Properties of Gases

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When the density of a gas is sufficiently low, the pressure, volume, and temperature of the gas tend to be related to one another in a fairly simple way. This relationship is a good approximation for the behavior of many real gases over a wide range of temperatures and pressures, provided their particles are not charged, as in a plasma. These observations have led scientists to develop the concept of an *ideal gas.*

Volume, pressure, and temperature are the three variables that completely describe the macroscopic state of an ideal gas. One of the most important equations in fluid mechanics relates these three quantities to each other.

The ideal gas law

The *ideal gas law* is an expression that relates the volume, pressure, and temperature of a gas. This relationship can be written as follows:

IDEAL GAS LAW

$$PV = Nk_BT$$

pressure × volume =
number of gas particles × Boltzmann's constant × temperature

The symbol k_B represents *Boltzmann's constant.* Its value has been experimentally determined to be approximately 1.38×10^{-23} J/K. Note that when applying the ideal gas law, you must express the temperature in the Kelvin scale. (See the chapter "Heat" to learn about the Kelvin scale.) Also, the ideal gas law makes no mention of the composition of the gas. The gas particles could be oxygen, carbon dioxide, or any other gas. In this sense, the ideal gas law is universally applicable to all gases.

If a gas undergoes a change in volume, pressure, or temperature (or any combination of these), the ideal gas law can be expressed in a particularly useful form. If the number of particles in the gas is constant, the initial and final states of the gas are related as follows:

$$N_1 = N_2$$
$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Figure 1
The balloon is inflated because the volume and pressure of the air inside are both increasing.

This relation is illustrated in the experiment shown in **Figure 1.** In this experiment, a flask filled with air (V_1 equals the volume of the flask) at room temperature (T_1) and atmospheric pressure ($P_1 = P_0$) is placed over a heat source, with a balloon placed over the opening of the flask. As the flask sits over the burner, the temperature of the air inside it increases from T_1 to T_2.