7.4: The pressure-temperature relationship

Consider a gas in a cylinder with a piston in Figure 7.4.1. Increasing temperature increases the average kinetic energy (KE) and the average velocity of the gas molecules resulting in more frequent and more forceful collisions which result in increased gas pressure applied on the piston or the walls of the gas container.

Gay-Lussac's law

Gay-Lussac's law states that the pressure of a gas is directly proportional to the absolute temperature provided the volume and amount of gas are not changed.

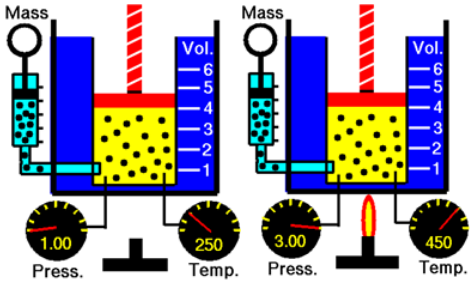

Figure 7.4.1: Increasing temperature increases pressure, i.e., $\frac{P_1}{T_1} = \frac{P_2}{T_2}$. Source: NASA's Glenn Research Center / Public domain.

The mathematical forms of Gay-Lussac's law are the following.

$$P \propto T$$

, or

$$P = \mathrm{k}T$$

, or

$$\frac{P}{T} = \mathrm{k},$$

where k is a constant, P is pressure, and T is the temperature (in kelvin scale) of the gas. Since Since $\frac{P}{T}$ is a constant, it implies that

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \mathrm{k},$$

where P_1 is the initial pressure, T_1 is the initial temperature in Kelvin, P_2 is the final pressure, and T_2 is the final temperature in Kelvin, provided the amount of gas and volume do not change.

Example 7.4.1

The pressure of an oxygen tank containing 15.0 L oxygen is 965 Torr at 55 ^{o}C. What will be the pressure when the tank is cooled to 16 ^{o}C.

Solution

First, convert the temperatures to the Kelvin scale before applying gas laws.

Given: T_1 = 55 ^{o}C + 273.15 = 328.15 K, T_2 = 16 ^{o}C + 273.15 = 289.15 K, P_1 = 965 Torr, P_2 = ?

Formula:

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

rearrange the formula to isolate the desired variable:

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

Plug in the values in the rearranged formula and calculate:

$$P_2 = \frac{965 \text{ Torr} \times 298.15 \text{ K}}{328.15 \text{ K}} = 850 \text{ Torr}$$
