2.1: The Empirical Gas Laws

A number of important relationships describing the nature of gas samples have been derived completely empirically (meaning based solely on observation rather making an attempt to define the theoretical reason these relationships may exist. These are the **empirical gas laws**.

Boyle's Law

One of the important relationships governing gas samples that can be modeled mathematically is the relationship between pressure and volume. Robert Boyle (1627 – 1691) (Hunter, 2004) did experiments to confirm the observations of Richard Towneley and Henry Powers to show that for a fixed sample of gas at a constant temperature, pressure and volume are inversely proportional.

$$pV = \text{constant}$$

or

$$p_1V_2 = p_2V_2$$

Boyle used a glass u-tube that was closed at one end and with the lower portion filled with mercury (trapping a sample of air in the closed end.) By adding mercury to the open end, he was able to observe and quantify the compression of the trapped air.

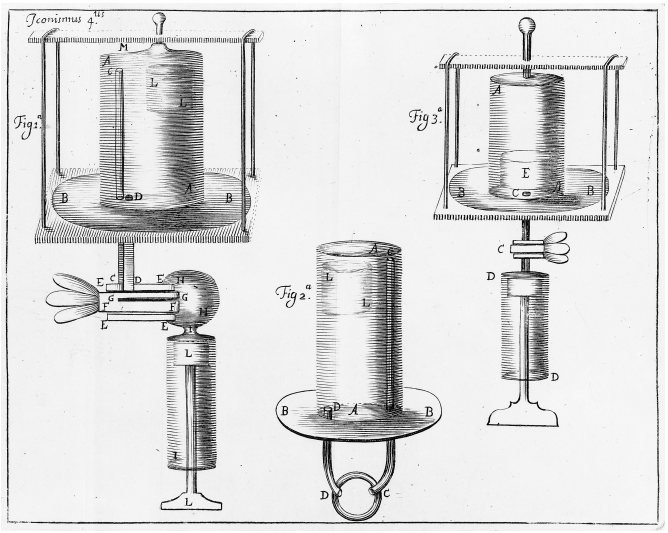

Figure 2.1.1: An apparatus similar to that used by Robert Boyle (1627 - 1691). Image taken from (Fazio, 1992).

Charles' Law

Charles' Law states that the volume of a fixed sample of gas at constant pressure is proportional to the temperature. For this law to work, there must be an absolute minimum to the temperature scale since there is certainly an absolute minimum to the volume scale!

$$\frac{V}{T} = \text{constant}$$

or

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

The second law of thermodynamics also predicts an absolute minimum temperature, but that will be developed in a later chapter.

Gay-Lussac's Law

Gay-Lussac's Law states that the pressure of a fixed sample of gas is proportional to the temperature. As with Charles' Law, this suggests the existence of an absolute minimum to the temperature scale since the pressure can never be negative.

$$\frac{p}{T} = \text{constant}$$

or

$$\frac{p_1}{T_2} = \frac{p_1}{T_2}$$

Combined Gas Law

Boyle's, Charles', and Gay-Lussac's Laws can be combined into a single empirical formula that can be useful. For a given amount of gas, the following relationship must hold:

$$\frac{pV}{T} = \text{constant}$$

or

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

Avogadro's Law

Amedeo Avogadro (1776-1856) (Encycolopedia, 2016) did extensive work with gases in his studies of matter. In the course of his work, he noted an important relationship between the number of moles in a gas sample. Avogadro's Law (Avogadro, 1811) states that at the same temperature and pressure, any sample of gas has the same number of molecules per unit volume.

$$\frac{n}{V} = \text{constant}$$

or

$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

Figure 2.1.2: Amedeao Avogadro (1776 - 1856)