About the Guide

The Ecology Center welcomes you to Terrain for Schools, a unique current events–based curriculum for colleges and high schools. Lessons in this guide address California State Content Standards for grades 9-12 in three categories: science, social science, and language arts. Overviews and applicable standards are found on the first page of each lesson.

The lessons are designed to be used with articles in the Spring 2006 issue of Terrain, which is available on the web at www.ecologycenter.org.

Teachers: Photocopy this material as needed. Loan the guide to fellow teachers. We welcome your feedback and participation.

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SCIENCE

# Water: the Miracle Molecule

by Constance Anders

Overview

**Students will:**
- Understand the water molecule.
- Relate the molecular characteristics of water to the physical characteristics of water.
- Watch five demonstrations and make observations, predictions, and hypotheses.

**Terrain Article:** "Working Water" page 20, Spring 2006

## Introduction

What is water? We drink it. We bathe in it. We irrigate crops with it. We swim, boat, and fish in it. It is odorless, tasteless, and colorless. It is part of nearly every aspect of our lives and the lives of all living things, but have we ever really thought about what makes water so special?

Let's find out.

*CA BIOLOGY/LIFE SCIENCES STANDARDS, GRADES 9-12: Chemistry: Chemical Bonds 2a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds. d. Students know the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form. h.Students know how to identify solids and liquids held together by van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/melting point temperatures. Solutions 6b. Students know how to describe the dissolving process at the molecular level by using the concept of random molecular motion. Chemical Thermodynamics 7a. Students know how to describe temperature and heat flow in terms of the motion of molecules (or atoms). d. Students know how to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.*

## Characteristics of Water

### Demo 1: Dissolving a Solute

In the following five demonstration activities, students will make observations and predictions about the nature of water.

**Materials**
Rubbing alcohol [isopropyl alcohol $(CH_3)_2CHOH$]
Water
1 clear glass beakers labeled "water"
1 clear glass beaker labeled "rubbing alcohol"
Salt
fi teaspoon measuring spoon
Graduated cylinder

**Teacher Directions**
1. Tell students to choose a partner. Pass out worksheet on **page 4**. Students should fill it out while you perform the demo.
2. Add 50mL of water to"water" beaker.
3. Add 50mL of rubbing alcohol to "rubbing alcohol" beaker.
4. Add fi teaspoon of salt to each beaker.
5. Ask students to discuss, predict, and record what will happen.
6. Swirl both beakers until the salt is reduced.
7. Ask students to record what occurred and hypothesize about the results.

### Demo 2: Density of Ice

**Materials**
Ice
Labeled beaker containing water
Labeled beaker containing rubbing alcohol

**Teacher Directions**
1. Tell students you are going to put ice in water and in alcohol.
2. Ask students to discuss, predict, and record what will happen.
3. Place the ice in the beakers.
4. Students should record results and hypothesize about the reason for the outcome.

### Demo 3: Cohesion

**Materials**
Rubbing alcohol
Water
2 small bathroom sized "Dixie" cups or other smooth rimmed small containers
2 droppers of the equal size
2 graduated cylinders

**Teacher Directions**
1. Determine the volume of the cup using a graduated cylinder.
2. Label one small cup, "water" and fill to the top with water.
3. Label a second cup "rubbing alcohol" and fill to the top with alcohol. Alcohol volume should equal water volume.
4. Ask the students to discuss, predict, and record how many drops it will take to make the alcohol and the water over flow the containers.
5. Count out loud as you add alcohol drops to the full cup.
6. Ask students to record the number of drops needed to cause an overflow.
7. Repeat the above instructions using water.
8. Ask students to observe and record any differences.

### Demo 4: Surface Tension

**Materials**
Aluminum foil
1 labeled beakers containing rubbing alcohol
1 labeled beaker containing water

**Teacher Directions**
1. Cut two 10cm x 10cm squares out of foil.
2. Fold foil in half four times to make 2.5" x 2.5" squares.
3. Make sure foil "boats" are absolutely flat.
4. Tell the students that you are going to put the foil "boats" in each beaker.
5. Ask students to discuss, predict, and record what will happen.
6. Place one foil raft on the water. (If the boat does not float rub it on your face to coat with oil and reflatten!)
7. Place the second raft on the alcohol.
8. Ask student to record what they observe and hypothesize about the results.

### Demo 5: Adhesion and Cohesion

**Materials**
Paper towels
Labeled beaker containing rubbing alcohol
Labeled beaker containing water
2 droppers of the same size

**Teacher Directions**
1. Place 2 unfolded pieces of paper towel on a flat surface.
2. Tell students that you are going to put a dropper full of water in the middle of one paper towel and a dropper full alcohol in the middle of the other.
3. Ask students to discuss, predict, and record what will happen.
4. Add the water and alcohol to the paper towels in a steady stream and measure the diameters of the absorbed liquids. Have students record the diameter and hypothesize about any differences they see.

# Water: Putting It Together

Student Worksheet

Name: Partner's Name:

## Section 1: Dissolving a Solute

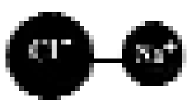
**During the Demonstration**

Predict the outcome of the demonstration and place your answer in the chart below. After the demonstration is completed, write down what you actually observed. In the hypothesis column, place your best explanation for the observed events.

| | Prediction | Actual | Hypothesis |
|---|---|---|---|
| Salt plus water | | | |
| Salt plus alcohol | | | |

**After the Lecture**

In the space provided, explain how water molecules dissolve salt. Which molecule is the solute and which molecule is the solvent? Below is a salt molecule.



## Section 2: Density of Ice

**During the Demonstration**

| | Prediction | Actual | Hypothesis |
|---|---|---|---|
| Ice plus water | | | |
| Ice plus alcohol | | | |

In the correct column place your prediction, the actual results, and your hypothesis explaining the outcome.

**After the Lecture**

Show all work when you answer the questions below.

Density of ice = .99707g/cm

Density of water = 1.000000g/cm

Density = mass/volume

1. If a sample of liquid water weighs 1000 grams, what is its volume?

2. If a sample of ice weighs 1000 grams, what is its volume?

3. If 50 grams of $H_2O$ has a volume of 50.147cm what is its density? Is it a solid (ice) or a liquid?

4. Ice floats. Is it more or less dense than liquid water?

## Student Worksheet Continued

### Section 3: Cohesion

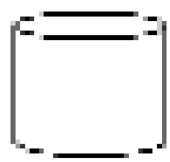
**During the Demonstration**

In the chart below place your prediction, the actual results, and your hypothesis.

| | Prediction | Actual | Hypothesis |
|---|---|---|---|
| Number of drops of water to overflow container | | | |
| Number of drops of rubbing alcohol to overflow container | | | |

**After the Lecture**

In the space provided, draw a picture showing water molecules forming a dome above the rim of the container. Hydrogen bonds must be present for this to be correct.



### Section 4: Surface Tension

**During the Demonstration**

Fill in the following chart with your prediction for the "boat" demonstration, record the actual occurrence, and hypothesize about the results.

| | Prediction | Actual | Hypothesis |
|---|---|---|---|
| "Boat" on water | | | |
| "Boat" on alcohol | | | |

**After the Lecture**

What is surface tension?

### Section 5: Adhesion and Cohesion

**During the Demonstration**

Fill in the following chart with your prediction of the absorption, the actual diameter, and your hypothesis.

| | Prediction of diameter in cm | Actual diameter in cm | Hypothesis |
|---|---|---|---|
| Water absorption | | | |
| Alcohol absorption | | | |

**After the Lecture**

Explain how adhesion and cohesion cause water to be absorbed by a paper towel.

## The Nature of Water

Lecture

Students will hear about the characteristics of water, take notes, and re-examine their hypotheses.

Water is a colorless, odorless, tasteless molecule that exists in nature as a solid, a liquid, and a gas.

Molecularly, water ($H_20$) is a covalent compound. This means that the valence electrons of two hydrogen atoms and one oxygen atom are shared. If the atoms in a compound have equal electronegativity—that is, an equal pull on the shared electrons, the compound has no charged regions and is called a nonpolar covalent compound.

However, if one atom in the molecule is highly electronegative, then the resultant compound has an uneven sharing of electrons and is called a polar covalent compound. Oxygen is a very electronegative element. When it combines with hydrogen to make water, the oxygen atom pulls electrons away from the hydrogen atoms and towards itself, producing a polar covalent bond.

As a consequence of this unequal sharing, there are negative and positive regions in the water molecule. The oxygen end of the molecule with its "extra" electrons becomes slightly negatively charged and the hydrogen end of the molecule becomes slightly positively charged. Because of these polar characteristics, the positive end of one water molecule is attracted to the negative end of another water molecule. This weak attraction is called a hydrogen bond.

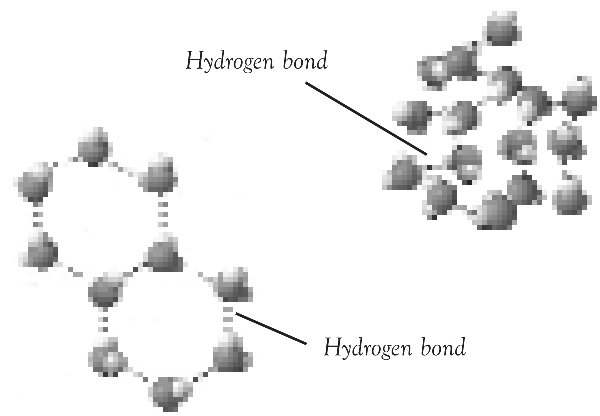
*Lewis Dot drawing of water*

**Water is a solvent.**
It can dissolve any ionic or polar covalent compound. The charged regions on the water molecule are attracted to the opposite charges on ionic and polar covalent compounds. Individual water molecules surround individual solute molecules separating them from each other and dispersing them equally throughout the water. When this occurs, the compound is said to be dissolved. The water is the solvent and the compound is the solute. The ability of water to act as a solvent allows for the making of solutions ranging from salty seas to DNA rich cells.

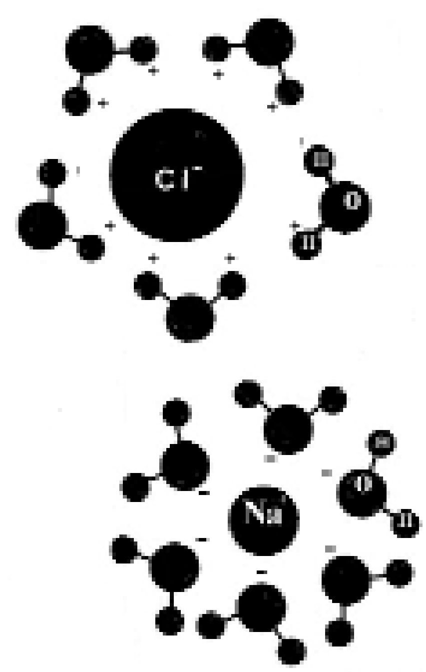
**Ice floats.**
Usually molecules are tightly packed as solids, more loosely packed as liquids and very loosely associated as gases. As such, the density or mass per unit volume is greatest in the solid state.

Water, however, is unusual. As the liquid water cools, a maximum number of hydrogen bonds form, producing a crystal lattice. The ice crystal geometric pattern takes up more space than does liquid water. Water, therefore, is denser as a liquid than it is as a solid. Because of this, less dense ice floats on liquid water.

*Liquid water*




*Solid Water/Ice*




*Above: water dissolving salt (NaCl)*

## Lecture Continued

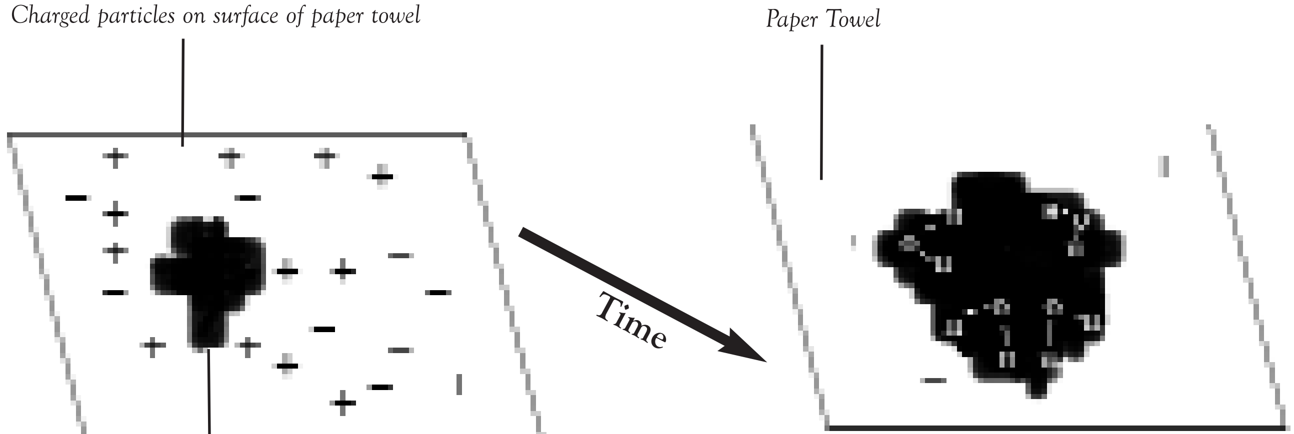
**Water is cohesive and has surface tension.**
The hydrogen bonds that form between water molecules cause water to act as a single aggregate. Because of this, a bucket of water acts like one giant molecule. The result of this attraction is cohesion.

At the boundary between water and air, surface tension is produced. This characteristic occurs because there is no attraction between water and air allowing the cohesive water molecules to produce a somewhat unified surface.

Because of the twin characteristics of cohesion and surface tension, water bugs can skate across the surface of a pond.


*Cohesion*

**Water is adhesive.**
Water molecules are attracted to a surface that has on it groups of charged atoms or molecules. This force explains how water makes things wet. We become wet when water spreads over our skin in a thin film. This means that we have charged molecules on our skin. A waxed car does not have any charged atoms or molecules on its surface. That's why water beads up on it. In the paper towel demonstration, water is absorbed through a combination of cohesion and adhesion.




*Adhesion and cohesion of water molecules*

**Water Purification**

When biological or chemical pollutants are added to water, its physical characteristics are altered. Biological contaminants include disease causing bacteria, viruses, fungi, algae, and parasites. These contaminants found in unclean drinking water are a major cause of worldwide disease. In countries where people do not have access to clean water, death rates are staggering.

The Spring Edition of *Terrain* featured the work of Ashok Gadgil, a senior scientist at Lawrence Berkeley National Laboratory who has developed a water purification system with colleagues based upon UV light technology. This technology works by damaging the DNA within the disease organism. This prevents DNA replication and protein synthesis. When DNA replication is interrupted, reproduction cannot occur and the disease population stops growing. When protein synthesis is halted, the organism cannot carry on its life processes and it dies. Thus, the UV light purification method is highly effective against biological pollutants. The technology developed by Dr. Gadgil and others is simple, inexpensive, and being made available to people in poor communities through out the world. Dr. Gadgil is currently working on technology that will address the chemical pollutant issues found in unclean water.