4.5: Gas Laws

Describe the relationship among temperature, pressure, and volume in the gas laws.

You have just learned about several properties of matter and how heat can cause some of those properties to change. Add enough heat to a substance and it will become a gas. This discussion is focused on gas and how it reacts with changes in temperature, pressure, and volume. One property of gases is the pressure of the gas. Recall that particles in gases are very loosely held and are free to move around within a container. (Generally, a gas will assume the volume of the container that holds it.) These individual particles move and therefore have kinetic energy associated with them. As they move in random directions, they collide with the edges of the container, resulting in a force. Pressure is found by taking the force divided by the area.

Pressure = Force/Area

The SI unit for pressure is the pascal (Pa), which is equal to 1 newton per square meter. There are three laws that describe the relationships among the temperature, pressure, and volume of a gas. These laws are known as the gas laws.

Law 1: Boyle's Law

Robert Boyle discovered in 1662 that the pressure of a gas multiplied by its volume always gave the same number. So if you take a gas at a given temperature and change its volume, then the pressure changes as well. The relationship is an inverse relationship because if you increase the volume, the pressure will do the opposite—decrease. So doubling the volume would result in one-half the pressure; tripling the pressure would result in one-third the volume, and so forth. Since the pressure multiplied by the volume is always the same number, we can write a formula to represent *Boyle's law:*

$$P_1V_1 = P_2V_2$$

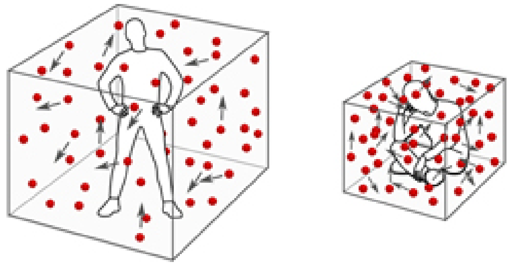

Figure 4.8: Boyle's law

Example 4.12:

The pressure of 50 liters of air is 0.00001 Pa. If we double the volume to 100 liters, what will the resulting pressure be?

Hide Answer

- P1V1 = P2V2
- (0.00001)(50) = P2 (100)
- 0.00050 = P2 (100) Divide both sides by 100.
- 0.000005 Pa = P2 Notice this is exactly one-half the original!

Law 2: Charles's Law

Around 1787, Jacques Charles discovered the relationship between volume and temperature of a gas. He found that at a constant pressure, the volume and the temperature change by the exact same amount. For example, if you double the temperature of a gas (while maintaining a constant pressure), its volume doubles as well. This is called a direct relationship. It is important to note that the temperatures here must be measured in Kelvins. Charles's law can be written as the following formula:

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

Example 4.13:

The temperature of 5 liters of air is 300 K. If we double the volume to 10 liters, what would the resulting temperature be?

Hide Answer

- $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
- $\frac{5}{300} = \frac{10}{T_2}$

To solve a proportion like this, cross multiply.

- (5)(T2) = (300)(10)
- 5 T2 = 3000 *Now divide both sides by 5.*

- **T2 = 600 K**

Law 3: Gay-Lussac's Law

Joseph Louis Gay-Lussac discovered another important relationship. He found that the relationship between pressure and temperature was a direct relationship, just like the relationship between volume and temperature. So if you double the pressure of a gas while maintaining a constant volume, the temperature doubles as well. It is important to note that the temperatures here must be measured in Kelvins as well. Gay-Lussac's law can be written as the following formula:

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

Example 4.14:

Air in a certain container has a pressure of 0.0005 Pa at a temperature of 270 K. If we change the temperature to 300 K, what will be the pressure?

Hide Answer

- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- $\frac{0.0005}{270} = \frac{P_2}{300}$

To solve a proportion like this, cross multiply.

- (270)(P2) = (0.0005)(300)
- (270)(P2) = 0.15 *Now divide both sides by 270.*
- P2 = 0.00056 Pa

Make sure you know the gas laws. Here is a simple table to help you remember them.

Boyle's Law	Charles' Law	Lussac's Law
inverse relationship	direct relationship	direct relationship
volume ↑ = pressure ↓ volume ↓ = pressure ↑	volume ↑ = temperature ↑ volume ↓ = temperature ↓	pressure ↑ = temperature ↑ pressure ↓ = temperature ↓
$P_1V_1 = P_2V_2$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Table 4.5: Gas Laws

If you want to think about some applications of gas laws, you only have to look at the internal combustion engine. You can also see them applied with the tanks used to fill balloons, add carbonation to your soda, or that are used in scuba diving.