Snack Name
Pop Bottle

Tagline
Put a new twist on pressure changes.

Introduction
Twisting a plastic water bottle changes its volume, pressure, and temperature—and ends with a bang.

Caution: Bottle caps will fly off; use eye protection for this activity.

Tools and Materials

- A ½ liter (500ml) clear, thin-walled, plastic water bottle with screw-on cap. Bottles with a thin transparent caps work the best.
- Goggles
- Optional: Hand-held digital thermometer

To Do and Notice

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

2. Put on your goggles.

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

4. 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.

   Do you notice the bottle feeling warmer as you do this?

5. Point the top of the bottle away from your own face or anyone else's. While holding tension on the twisted bottle, remove the cap with a sideways flick of your thumb. Listen and watch carefully after the cap is released!

   Did you hear a pop?
   Did the cap fly off?
   Did you notice a small puff of mist form near the mouth of the bottle?

Caution: The cap will fly off rapidly. Never aim it at another person.

6. If you happen to have a digital thermometer, repeat the experiment and measure the change in temperature as the bottle is squeezed and released.

Exploratorium by Eric Muller 2018

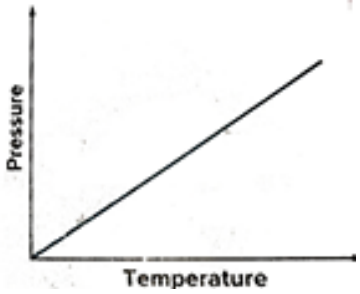
What's going on?
Did the cap go flying off? Did it make a "pop" sound? Did you see mist wafting from the mouth of the bottle? All of this tells you that your "empty" bottle was anything but empty.

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 increases. This increased pressure is what causes the cap to fly across the room when you release it.

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 surrounding lower-pressure in the room. This sudden expansion causes a pressure wave to hit your ear, which you hear as sound.

As you twisted the bottle, you might have felt (or measured) it getting warmer. After the cap flew off, you might have noticed it gets cooler. There is a direct relationship between pressure and temperature in a gas: Increasing the pressure increases the temperature. Meanwhile, 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 of 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.

- How far will your cap fly? Is there a relationship between the number of twists and the distance at which the cap lands?
- Use a digital thermometer to measure exactly how much the temperature changes when you twist the bottle.
- 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 did the volume change? Can you figure this out using graduated cylinders, measuring cups or other tools?
- Can you use your above measurements to come up with a relationship between temperature, pressure, and volume? This relationship is known as the *ideal gas law*.

Teacher Tips and Science Standards

- **If you want to do this activity again, just blow into the bottle to re-inflate it; then you're ready to go. The bottle can be used multiple times.**
  Note: Since you can re-inflate your bottle by mouth, it's a good idea that each experimenter have their own bottle.

- **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's lower vapor pressure will condense more easily than water vapor when you unscrew the cap.**

- **This Snack can help explain many gas law concepts, as wells as concepts used in the engineering of many modern machines: from combustion engines to refrigerators.**

- **It can be use to demonstrate Newton's Laws of Motion.**

Subject category

Atmosphere
States of Matter
Heat & Temperature
Sound

Keywords

Gas laws, ideal gas, meteorology, kinematics, mechanics, force, newton, torsion, physics, chemistry, cloud, fog, Avogadro, delta, compression, expansion, pressure, volume, temperature, Guy- Lussac