National Next Generation Science Standards

Students who demonstrate understanding can:

5-PS1-1.
Develop a model to describe that matter is made of particles too small to be seen.

MS-PS1-1.
Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-4.
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science

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.

TEACHERS GUIDE

GRADE LEVEL 5-12

CAPILLARY TUBE SET -
COMMUNICATING CAPILLARIES
ITEM # 3447-00

CHEMISTRY - PROPERTIES OF MATTER

Can water flow upward?
Defy the downward forces of gravity and discover the science behind rising fluids. Capillary action is dependent upon the inner diameter of the glass tubes. Demonstrates how molecules of a liquid are more attracted to glass than to similar liquid molecules. The Capillary Tube Set consists of four glass capillary tubes of different inner diameters with a large tube serving as reservoir.

Mounted on a stand. Height of the tubes is about 6” (150mm).

Materials

- Liquid Measuring Device/ Capillary Tube Set
- journal paper
- filter paper or absorbent paper
- towel
- food coloring
- cooking oil
- water
- 2 empty containers (for holding water)
- aluminum can
- a fuel to burn (paper, cheetos, candle)
- pepper
- pennies
- dropper
- paper clips
- shallow pans
- soap
- celery
- rubbing alcohol
- hydrogen peroxide
- salt
- sugar
- ruler
- student handout
- internet access

Goals & Objectives

Students will:

- understand capillary action.
- know the difference between concave and convex.
- explain gravity.
- identify solids and liquids.
- **See Page 8 for National Next Generation Science Standards**

Introduction

A compound is first described by its state of matter. Is it a solid, liquid, or gas? We use the properties of the compound to decide which it is, but we give little thought to what those properties are or how to explain them.

Solids maintain their shape and volume when placed in a container. Liquids maintain volume, but not their shape, and gasses maintain neither. This apparatus allows students to examine other properties beyond that. They don't just take on the shape of their container, but they also can take on different shapes with the same container. Some liquids form an upwards meniscus or a downwards meniscus. If they are attracted to the material the container is made from, the meniscus is concave shaped. If they are more attracted to each other, then they form a convex meniscus.

The property of capillary action will give you an opportunity to deepen your students' understanding of particles and the forces that hold them together.

Discussion

Additional Discussion and Real Life Applications

1. How do plants grow so tall if the water column height is limited by gravity?
2. Why does water behave the way it does in microgravity (the ISS)?
3. What other properties do liquids have because of intermolecular forces?
4. What kind of intramolecular (within the molecule) forces are in liquids?
5. Mercury is the only metal which is a liquid at room temperature. Would it be more attracted to itself or to the glass?

   What does that tell you about the relative strengths of intermolecular forces versus intermolecular forces?

Quiz

Have students use the following terms to fill in the blanks on the Quiz.

meniscus	capillary action	liquid
gravity	adhesion	concave
convex	cohesion	
glass	hypothesis	

Answer Key:

1. A downward force is **_gravity_**.
2. **_Capillary_** **_action_** occurs when a liquid moves upward within a glass tube.
3. An example of a solid is **_glass_**.
4. A water line is referred to as a **_meniscus_**.
5. When a shape is lower in the middle and higher on the edges it is **_concave_**.
6. Water is an example of a **_liquid_**.
7. **_Adhesion_** occurs between a solid and liquid where molecules are not like each other.
8. When similar molecules group together, it is **_cohesion_**.
9. A raindrop has a **_convex_** shape, being higher in the middle than on the edges.
10. A scientific prediction is a **_hypothesis_**.

Activities

continued

6a How many drops can you get on a penny before the water falls off the penny?

6b How many paper clips can you float on the surface of a pan of water before they sink?

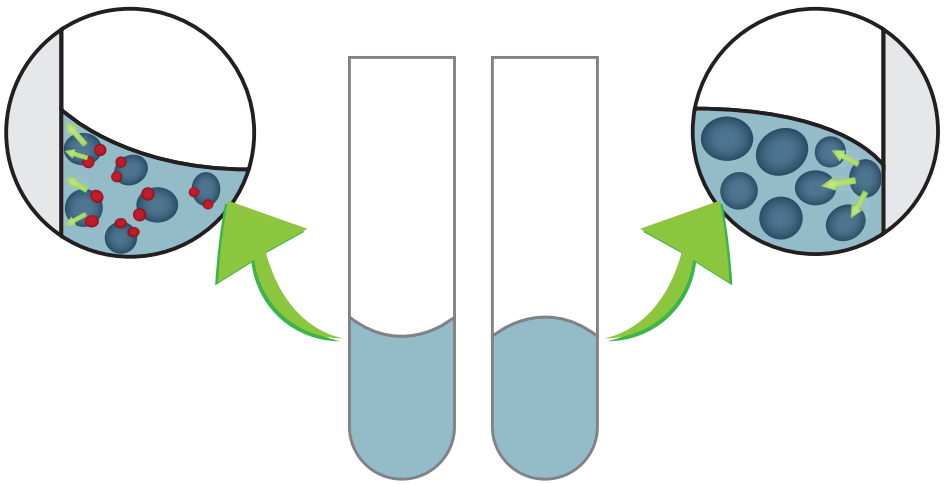
6c Float some pepper on the surface of water. Add one drop of soap and observe. What happens and why?

Explain in terms of adhesion and surface tension.

7 How will a water droplet behave if it does not stick to the container, too?
Use an aluminum can and hold the bottom above a burning candle, Cheeto, corn chip, or some other kind of burning fuel that will deposit a layer of carbon on the bottom of the can.

Use a dropper to put a drop of water on the carbon.
How is this different from the glass? *(not attracted – repelled)*.

If the capillary action demo was made from carbon instead of glass, would the meniscus be the same? What do you predict would happen?



Concave up meniscus Concave down meniscus

How it works

Atoms, ions, and molecules are sticky particles. They stick to each other through electrostatic attractive forces. They don't stick when those same forces are neutral or repulsive.

Compounds are solids, liquids, or gasses because of increasing or decreasing attractive forces. Solids have the strongest attractiveness and gasses have the least. Liquids are intermediate.

The observable properties of each state of matter can be explained using electrostatic attractive forces, including capillary action of liquids. Solids don't exhibit this property because they are always more attracted to each other more than the container they are in. Therefore, solids will always maintain their shape and volume.

Gasses are only attracted to each other weakly (if at all) and therefore do not exhibit this because they never maintain their shape or volume. They will completely fill whatever container they are in, not because of attractive forces but because their molecules lack attractive forces.

Liquids are intermediate, they stick to each other (cohesive forces) and they stick to the sides of their container (adhesive forces) and therefore do not maintain their shape but they do maintain their volume.

The attractive forces between the liquid particles and the attractive forces between the glass and liquid particles can appear to defy gravity when the diameter of the tube is small enough to allow the attractive forces between the glass and liquid to be stronger than the attractive force between the liquid and the earth (gravity).

Assessment

1
- Participation in discussion
- Quiz/Student Handout
- Vocabulary

2 **Vocabulary:**
adhesion, capillary action, cohesion, concave, convex, glass, gravity, hypothesis, intermolecular forces, liquid, meniscus, paper chromatography, surface tension

ACTIVITIES

1 Gravity versus Capillary Action

a Pour water from one container to another container. What is the direction of the water? Why is the water flowing downward? *Answer: gravity*

b Hold a filter strip or absorbent paper towel strip in one of the water containers. What is the direction of the water? Why is water flowing upward? *Answer: capillary action*

Note:

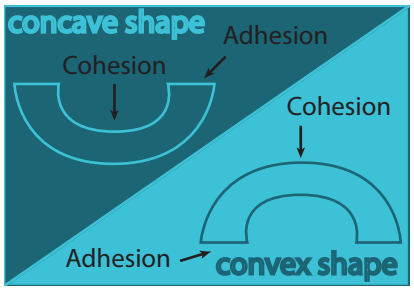
It is always best to practice an experiment ahead of time to be able to best present it to the class.

2 Shape of Water Line in Capillary Tube verses a Raindrop

a Discuss the fact that glass is a solid and water is a liquid. As a class, make a list of solids and a list of liquids.

b Each student observes at eye level the water line shape in the largest capillary tube. This water line is a meniscus. Have each student draw a picture of the water line shape.

c As a class, discuss the concave shape. Discuss why the water is higher toward the outer glass surface (adhesion) and lower in the middle (cohesion). Have students label their water line picture with terms learned. Cohesion and adhesion cause the liquids to work against gravity.



d Ask students to remember seeing a raindrop hit a hard surface like a driveway. What was the shape of the raindrop? Discuss a convex shape along with adhesion and cohesion. Students should draw and label a picture of a raindrop.

3 Water Level Experiments

a Students observe the glass capillary tube set. Explain that water will be poured into the large reservoir tube and flow into the other 3 tubes.

ACTIVITIES

3 b Have students write down a prediction of the water levels in each of the three tubes. How is each tube different? *Answer: inner diameter*

c Measure water in a measuring cup or graduated cylinder. Mix in food coloring. Pour the colored water into the largest reservoir glass tube. Are the water heights the same in each tube?
Have students measure and record the height of the water in each capillary tube (small, medium, and large).

Is there a relationship between the height the water reaches and the inside diameter of the tube? Graph it.

Is there a linear relationship? Is it a constant? Make a ratio between the height and the diameter of the tube. Can you predict the diameter or height of water in another tube using a proportion?

d If you put different liquids in the capillary tubes, do they reach different heights? Why? Try rubbing alcohol or hydrogen peroxide.

What happens if you add a solute like sugar or salt to the water?
Does the height change? Why? Explain in terms of attractive forces.

4 Use capillary action to separate black water soluble markers into their component inks

You will need strips of coffee filter paper and black markers.
Mark a black dot about one inch from one end of the paper. Cut the end into a point. Place the point in water (be sure not to get the black dot in the water).
Watch the water climb the paper through capillary action and separate the ink into different colors.
Why do some colors stop climbing the paper with the solvent? *(They are more attracted to the paper than the water and/or they are bigger, so gravity pulls them more)*.

5 Celery and Food Colored Water

Cut the end of celery (with leafy parts still attached) and place it in red food colored water.
Measure the capillary action moving the red color up the plant.
How long does it take to get to the leafy parts?
How much does it move up the stalk each day?

6 Have a Water Olympics

There are many activities to explore the adhesive, cohesive, and surface tension in water due to intermolecular “stickiness”.

Continued on P. 6

STUDENT HANDOUT

QUIZ

Student Name: _____

Use the following terms to fill in the blanks.

meniscus	capillary action	liquid
gravity	adhesion	concave
convex	cohesion	
glass	hypothesis	

1. A downward force is _____.

2. _____ _____ occurs when a liquid moves upward within a glass tube.

3. An example of a solid is _____.

4. A water line is referred to as a _____.

5. When a shape is lower in the middle and higher on the edges it is _____.

6. Water is an example of a _____.

7. _____ occurs between a solid and liquid where molecules are not like each other.

8. When similar molecules group together, it is _____.

9. A raindrop has a _____ shape, being higher in the middle than on the edges.

10. A scientific prediction is a _____.