out of solution when the soda is warm.

Q: So you're saying that gas dissolves better in cold water than in hot water?
A: Yes.

Q: Would you say that dissolving a gas in water is a chemical change or a physical change?
A: Physical.

Q: Why do you think so?
A: Because you can get all the original gas and water back.

12. Go back to the hotplate with the sugar dissolving in it.

Q: It looks like more of our sugar has dissolved as the water has heated up. How do you explain that?
A: Solids dissolve more easily in hot water than in cold water, unlike gases, which dissolve better in cold water than in hot water.

Q: And is dissolving sugar in water a chemical change or a physical change?
A: Physical, because you can get the original ingredients back.

Q: How?
A: Allow the water to evaporate and the dissolved sugar will recrystallize in the beaker.

13. Tell the class that you're going to test that hypothesis. Remove the beaker from the hotplate. Put the string into the sugar-water solution and place the pencil across the top of the beaker with the string hanging down into the sugar solution. Put the beaker in the window ledge in the sun. Tell the class that we'll leave the sugar-water solution here for a couple of days and see what happens.

Wrap-up

After a couple of days, you should be able to show the class that sugar crystals are forming on the string. Review the prediction that the original ingredients are recoverable because the dissolution of sugar in water is a physical change rather than a chemical change.

Activity 1.4 Density of Water

Estimated Time

(2) 50-minute class periods

Learning Standards

MLS: 6-8.PS1.A.2
NGSS: MS-PS1-2

Objectives

Students will be able to:

1. Analyze and interpret quantitative and qualitative data.
2. Create a model that demonstrates the properties of water in relation to temperature.
3. Explain how temperature affects water density.

Teacher Preparation

Students should work in small groups for this two-part (two separate days) activity. On Day 1 of the activity, students will determine the density of water and prepare an experiment to see if freezing water will change the density of water. On Day 2 of the activity, students will finish their experiment on temperature by calculating the density of their frozen water samples and create a model that demonstrates the effects of temperature on water density.

Note:
At the end of Day 1 activity:

- Students will need access to overnight freezer space for their graduated cylinders.
- You will need to freeze an ice cube tray filled with water dyed dark blue.

During Day 2 activity:

- You will need to place water in the clear, plastic, shoebox-size container at the beginning of the class in order to ensure it is at room temperature when you are ready to begin Step 5.
- You will need access to hot water.

Materials

- ➤ Student science notebooks
- ➤ Pencils
- ➤ *Activity 1.4 Density of Water Data Sheet* (included in student science notebook)
- ➤ Water (approximately 1–2 gallons)
- ➤ Plastic graduated cylinders (one per group)
- ➤ Scales (calibrated in grams)
- ➤ Water (at room temperature)
- ➤ Blue food coloring (10–20 drops)
- ➤ Red food coloring (10–20 drops)
- ➤ Freezer
- ➤ Clear plastic container (about the size of a shoebox)
- ➤ Small plastic bottle
- ➤ Hot water

Procedure

Day 1

1. Have students prepare headings in their science notebooks. Refer students to Page 6 of the student book for a review of density.
2. Review density with students.

   Q: What is density?
   A: Density is a measurement of how much matter is packed into a specific space.

   Q: How do you measure density?
   A: To measure density we need to know how much an object, or in this case, a liquid, weighs (mass) and how much space it occupies (volume). To find an object's density, you divide its mass by its volume (D = M/V).

3. Divide students into small groups. To calculate the density of water, each group will need a graduated cylinder, distilled water, and a scale that can measure in grams.
   - A. To determine the mass of water, have students record the results of each step below in their science notebooks:
     - Weigh and record the mass of the graduated cylinder in grams.
     - Add distilled water to the graduated cylinder, leaving at least 3 inches of airspace at the top.
     - Weigh and record the mass of the filled graduated cylinder in grams.
     - Subtract the mass of the empty graduated cylinder from the mass of the filled graduated cylinder.
     - Label this in science notebooks as the mass of the water.
   - B. To determine the volume of the water, have students:
     - Record in science notebooks the volume of water in the graduated cylinder.
   - C. To calculate the density of the water, have students:
     - Use the formula Density = Mass/Volume.
     - Label this in science notebooks as the density of the water.

   Q: What causes solid water to be less dense than water in its liquid form?
   A: When water freezes, the crystal structure is formed by a more open organization of molecules.

4. Have students place their filled graduated cylinders in the designated freezer. Keep these in the freezer at least overnight.

   Q: Why should you be careful not to spill or add water to your cylinders?
   A: Losing or adding water will change the mass of the sample. The goal is to keep the mass the same but have a change in volume due to the water expanding.

5. Have students observe as you fill an ice cube tray with water and add enough drops of blue food coloring to make the cubes dark blue. Freeze this tray at least overnight. This will be used for the model segment of the activity on Day 2.

Day 2

1. Fill the clear plastic shoebox-size container with tap water at the beginning of the class.
2. Have students work in the same groups as Day 1 and retrieve their frozen graduated cylinder.
3. Have groups:
   - A. Calculate the density of their frozen water samples and record the results of each step in their science notebooks:
     - Weigh and record the mass of their graduated cylinder (frozen overnight) in grams.
     - Subtract the mass of the empty graduated cylinder (recorded on Day 1) from the mass of the frozen graduated cylinder.
     - Label this in science notebooks as the mass of the frozen water.

4. Have groups:
    A. Determine the volume and density of the frozen water and record the results of each step in their science notebooks:
        - Record the volume of frozen water in the graduated cylinder.
        - Use the formula Density = Mass/Volume.
        - Label this in their science notebooks as the density of the water.
5. Have students analyze and interpret their data.

    Q: Based on your calculations, how does the density of your water in liquid state compare to the density of the same water in frozen state?
    A: The water in its frozen state is less dense than the water in its liquid state.

    Q: What factors might have affected results that would not support the idea that frozen water is less dense than liquid water?
    A: Answers may vary: Water was spilled or added to the graduated cylinder; the volume of water was misread; the formulas were miscalculated; etc.

    Q: Why did your results show that water is less dense in its frozen state?
    A: Water is weird. When the water froze, the hydrogen bonds joining the molecules lengthened. This pushed the molecules farther apart and made the solid water less dense than the liquid water.

    Q: How would you redesign this experiment to show that frozen water is less dense than liquid water?
    A: Answers may vary.

6. Have students finish analyzing, interpreting, and recording their data.
7. Have students predict whether hot water is less or more dense than cold water and record their predictions in their science notebooks.
8. Within clear view of the entire class:
    - Retrieve the tray with the dark blue ice cubes.
    - Place the clear plastic shoebox-size container (filled with water at the beginning of the class) on a table.
    - Have students take the room temperature and the temperature of the water in the container to ensure the water within the container is now at room temperature.
    - Fill the small plastic bottle with hot water and add enough drops of red food coloring to make the water dark red.
9. Explain to the class:
    - The water in this large container represents a body of water, like a lake.
    - The dark blue ice cube represents ice floating on the lake.
    - This bottle of (red) hot water represents the water in the lake heated by the sun.
10. Have students use their science notebooks to record their predictions to the following:
    - When a blue ice cube is added to the room-temperature water in the container, and the blue ice cube begins to melt, how will the cold blue-dyed water react? Will it rise to the top, float in the middle, or sink to the bottom?
    - When the hot, red-dyed water is added to the room-temperature water in the container, how will it react? Will the hot, red-dyed water rise to the top, float in the middle, or sink to the bottom?
    - When the hot, red-dyed water is added to the room-temperature water in the container, how will the blue ice cube react? Will it rise to the top, float in the middle, or sink to the bottom?
11. After students have made their predictions:
    - Place the blue ice cube into the water. Have the students record their observations.
    - Place the whole bottle of hot red water on its side (lid off) in the tank with the ice cube.
    - Have students record their observations of the red-dyed hot water and the blue ice cube.

12. Have students;
- Analyze and interpret the qualitative data they have collected by discussing the results of the experiment.
- Determine and discuss which of their results were quantitative and which were qualitative.

Wrap-up

After students have completed both activities, have them reflect in their science notebooks on the following (using short answer, drawing, diagram, etc.).
- How does temperature affect the density of water?
- How does the density of ice affect aquatic organisms?

Extension

Which has greater density? Students may come up with other ways to test their predictions, but one basic way would be to fill a sink or plastic tub with water and see which fruit, can, egg, etc. floats and which sinks.
- Have students work in groups to predict which of two items (one set) is more dense than the other in that set.
- Have groups determine ways to test out their predictions.
  - Examples of possible item sets:
    - Can of Coke versus a can of Diet Coke
    - Can of Coke versus a can of 7-Up
    - Can of 7-Up versus a can of Diet 7-Up
    - Compare different fruits:
      - An apple versus an orange
      - An orange versus a banana
  - A raw egg versus a hardboiled egg
- Have groups:
  - Discuss the results of their tests.
  - Discuss why/why not one item in each set was denser than the other.
  - Discuss other ways to test prediction.

Adapted from "The Answer Files" at **whyfiles.org/071questions/5.html**

Cross-Curricular

Oil and Water Droplet Paintings

This process painting activity demonstrates the density differences between oil and water. As oil is less dense, water sinks below oil, which is nonpolar.

Procedure: Using a small shallow pan (yet deep enough to hold a sheet of paper), place liquid watercolor (or water dyed with food coloring) in the bottom of the pan.

Pour 1/2 cup cooking oil into a small separate bowl. Have students use eyedroppers or pipettes to gather drops of oil to place in the shallow pan of colored water (or liquid watercolor). This will cause the less dense oil to remain on the surface, creating areas that will not transfer color to paper.

Place watercolor paper face down into the shallow pan and then place the paper on a drying rack. The finished result is a marbled effect of resist area created by the different densities of water and oil. Let the paintings dry, discuss water's polarity, and compare the densities of water and oil.

Activity 1.4 Density of Water Data Sheet

<table>
<tr><td colspan="3">Day 1</td><td>Notes</td></tr>
<tr><td colspan="3">Mass of Water Sample
Filled Cylinder — Empty Cylinder = Mass of Water</td><td rowspan="9"></td></tr>
<tr><td>Mass of Filled Graduated Cylinder</td><td>Mass of Empty Graduated Cylinder</td><td>Mass of Water</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Volume of Water Sample
Read the graduated cylinder to determine the volume of water</td></tr>
<tr><td colspan="3">Volume</td></tr>
<tr><td colspan="3">Density of Water Sample
Density = Mass/Volume</td></tr>
<tr><td>Mass</td><td>Volume</td><td>Density</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Day 2</td><td>Notes</td></tr>
<tr><td colspan="3">Mass of Frozen Water Sample
(Note: Use empty graduated cylinder measurement from Day 1)</td><td rowspan="9"></td></tr>
<tr><td>Mass of Filled Graduated Cylinder</td><td>Mass of Empty Graduated Cylinder</td><td>Mass of Water</td></tr>
<tr><td></td><td></td><td></td></tr>
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