6.3: Joule-Kelvin Expansion

The expansion of a gas through a small opening or a porous plug with the pressure on either side being maintained is called Joule-Kelvin expansion. It is sometimes referred to as the Joule-Thomson expansion since Thomson was Lord Kelvin's original name. The pressures are maintained by the flow of gases but for the theoretical discussion, we may think of them as being maintained by pistons which move in or out to keep the pressure the same. The values of the pressures on the two sides of the plug are not the same. The gas undergoes a decrease in volume on one side as the molecules move through the opening to the other side. The volume on the other side increases as molecules move in. The whole system is adiabatically sealed so that the net flow of heat in or out is zero.

Since $dQ = 0$, we can write, from the first law,

$$dU + p dV = 0 \tag{6.3.1}$$

Consider the gas on one side starting with volume V_1 going down to zero while on the other side the volume increases from zero to V_2. Integrating Equation 6.3.1, we find

$$\int_{p_1,V_1,U_1}^{0} (dU + p dV) + \int_{0}^{p_2,V_2,U_2} (dU + p dV) = 0 \tag{6.3.2}$$

This yields the relation

$$U_1 + p_1 V_1 = U_2 + p_2 V_2 \tag{6.3.3}$$

Thus the enthalpy on either side of the opening is the same. It is isenthalpic expansion. The change in the temperature of the gas is given by

$$\Delta T = \int_{p_1}^{p_2} dp \left(\frac{\partial T}{\partial p}\right)_H = \int_{p_1}^{p_2} dp\, \mu_{JK} \tag{6.3.4}$$

The quantity

$$\mu_{JK} = \left(\frac{\partial T}{\partial p}\right)_H \tag{6.3.5}$$

is called the **Joule-Kelvin coefficient**. From the variation of H we have

$$dH = C_p dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)_p\right] dp \tag{6.3.6}$$

so that, considering an isenthalpic process we get

$$\mu_{JK} = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right] \tag{6.3.7}$$

This gives a convenient formula for μ_{JK}. Depending on whether this coefficient is positive or negative, there will be heating or cooling of the gas upon expansion by this process. By choosing a range of pressures for which μ_{JK} is negative, this process can be used for cooling and eventual liquifaction of gases.