Science Snack

Pop Bottle

Put a new twist on pressure changes.

Grade Band: **Grades 6-8, Grades 9-12**

Subject **States of Matter Heat and Temperature Sound Atmosphere**

Activity Tags:**gas, phase change, force, Newton's laws, water, fog, pressure, volume, temperature**

Next Generation Science Standards **Cause and Effect Scale, Proportion, and Quantity Systems and System Models Energy And Matter Stability and Change ESS2 PS1 PS2 PS3 ETS1**

Put a new twist on pressure changes.
Twisting a plastic water bottle changes its volume, pressure, and temperature—and ends with a bang.

Caution: This Snack involves flying bottle caps. Use eye protection and aim safely away from yourself or anyone nearby.

Tools and Materials

- One half-liter (500 ml) clear, thin-walled plastic water bottle with screw-on cap (bottles with thin, transparent caps work best)
- Goggles
- Optional: isopropyl alcohol, hand-held infrared thermometer, a partner

Assembly

None needed.

To Do and Notice

Note: If your water bottle happens to be full of water, drink up to empty it. It's fine—even preferable—if there are still a few droplets of water left inside.

Put on your goggles.

Screw the cap on the bottle, but not all the way: The cap should be tight enough to make an airtight seal, but loose enough so you can unscrew it with a flick of your thumb. (You'll figure this out after one or two tries.)

Grab the bottle at both ends and twist your hands in opposite directions. Twist hard—hard enough to create a narrow "waist" around the middle of the bottle. (Click to enlarge photos below.) Do you notice the bottle feeling warmer as you do this?


Point the top of the bottle away from yourself or anyone nearby. While holding tension on the twisted bottle, remove the cap with a sideways flick of your thumb. ***Caution: The cap will fly off rapidly. Never aim it at another person.***

Watch carefully: You may see a small cloud of mist form near the mouth of the bottle after you release the cap. *Note: If you can't get mist to emerge from the mouth of the bottle, try adding a few drops of isopropyl alcohol, and then shake the bottle. Isopropyl alcohol's lower vapor pressure will condense more easily than water vapor when you unscrew the cap.*

If you happen to have an infrared thermometer, repeat the experiment and have a partner measure the temperature of the bottle before you squeeze it, as it is being squeezed, and then after the cap has been released. (Click photo to enlarge.)

If you want to do this Snack again, just blow into the bottle to re-inflate it and you'll be ready to go. The bottle can be used multiple times. *Note: Do not re-inflate by mouth if you've previously used isopropyl alcohol in the bottle.*

What's Going On?

Did the cap go flying off? Did you hear a “pop”? Did you see mist wafting from the mouth of the bottle? All of these events tell you that your “empty” bottle was anything but empty.

When you twist the sealed bottle, you decrease the volume of the air trapped inside. When gas molecules are forced closer together in this way, the pressure inside the bottle increases. This increased pressure is what makes the cap fly across the room when released.

The “pop” you hear is caused by a sudden change in air pressure. When you release the cap, the higher-pressure air inside the bottle rushes out into the lower-pressure air inside the room. This sudden expansion creates a pressure wave that you hear as sound.

As you twist the bottle, you might feel (or measure) it getting warmer. After the cap flies, you might notice the bottle getting cooler. There is a direct relationship between pressure and temperature in a gas: increasing the pressure increases the temperature; reducing the pressure reduces the temperature.

The mist that forms reveals that there's not just air inside your bottle, but also some water vapor. At the relatively higher temperatures and pressures inside the twisted bottle, the water vapor remains a gas. But when you release the cap, the sudden drop in pressure and temperature causes the water to condense into visible droplets of liquid water.

Going Further

There are several other experiments and engineering challenges you can do with this Snack. For instance, you might want to investigate how far your cap will fly. Is there a relationship between the number of twists and the distance at which the cap lands?

How much does the pressure change when you twist the bottle? Can you engineer a system to determine the internal pressure of the bottle before and after twisting?

How much does the volume change? Can you figure this out using graduated cylinders, measuring cups, or other tools?

Can you use the measurements from the activities above to come up with a relationship between temperature, pressure, and volume? This relationship is known as the *ideal gas law*.

Teaching Tips

As a homework assignment, ask students to bring in empty plastic water bottles. Take students outside or into a gym. With no introduction and with a twist of the wrist and a flick of the thumb pop the top off a bottle. This is an exciting way to introduce this Snack with a bang!

Let students engage in this activity after a quick demonstration (including a discussion of proper safety precautions). *Note: Since you can re-inflate your bottle by mouth, each experimenter should have their own bottle. Do not re-inflate by mouth if you've previously used isopropyl alcohol in the bottle. Depending on the number of students involved a further safety precaution would be to label each bottle and cap so students can retrieve their own associated part.*

After students have had a chance to launch their bottle caps, ask them what they want to do or try next. This Snack can lead to an explosion of investigations and questions relating directly relate to core scientific concepts and Science and Engineering Practices. Many questions or self-imposed challenges might arise such as: How can I make my cap go further? Who can make the most clouds in their bottle? Who can make the loudest pop? Have students take notes and make measurements; encourage them to write down their questions and design experiments to investigate further.

This Snack requires no background knowledge, just a strong wrist and fast thumb. However, this Snack can lead to discussions and lessons on a variety of gas-laws as well as kinematic concepts. It can reveal practical applications of this phenomena in modern machines—like combustion engines, refrigerators, and rockets—as well as the study of the weather (meteorology).