Chemistry Lecture #69: Gay-Lussac's Law and the Combined Gas Law

The volume of gas can be affected by temperature and pressure. If the temperature increases, the volume increases. If the gas is compressed, or put under higher pressure, its volume decreases.

What would happen if we kept the volume of a gas constant, and increased the temperature? Under these conditions, the pressure of the gas would increase.

For example, suppose I take a glass jar with the lid screwed on top. The volume of the gas inside the jar does not change.

The volume of a gas in a sealed jar does not change.

If we heat the jar, the temperature of the gas inside increases, and the gas molecules move faster. If the gas molecules move faster, they exert more pressure.

Gas molecules in a sealed jar move faster and exert more pressure when the jar is heated.

Thus, a gas at a higher temperature exerts more pressure if the volume is kept constant. This is an example of Gay-Lussac's law.

Mathematically, Gay-Lussac's law can be expressed as

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

P_1 = initial pressure of the gas
T_1 = initial temperature of the gas *in Kelvins*

P_2 = new pressure of the gas
T_2 = new temperature of the gas *in Kelvins*

Notice that the temperature must be in Kelvins for the formula to work.

The pressure of a gas in a sealed glass jar is 101 kPa at 22.0 °C. If the temperature rises to 60.0 °C, what will be the gas pressure in the jar?

Solution

We need to convert Celsius temperatures to Kelvin.

$K = C + 273 = 22.0 + 273 = 295$ Kelvin $= T_1$

$K = C + 273 = 60.0 + 273 = 333$ Kelvin $= T_2$

$P_1 = 101$ kPa $\qquad P_2 = ?$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{101}{295} = \frac{P_2}{333}$$ cross multiply

$$(295)\,P_2 = (101)(333)$$

$$P_2 = \frac{(101)(333)}{295}$$

$$P_2 = 114.01 = 114 \text{ kPa}$$

Thus, the pressure increases from 101 kPa to 114 kPa when the temperature increases from 22.0 °C to 60.0 °C.

A gas has the properties of pressure, volume and temperature. Gay-Lussac's law predicts changes in pressure when temperature changes. Charles's law predicts changes in volume when temperature changes. Boyle's law predicts changes in volume when pressure changes. How would we predict the change in volume if both pressure and temperature change?

The combined gas law can predict the change in one gas property if two properties change. Mathematically, it is expressed as

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

P_1 = initial pressure
V_1 = initial volume
T_1 = initial temperature *in Kelvins*

P_2 = new pressure
V_2 = new volume
T_2 = new temperature *in Kelvins*

Again, notice that the temperature must be in Kelvins for the formula to work.

A gas at 112 kPa and 30.0 °C has an initial volume of 2.00 L. Find the volume if the temperature is raised to 80.0 °C and the pressure is raised to 445 kPa.

Solution

First, change the temperatures to Kelvin.

$K = C + 273 = 30.0 + 273 = 303 \text{ Kelvin} = T_1$

$K = C + 273 = 80.0 + 273 = 353 \text{ Kelvin} = T_2$

$P_1 = 112 \text{ kPa}$ $\qquad$ $P_2 = 445 \text{ kPa}$

$V_1 = 2.00 \text{ L}$ $\qquad$ $V_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(112)(2.00)}{303} = \frac{(445)\,V_2}{353}$$

$$(303)(445)\,V_2 = (112)(2.00)(353)$$

$$V_2 = \frac{(112)(2.00)(353)}{(303)(445)}$$

$$V_2 = 0.5864 = 0.586 \text{ L}$$