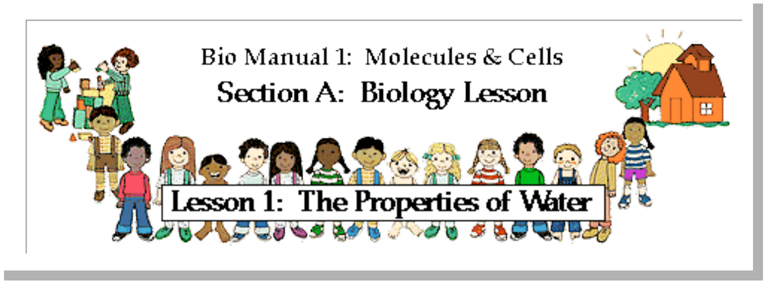


The Properties of Water

Grade Level

Prospective and Practicing 9-12 Teacher.

Time

Exercises 1-4 take approximately 2 hours.

To Ponder

Water is everywhere. It's in the air we breathe. It's in our sink faucets, and it's in every cell of our body. Water is an unusual substance with special properties. Just think about the wonder of water:

1. How does water rise from the roots of a redwood tree to the very top?
2. How do insects walk on water?
3. Why does ice float rather than sink?
4. Why do people become seriously ill, or die, if they go without **liquid** for a week or so?
5. How would life in a lake be affected if ice sank and lakes froze from the bottom up?

In this first lab, we will investigate the properties of water in an attempt to understand how water behaves in relation to both our bodies and the environment. Through a concise set of experiments, the unique properties of water and its consequent importance to living things will become apparent.

Supplies

MATERIALS PER GROUP

penny
2 slides – 1 glass and 1 plastic
piece of wax paper
strip of chromatography paper
flask filled with water
plastic dropper
1 large graduated cylinder (50 ml)
2 small graduated cylinders (10 ml)
stirring rod
blue or black pen
2 small paper cups or breakers

SHARED MATERIALS

beaker with detergent
beaker with oil
food coloring
ground black pepper

Objectives

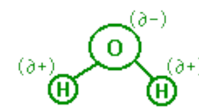
Once you have completed this exercise you should be able to:

1. Describe the **polarity** of a water molecule and explain how that **polarity** affects the properties of water.
2. Explain why water climbs the inside of a thin glass capillary but not a thin plastic capillary.
3. Explain why water climbs a paper strip.
4. Describe a system whereby the components of a water-based substance might be separated and discuss how this separation occurs.
5. Explain why oil and water don't mix.
6. Predict whether a substance, based on its **hydrophilic** and/or **hydrophobic** properties, will dissolve into water or oil.

Background Information

Water covers about three fourths of the surface of the earth? It is ubiquitous. It is also one of the simplest yet most important molecules in living systems. It makes up from 50 to 95 percent of the weight of living organisms. The cytoplasm of a cell is a water-based solution that contains a variety of ions, salts, and molecules which make life 'happen.' Water is literally involved in every facet of life.

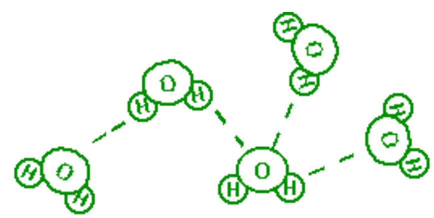
Figure 2. Polarity of Water Molecule



The simplicity of the water molecule belies the complexity of its properties. Based on its small size and light weight, one can predict how it *should* behave, yet it remains **liquid** at a much higher temperatures than expected. It also **boils** and **freezes** at much too high, or low, of a temperature for a molecule of its size. Many of these unexpected properties of water are due to the fact that water molecules are attracted to each other like small magnets (**cohesion**). This attraction results in turn from the structure of the water molecule and the characteristics of the atoms it contains.

Each molecule of water is made up of two atoms of hydrogen connected to one atom of oxygen, as shown below. This is summarized in the familiar formula, H_2O.

Figure 3. Hydrogen Bonding in Water



Powerful Idea

Atoms are most stable when they have a particular configuration of their outer shells, a concept which will be discussed in future labs. These configurations explain why hydrogen in water will take on a **partial positive charge** and why oxygen will take on a **partial negative charge**. These partial charges cause water molecules to 'stick' to each other like magnets. *The 'stickiness' in this particular case is due to '**hydrogen bonding**'. In this case, hydrogen bonding involves the attraction between the positively charged hydrogen atom of one water molecule and the negatively charged oxygen atom of another water molecule*. As no electrons are actually shared however, **hydrogen bonds** are much weaker than covalent bonds - they easily break and easily form again.

Exercise 1 Surface Tension & Adhesion

1a Drop Behavior - Water on Penny

To Do

1. Obtain a medicine dropper and a small (10 ml) graduated cylinder. Make sure the dropper is clean.
2. Drop water into the graduated cylinder with the dropper, counting each drop.
3. How many drops, of the size produced by your medicine dropper, are in each cubic centimeter (cc) of water? (1 cubic centimeter = 1 milliliter)? __________ drops

Data Collection

4. Conversely, how much water is in each drop? (divide 1cc by the number of drops) __________ cc. per drop, average.
5. Now, let's see how many drops of water you can you place on the surface of a penny before it overflows.

Data Collection

6. How many drops do you predict?

Table 1. Number of Drops Predicted

person	#1	___________
person	#2	___________
person	#3	___________
person	#4	___________
Total	1 - 4	___________
Average		___________

To Do

7. Drop water from the dropper onto a penny, keeping careful count of each drop. Draw a diagram below showing the shape of the water on the penny after one drop, when the penny is about half full, and just before it overflows.

Data Collection

Figure 4. Drawing of Drops

Results

8. How many drops were you able to place on the surface of the penny before it overflowed? __________ drops

Interpret

9. If the number of drops is very different from your prediction, explain what accounts for the difference.
10. Explain your results in terms of **cohesion**

1b Effects of Detergent

To Do

1. With your finger, spread one small drop of **detergent** on the surface of a dry penny.

Predict

2. How many drops do you think this penny will hold after being smeared with **detergent**, more, less, or the same as before? Why?
3. Specifically, how many drops do you think it will hold?

Table 2. Prediction of Number of Drops of Water on a Penny with Detergent

person	#1	___________
person	#2	___________
person	#3	___________
person	#4	___________
Average		___________

To Do

4. Using the same dropper as before, add drops of water to the penny surface. Keep careful count of the number of drops, and draw the water on the penny after one drop, about half full, and just before overflowing.

Figure 5. Drawing of Drops on a Penny with Detergent

Results

5. How many drops were you able to place on the penny before it overflowed this time? __________ drops

Question

6. Did the **detergent** make a difference? Describe the effect of the **detergent**.
7. What does the **detergent** do to have this effect on water?

Interpret

8. Explain how **detergents** act as cleaning agents, considering the **cohesion** among water molecules and the affects of **amphipathic molecules** .

1c Drop Shape on Glass and Wax Paper

Question

1. What will be the shape of a drop of water on (a) a piece of wax paper, (b) a glass slide, and (c) a plastic slide. Draw the shape of the drop you expect on each surface:

__________	__________	__________
wax paper	glass	plastic

2. Why did you predict as you did? What assumptions are guiding your thinking?

To Do

3. Perform the experiment. Place several drops of water on each surface and draw the results below.

Interpret

__________	__________	__________
wax paper	glass	plastic

4. Compare your predictions with your observations and explain.

5. Can you explain the differences in drop behavior in terms of **adhesion** - that is, the formation (or absence) of **hydrogen bonds** between molecules of different types? Which molecules?

Exercise 2 The Climbing Property of Water

Background

1. Water moves to the tops of tall trees due to **capillary action** combined with root pressure and **evaporation** from the stomata (openings) in the leaves. Water will also climb up paper, and often the migrating water will carry other molecules along with it. The distance traveled by these other molecules will vary with their **mass** and **charge**.

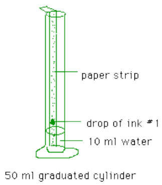
Predict

2. How fast do you think water would climb a strip of absorbent paper about one-half inch wide?
about one inch per ____________________ (time)

To Do

3. Obtain a 50 ml graduated cylinder, and tear off a strip of chromatography paper that is just long enough to hang over the side of the cylinder (inside) and reach to the bottom.

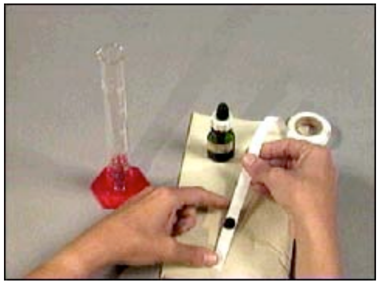
Figure 6. 50 ml Graduated Cylinder with Chromatography Paper & Ink



To Do

4. Run the paper strip along the edge of a scissors to take the curl out of it.
5. Place a single small drop of ink from a black vis-a-vis pen on the paper, about one inch from the bottom, and let it dry completely.

Figure 7. Ink on Chromatography Paper



6. Put 10 ml of water into the graduated cylinder and place the strip of paper in the cylinder so that the bottom end is immersed in water and the drop of ink is just above the surface of the water. Fold the paper over the top side.

Figure 8. Close-up of Ink

7. Note the starting time below.

Data Collection

8. Watch and note the time at 5 minute intervals. When the water climbs to the top of the paper, remove the paper from the water, and let it dry.

Table 3. Time of Water Climbing

Time (minutes)	Distance (inches)
0	_____________
5	_____________
10	_____________
15	_____________
20	_____________
25	_____________
30	_____________

To Do 9. How did the ink change? Glue the paper onto the page here, and label each color on the strip.

10. How do you explain the results? Your explanation should involve **capillary action**, **polar molecules** and **hydrogen bonding**.

Exercise 3 Cohesion of Water

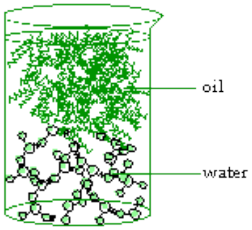
3a Water & Oil

To Do 1. Put 8 ml of water into a 10 ml graduated cylinder.

Predict 2. What will happen if you add cooking oil? (Predict by choosing a, b, c, d, or e below)
a. the oil will float on top of the water
b. the oil will sink to the bottom of the water
c. the oil will dissolve in the water
d. the oil will become mixed up with the water
e. other (what?)

Oil is a **hydrophobic** or 'water hating' molecule, so called because its chemical structure does not allow the formation of hydrogen bonds. Therefore, oil does not dissolve in water. When mixed, the two substances form separate layers, and because oil is less dense, it sits on top of water.

Figure 9. Water and Oil



3. Gently add 2 ml of cooking oil by tilting the cylinder of water slightly and letting the oil run slowly down the inside of the cylinder.

Results 4. What happened?

To Do 5. Save this graduated cylinder with its contents and get a clean 10 ml cylinder for the next experiment.

3b Oil & Water

To Do 1. Place 8 ml of cooking oil in a 10 ml graduated cylinder.

Predict 2. What will happen when you add water? (Predict by choosing a, b, c, d, or e below)
a. the water will float on top of the oil
b. the water will sink to the bottom of the oil
c. the water will dissolve in the oil
d. the water will become mixed up with the oil
e. other (what?)

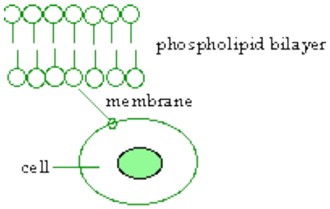
To Do 3. Gently add 2 ml of water by tilting the cylinder of oil slightly and letting the water run slowly down the inside of the cylinder.

Results What happened?

Question 4. Which is less dense (that is that has less weight per ml.), oil or water? ____________________

Interpret 5. This characteristic behavior of water and oil is of critical importance for living things, determining many properties of the cell. Can you explain how? Consider the picture that follows:

Figure 10. Enlargement of Cell Membrane to Show Phospholipid Bilayer.



Question 6. What mechanism causes water molecules and oil molecules to separate from one another? Your explanation should involve **polar** and **non-polar** molecules, the effects of **polarity** on the molecular interactions, and **hydrogen bonding**.

3c Water, Oil, and Dye

Predict 1. Predict what will happen if you add a few drops of a water-soluble dye solution to each of the above graduated cylinders containing water and oil. Will the dye mix with the water, the oil, or both?

To Do 2. Perform the experiment. Add a few drops of dye to each cylinder. Use a glass stirring rod to penetrate the interface between each layer, giving the dye access to both water and oil. How does the dye behave in each cylinder? Does it diffuse into the oil? Into the water?

Results 3. Compare your predictions and results. Explain any differences.

To Do 4. Stir the contents of each cylinder with a stirring rod and then let it sit.

Predict 5. Will the contents remain mixed? Why do you think so?

Interpret 6. Observe what happens, compare with your prediction, and explain why it happens. Your explanation should involve **polarity**, **polar** and **non-polar** molecules, **solution** and **hydrogen bonding**.

3d Sheen

Predict 1. Take a clean beaker of water. Predict what will happen if you add one small drop of oil to the water using a medicine dropper.

To Do 2. Do this experiment. Can you see the oil? Was your prediction correct? Add more drops of oil if necessary to see it clearly. Describe. Your description should focus on the separation of **polar** and **non-polar** layers and why that occurs.

Predict 3. Predict what will happen if you add a drop of **detergent** to the beaker.

To Do 4. Now add a drop of **detergent** to the beaker of water with oil on top. Record your results

Interpret 5. Compare the results with your prediction, and explain how the **detergent** works in molecular terms. Your explanation should focus on the ways in which **amphipathic** molecules disrupt **cohesion**.

Interpret 6. Explain some of the consequences of oil spills in the sea. What effects do they have on sea life and bird life, and what methods are used to 'clean up' oil spills?

Exercise 4 More Surface Tension!

To Do 1. Pour some water into each of two small paper cups.

2. Shake a little bit of ground black pepper into each cup.

Observe 3. Describe the appearance inside the cups.

To Do 4. Dip your finger into the detergent solution. Then stick your finger into 1 of the cups.

Observe 5. Now describe the appearance inside the cup in which you stuck your finger.

Interpret 6. Explain what happened in this experiment using the idea of SURFACE TENSION.

Exercise 5 Class Summary

To Do 1. Summarize class results with respect to drops on a penny in the table below.

Table 4. Number of Drops on a Penny

Group	# Drops without Detergent	# Drops with Detergent
1	___________	___________
2	___________	___________
3	___________	___________
4	___________	___________
5	___________	___________
6	___________	___________
7	___________	___________
8	___________	___________
Average	___________	___________

Interpret 2. Explain the variation from group to group.

3. What general conclusions can you draw from the class data?

Exercise 6 Organizing Your Knowledge

1. Describe at least one observation you have made outside the laboratory that illustrates each phenomenon below.

a. **Polarity**

b. **Hydrogen bonds**

c. **Cohesion**

d. **Surface tension**

e. **Adhesion**

f. **Capillary action**

g. **Amphipathic**

h. **Dissolving**

i. **Density**

2. The following table summarizes nine phenomena associated with water across the top and list the exercises we have performed down the side. For each exercise, indicate which phenomena are illustrated.

Table 5. Ideas Illustrated by Each Lab Exercise

Ideas: Lab Exercise	polarity	H-bonds	cohesion	surface tension	adhesion	capillary action	amphipathic	dissolving	density
1a drops-penny									
1b drops-penny-detergent									
1c drops-glass, wax paper									
2 chromotogr paper									
3a H_2O & oil									
3b oil & H_2O									
3c oil, H_2O, dye									
3d sheen									