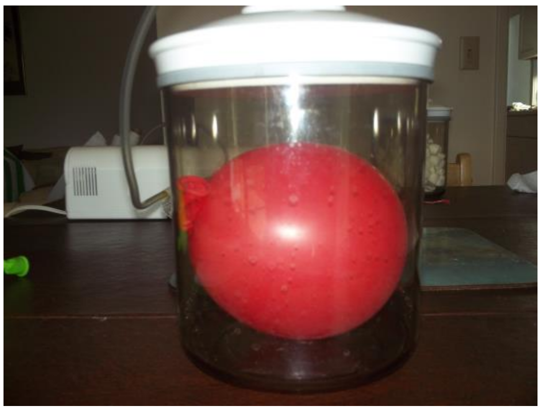
Chemistry Lecture #67: Demonstration of Boyle's Law & Charles's Law

According to Boyle's law, the volume of a gas depends on the pressure it is under. For example, a balloon will maintain its size as long as the gas pressure inside the balloon is the same as the atmospheric pressure outside the balloon.

If the atmospheric pressure outside the balloon decreases, the pressure inside the balloon will be greater, causing the balloon to expand. As the balloon expands, the pressure inside the balloon decreases until it matches the surrounding atmospheric pressure. When the pressure inside the balloon matches the outside pressure, the balloon stops expanding.

We can put a balloon inside a container and remove some of the air from the container using a gadget called the FoodSaver. When the balloon is surrounded by less air, there will be less atmospheric pressure, and the balloon will expand.

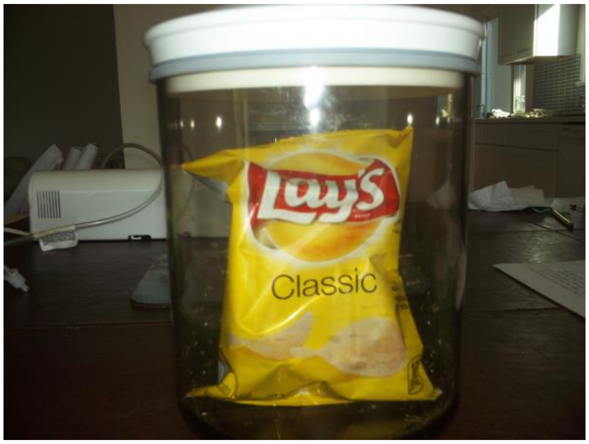
The balloon in the container is surrounded by air molecules.



When air is removed from the container, the balloon expands.

If the air is allowed back into the container, the balloon will be surrounded by more air molecules, which increases the atmospheric pressure. The balloon will then decrease in size.

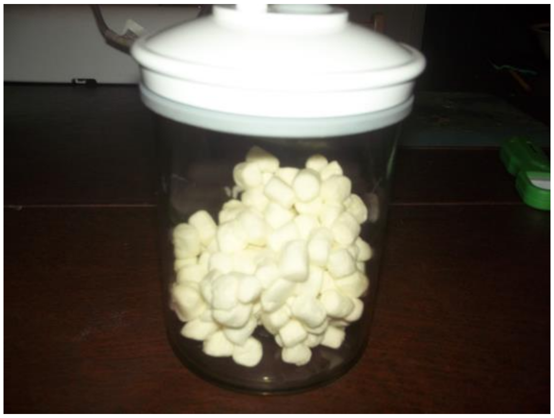
The same phenomenon occurs when you look at a bag of potato chips as you drive over a mountain range. At higher altitudes, the air is thinner, which reduces the atmospheric pressure. A bag of chips will expand as you go up the mountain. The bag will shrink as you go down the mountain.



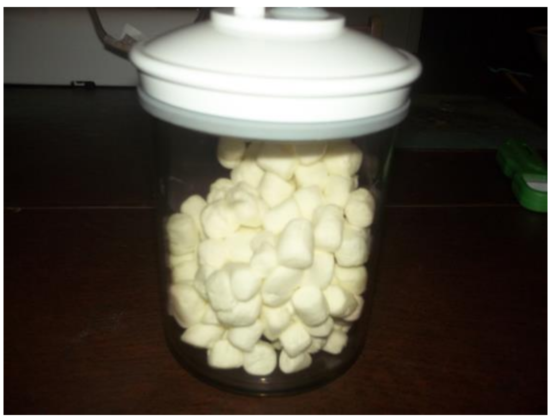
This is what a bag of chips looks like under regular atmospheric pressure.

This is what a bag of chips looks like at the top of a tall mountain (where the air is thinner).

Marshmallows will also expand and shrink as the atmospheric pressure changes. This occurs because marshmallows are filled with tiny pockets of air.



This is what marshmallows normally look like.



The marshmallows swell in size when the surrounding atmospheric pressure decreases.

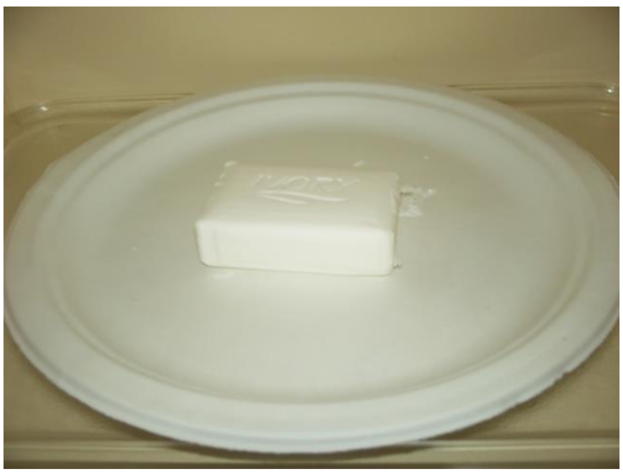
We can also use the FoodSaver to demonstrate how atmospheric pressure influences boiling. At higher altitudes, water boils more easily at lower temperatures since there is less atmospheric pressure pushing on the surface of the water. We don't have to boil water to show this influence; we can use soda water and watch the bubbles rise to the surface. We can remove some of the air above the surface of the soda water. This will reduce the air pressure above the liquid, which should cause more bubbles to rise to the surface.

A sealed container of soda water. Notice that most of the bubbles are on the bottom.

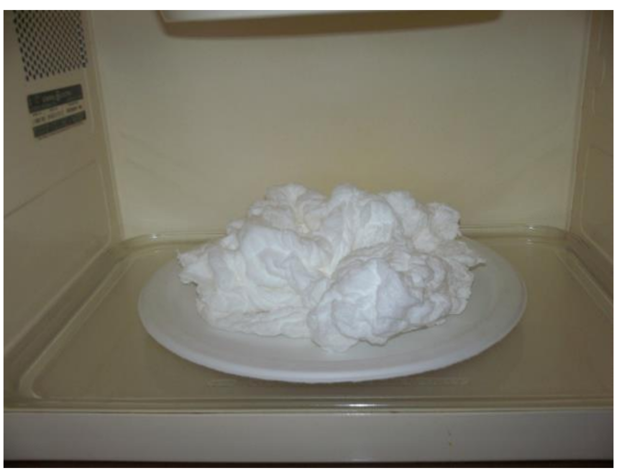
Air has been removed from the container. Notice that there are now more bubbles rising to the surface.

We've seen that atmospheric pressure influences both boiling and the volume of a gas. The volume of a gas is also influenced by temperature. According the Charles's law, a gas will have a higher volume at a higher temperature.

One way to observe Charles's law is with a bar of Ivory soap. Unlike most other bars of soap, Ivory soap has pockets of air trapped inside. If the air in the soap is heated, its volume will increase, causing the soap to expand. We can heat the soap by putting it in a microwave and heating it for a few minutes.



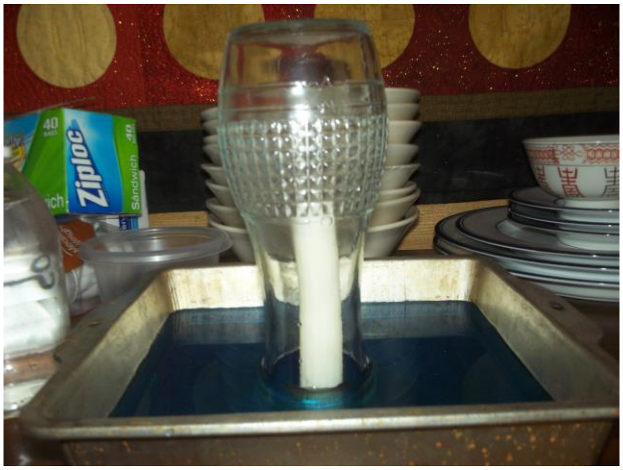
A bar of Ivory soap before it is heated in a microwave.



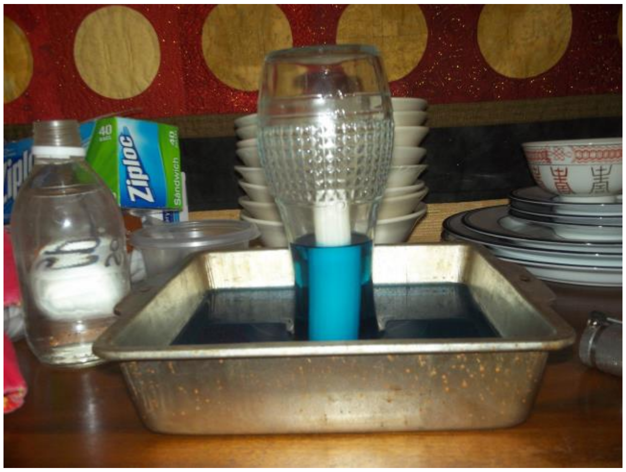
A bar of Ivory soap after being heated in a microwave. The heating causes the pockets of air in the soap to expand. This demonstrates the concept of Charles's law.

One other way to demonstrate Charles's law is to place a candle in a pan of water, light the candle, then cover the candle with a glass container.

As the flame heats the air in the container, the gas will expand, and some of it will go into the water. When the flame goes out, the temperature of the air decreases. At lower temperature, the air exerts less pressure. When the air pressure inside the glass drops below the air pressure outside the glass, the outside air pressure will push water into the glass.



A candle is placed in a pan of water. The candle is lit, and a glass container is inverted over the candle. Note the initial level of the water in the glass.



When the candle flame goes out, water moves into the glass.

The outside air pressure pushes on the surface of the water outside of the glass, which keeps the water level elevated on the inside of the glass. If the outside air pressure goes up and down, the water level in the glass would also go up and down. This is how a barometer works. The only difference is that a barometer uses liquid mercury instead of water.