Chemistry Lecture #68: Boyle's Law & Charles Law

Boyle's law predicts that if a balloon filled with gas is taken to the top of a mountain, the balloon will swell because the atmospheric pressure is lower. We can use a formula to mathematically predict the new volume of a balloon or gas when the pressure changes.

Boyle's law formula: $P_1V_1 = P_2V_2$

P_1 = initial pressure of the gas
V_1 = initial volume of the gas

P_2 = new pressure of the gas
V_2 = new volume of the gas

A gas has a volume of 242 mL and a pressure of 87.6 kPa. What is its volume at standard atmospheric pressure (101 kPa)?

Solution

P_1 = 87.6 kPa $\qquad$ P_2 = 101 kPa
V_1 = 242 mL $\qquad$ V_2 = ?

$P_1V_1 = P_2V_2$
$(87.6 \text{ kPa})(242 \text{ mL}) = (101 \text{ kPa})V_2$
$(87.6)(242) = 101\ V_2$
$$V_2 = \frac{(87.6)(242)}{101} = 209.893 = 2.10 \times 10^2 \text{ mL}$$

It doesn't matter what units of pressure we use. We could have used mm Hg, atm, or kPa. Also, the units of volume could have also been L, gallons, mL, etc.

Charles's law predicts that the volume of a gas will increase if its temperature increases. We can use a formula to predict the new volume of a gas when its temperature changes.

Charles's law formula

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

V_1 = initial volume of gas
T_1 = initial temperature of gas *in Kelvins*

V_2 = new volume of gas
T_2 = new temperature of gas *in Kelvins*

Notice that in order for this formula to work, the temperatures must be in Kelvins. Any type of unit can be used for volume.

A 234 mL volume of gas is heated from 50.0 °C to 100.0 °C. What is the new volume?

Solution

You might be tricked into thinking that since the temperature doubles from 50.0 to 100.0 degrees Celsius, the volume will also double. But Celsius is not an accurate measure of the kinetic energy of the gas. We need to convert the temperatures to Kelvin.

$K = C + 273$

$K = 50.0 + 273 = 323\ K = T_1$

$K = C + 273 = 100.0 + 273 = 373\ K = T_2$

$V_1 = 234\ mL \qquad V_2 = ?$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{234\ mL}{323\ K} = \frac{V_2}{373\ K}$$

$$V_2 = \frac{(234)(373)}{323}$$

$V_2 = 270.229 = 2.70 \times 10^2\ mL$