# The Air Around You

*Section* PROPERTIES OF MATTER *Topic* STATES OF MATTER

**Estimated Time** Setup: 5 minutes; Procedure: 5-10 minutes

## OVERVIEW

Students place an inverted cup containing a paper towel into a bowl of water to show that air takes up space.

This activity demonstrates the presence of gas, a state of matter that can be difficult to see, by providing a method to show that air (a mixture of gases) takes up space. In this activity, a paper towel is lodged in the bottom of a cup. The cup is inverted and placed into a bowl of water until it is submerged. Since air takes up space and prevents the water from entering the cup, the paper towel remains dry even when the cup is submerged in water.

## MATERIALS

**For one setup:**

- Clear glass or plastic cup
- Bowl or container, deep enough to submerge cup
- Bounty® paper towels
- Tape
- Water

## INQUIRY QUESTIONS

**Getting Started:**

- How can we see that all matter takes up space?

**Learning More:**

- How can we observe and measure properties of matter?

**Diving Deeper:**

- Can we develop a model to show that air takes up space?

## ACTIVITY NOTES

**This activity is good for:**

- Demonstration
- Small or large groups
- Concept introduction

**Safety Tips & Reminders:**

- This activity can be messy with younger students. Have plenty of paper towels and a clear space.
- Review the Safety First section in the Resource Guide for additional information.

## CONTENT TOPICS

**This activity covers the following content topics:** states of matter, properties of matter, physical properties

**This activity can be extended to discuss the following:** displacement, volume, surface tension, gas pressure, contact forces, particles interactions, kinetic energy

## NGSS CONNECTIONS

**This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:**

- **2-PS1-1:** Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
- **5-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **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.

# ENGAGE

Use the following ideas to engage your students in learning about states of matter:

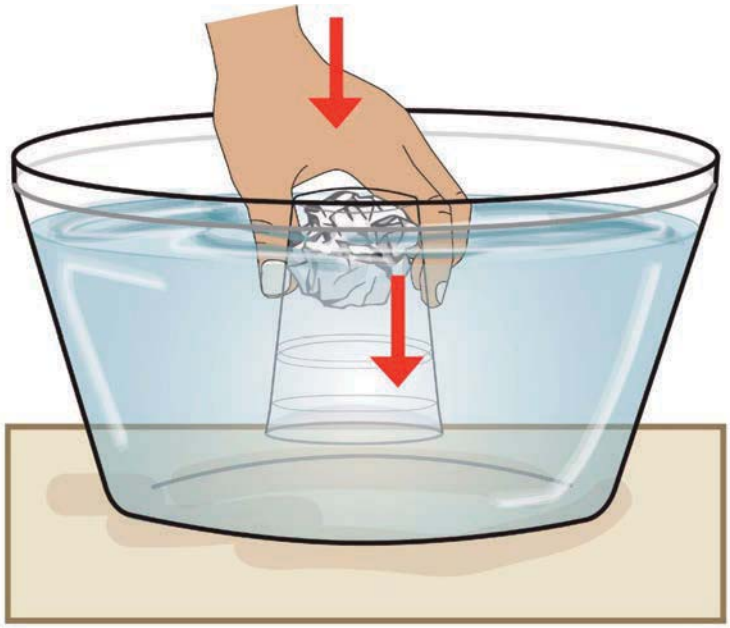
- Challenge your students to put a paper towel in a bowl of water without getting the paper towel wet. Provide them with all the materials for this experiment and pose the question as a mystery problem.
- Use a balloon to show the air pressure inside of a plastic bottle. Put an un-inflated balloon inside of a plastic bottle so that the opening to the balloon is around the mouth of the bottle. Have students try blowing up the balloon inside the bottle. Why can't they do it? How can they change the setup so that the balloon will inflate? Use a nail or other sharp object to poke a hole in the bottom of the plastic bottle. Do they think the balloon will be able to inflate now? Why?

See more ideas for engagement in the States of Matter Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

# EXPLORE

## Procedure:

1. Crumple a Bounty® paper towel into a ball and push it to the bottom of the cup until it stays in place. The paper towel should not fall out when the cup is inverted. Tape it to the cup if necessary.
2. Fill a deep bowl with enough water to submerge the cup.
3. Turn the cup upside down and push it straight down into the bowl of water, but be sure to not let the cup touch the bottom. Hold the cup still while it is submerged in the water for a few seconds.
4. Pull the cup straight out of the water and feel the paper towel. Record your observations.



## *Fun Fact* #1

**The earth is wrapped in a layer of gas called the atmosphere. Gravity keeps the atmosphere from dissipating into space. The atmosphere remains connected to the earth by gravity, so it does not float off into space.**

# Notes

## DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- What happens when you push the cup down in the water? What does the water do?
- Why can we fully submerge a cup in water and still have a dry paper towel?
- When you pull the cup out of the water, is the paper towel wet? Why or why not?
- If there is not any water in the cup, is the cup empty?
- If you place the cup into the water at an angle, will the result stay the same? What do you notice is different when you do this? Is it easier or more difficult to push the cup down at an angle? Why?
- In what other ways or situations can it be seen that air takes up space? What other proof is there that air is a type of matter and takes up space?

*Fun Fact #2*

**Wind energy is an abundant source of energy in many parts of the U.S. It is used mainly to generate electricity. Wind is a type of renewable energy, meaning it does not use up the earth's resources.**

# EXPLAIN

## What's happening in this Activity?

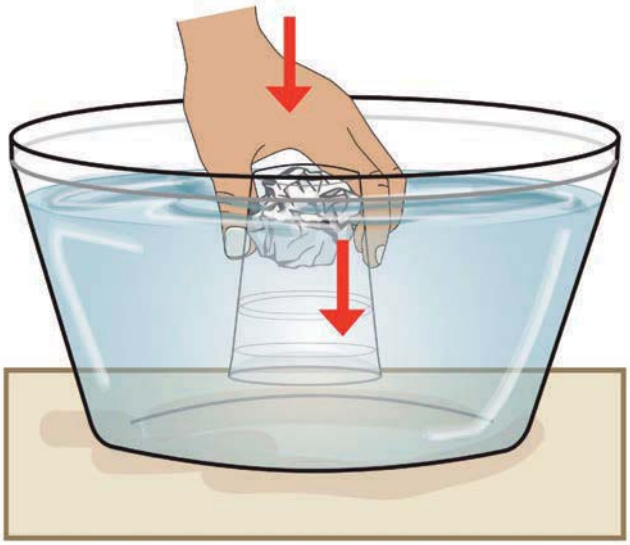
First review the States of Matter Background section to gain a deeper understanding of the scientific principles behind this activity.

All matter takes up space. For many types of matter we can see this, but for others we can't. Solids, liquids, and gases are all states of matter, and therefore all take up space. It is easy to see a solid or liquid taking up space, but it can be difficult to see a gas taking space.

However, there are other ways we can observe the presence of a gas. For example, we may not be able to see the air around us, but we can feel it in different situations, such as a gust of wind or a balloon expanding as it is blown up. This expansion occurs because the gases you exhale are taking up space within the balloon, pushing the sides of the balloon outward.

In this experiment, a paper towel is lodged in the bottom of a cup. Then the cup is inverted and placed straight down into a bowl of water. In order for air to occupy space in the bowl, the water that was already there needs to move out of the way. The cup and the air inside it displace some of the water in the bowl, causing the water level to rise. Air in the cup takes up space and prevents the water from entering the cup. The air remains in the space surrounding the paper towel, keeping the paper towel dry.

Water can only enter the cup (and get the paper towel wet) if air escapes. Because air is matter and takes up space, it prevents water from filling up the cup.



Diving deeper in the concepts at play in this activity, we can also see **displacement** in action. **Displacement** occurs when an object takes up space in a fluid (a liquid or gas) and pushes the fluid that was there out of the way. As the cup and air moves into the space where the water used to be, the water is forced out of the way—or displaced—and the volume of the system (water and cup and air) increases. The amount of water that is moved, or displaced, is equal to the object's volume. Think about when you get into a full bathtub, or when you pour a box of pasta into boiling water. The water level rises when objects are added.

# EXPLAIN continued

## Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

### GETTING STARTED

**For younger students, emphasize the following concepts:**

- Matter has mass and takes up space
- Matter exists in different phases and is made up of particles too small to be seen.
- Each state of matter of a substance has unique physical properties.
- Air is a gas and takes up space
- Volume measures the amount of space an object occupies

### DIVING DEEPER

**For more advanced students, emphasize the following concepts:**

- Displacement is the act of moving something out of its original position or of one substance taking the place of another.
- There are various ways to calculate volume based on the state and shape of the substance, including displacement and mathematical formulas

# ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Conduct the experiment as described. Then after completing Step 4, place the cup back in the water, but this time, tilt the cup. When the cup is tilted, air can escape from the cup, and water can displace the air. The amount of water that displaces the air can be controlled by how much you tilt the cup in the water. Tilting the cup about 45 degrees should cause the water to enter halfway, pushing out half of the air.
- After the paper towel is lodged in the bottom of the cup, pose the experiment as a challenge to determine what volume of water the cup can hold without getting the paper towel wet. Provide students with a large measuring cup to hold the water instead of a bowl. See if students can figure out that they need to invert the cup and record how much the water in the measuring cup rises.
- Tie in the experiment with pressure and changes in pressure. How deep would you have to submerge the cup before the paper towel gets wet? How many miles below sea level? How would the pressure change?
- Perform the experiment as described but take the explanation further to focus more on displacement and volume. Because air has mass, the air inside of the cup takes up space. This space can be determined by calculating the volume of the cup. **Volume** is a measure of the amount of space an object occupies. There are various ways to calculate volume based on the state and shape of the substance. The approximate volume of the gas inside a glass can be calculated by the equation: $V = h\pi r2$. In this equation, h is the height of the glass, r is the radius of the bottom of the glass, and π is a constant multiplier. This is the equation for the volume of a cylinder.

# EVALUATE

- Have the students draw a diagram showing all of the forces acting on the air in the cup and on the water when the cup is inverted. Have them write down conclusions they can make about the relative strengths of the different forces.
- Have each student find a method of measuring air pressure, either current or from the past. How does each method work?
- Are there any other ways we can determine if gas takes up space? Challenge students to develop a different model to show that gases are a state of matter and therefore take up space.

# CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

## Real-World Applications

The idea of inverting a container and submerging it underwater was used to build the Brooklyn Bridge. The large containers, called caissons, were inverted and submerged in the Hudson (the river the Brooklyn Bridge crosses) allowing workers to dig on the bottom of the river and keep the water out.

Wind is simply movement of air on a large scale caused by differences in air pressure within our atmosphere. While most of the time we can't even feel the air, wind can lift the roof off a building, blow down trees, and push us around. The movement of air also makes the temperature feel cooler. This is often referred to as wind-chill. The movement of the air increases the amount of heat lost from your body. The wind-chill factor is similar to using a fan to help cool you down or blowing on a hot cup of tea.

**Air pressure** varies with altitude. At higher elevations, the air pressure is lower than at sea level. When you fly in a plane or travel up a mountain, your ears may "pop." As you travel higher in the atmosphere, outside air pressure decreases. As a result, the air pressure exerted by the air trapped in your inner ear is no longer balanced with the air pressure outside. The trapped air will begin to push outward toward the lower pressure area, which can cause discomfort. The pressure can equalize when some air from your inner ear escapes through the Eustachian tubes, the small channel in each ear that connects the inner ear to the throat. When they open, you feel the pressure release—the "pop." You can hear this change because it is happening in your ear. However, before the pop, you may notice that your hearing ability decreases. The buildup of pressure inside your ear makes it more difficult to transmit sound.

The atmosphere has a clear layer of a gas called ozone ($O_3$) which protects us from many of the sun's harmful rays.

## Careers in Chemistry

- Atmospheric scientists study air pressure and other properties of the atmosphere to analyze climate patterns. Scientists can use a variety of instruments to measure air pressure changes and patterns to understand climate and weather patterns, and even predict short or long-term weather forecasts.

## Notes