Sizing up temperature

Explore Charles' Law in a syringe

Materials
plastic disposable syringe (5-10ml volumes work well)
beakers or glass cups
thermometer
water
microwave or heat block
ice
graph paper
(optional) food coloring

To do and notice

1. Move the plunger on the syringe so that 1/3 of the barrel is full of room temperature air.

2. Submerge the syringe tip in room temperature water and draw up water until the end of the plunger is at the maximum volume marking on the syringe. (optional) Add food coloring to the water to better visualize the movement of fluid in the syringe.

3. Record the volume of air trapped in the barrel by subtracting the volume of water from the maximum volume of the syringe. Also record the temperature in °C for this volume.

new temperature

4. Fill another beaker with water that is a different temperature, i.e. heated in a microwave or cooled with ice. Quickly transfer the syringe into the new beaker, making sure that the barrel is fully submerged.

5. Wait a few minutes for the gas trapped in the barrel to come to the temperature of the water. You will know that the temperature has equilibrated when the water level in the syringe stops moving. When stabilized, record the temperature of the water and the corresponding volume of gas. Note: if the water level in the syringe ever gets so low that gas bubbles come out, you have to start over with less air!

6. Repeat steps 4 and 5 until you have volume and temperature data for at least 5 different temperatures.

7. In chemistry, it is often inconvenient to deal with negative temperatures, which can occur on the Celsius or Fahrenheit scale. To get around this, temperatures are converted to the Kelvin scale, which never has negative values. Convert your Celsius (°C) temperature data to the Kelvin (K) scale by adding 273: temp(K) = temp(°C) +273

8. Plot the points for each volume (ml) and temperature (K) on a Cartesian graph. Do you notice a trend?

What's going on?

Charles' Law states that at a fixed pressure, the volume of a given amount of gas is directly proportional to its temperature. This means that if the temperature of the gas increases, its volume should as well. By leaving an air gap in the syringe barrel, you trapped a fixed amount of gas. When this increases or decreases in volume, it pushes out or pulls in water through the tip. You should have noticed that the volume of air in the syringe barrel changed when you brought it to a different temperature. By plotting volume vs. temperature on a graph, you may have noticed that the points tend to line up along a straight line. You could represent the equation of the line in the form, $V=kT$, where k is a constant (the slope of the line), which is the mathematical representation of Charles' Law.

Charles' Law can be combined with Boyle's Law (which relates pressure and volume), Gay-Lussac's Law (which relates temperature and pressure), and Avogadro's law (which relates volume and the amount of gas) to form the ideal gas law: $pV=nRT$.