How are pressure and volume related?

An interactive investigation of the science of the atmosphere

Overview

Pressure and volume are inversely proportional to each other. This means that as the pressure decreases, the volume increases, and as the pressure increases, the volume decreases. One way to think of this is if you push on a gas by decreasing its volume, it pushes back by increasing its pressure. This relationship is called Boyle's Law and makes up part of the ideal gas law.

Necessary materials:

- Vacuum containers
- Marshmallows
- Whipped cream

Theory

When the volume of a gas shrinks, the gas molecules have less space to move around and so they hit their container more often. The more frequently the gas impacts the container walls, the higher the pressure. So, as volume decreases, the pressure increases. If the container expands, the impacts are less frequent and the pressure decreases.

This relationship can be described using mathematics as well. Mathematically, Boyle's Law states that

$$PV = k$$

where k is any constant.

Boyle's Law is important for both astronauts and divers. Since the pressure in space is near zero, space suits have to be able to withstand the expansion of the air that is within the suit when the astronaut goes outside. When divers are surfacing, they must exhale. If they don't, the air that is held in their lungs will expand and could rupture the lung tissue.

This experiment shows how the volume of the air in whipped cream reacts to lowering pressure.

Doing the Experiment

SAFETY NOTE: Be very careful with all glassware, especially when under vacuum.

The experiment goes like this:

- Set up the vacuum container.
- Place a marshmallow inside the container.
- Start the vacuum.
- Notice what happens to the size of the marshmallow.
- Remove the marshmallow and place some whipped cream in the container.
- Start the vacuum again.
- Notice what happens to the size of the whipped cream.

Why did the size of the whipped cream change? What do you think happens to air as it rises and encounters lower pressures?

Summing Up

This exercise is a quick example of how pressure and volume change together. Boyle's Law is one part of the ideal gas law and explains how gases change when temperature is held constant. As the pressure in the bell jar decreases, the volume of the air bubbles in the whipped cream expand, forcing the cream part to also become bigger and expand. This experiment can also be done with shaving cream, but it's not as tasty! ☺ Thinking of the atmosphere, how would the volume of an air parcel change as it rises and encounters lower pressure? What would happen to the density if the mass stayed the same (density = mass/volume)? If the temperature stayed the same, what would happen to the buoyancy of the air parcel?

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu