Ideal Gas Law

1 Main Expressions

If the gas has pressure lower than critical pressure and temperature higher than critical temperature (**low p, high T**), we can assume the gas is **ideal**, but this is never perfectly accurate.

Main expression:

$$pv = RT \tag{1}$$

Some remarks:

1. Here p, v, T are all intensive variables, where $v = V/m$ is the specific volume. We must know 2 of them to find the rest.

2. R is the mass specific gas constant, $R = \bar{R}/\bar{M}$, where $\bar{R}$ is the universal gas constant, $\bar{M}$ is the molar mass.

There are many other versions of this equation (m is mass, n is number of moles, N is number of molecules):

$$pV = mRT \tag{2}$$

$$p = \rho RT \tag{3}$$

$$pv = RT \tag{4}$$

$$p\frac{V}{m} = \frac{\bar{R}}{\bar{M}}T,\ pV = \frac{m}{\bar{M}}\bar{R}T,\ pV = n\bar{R}T \tag{5}$$

$$p\bar{v} = \bar{R}T, \bar{v} = V/n \tag{6}$$

$$pV = Nk_BT \tag{7}$$

2 Gas Constants

2.1 Universal Gas Constant

$$\bar{R} = 8.314\frac{J}{mol \cdot K} = 8.314\frac{KJ}{kmol \cdot K} \tag{8}$$

2.2 Mass specific gas constant

$$R = \bar{R}/\bar{M} \tag{9}$$

Notice that the unit of molar mass is $kg/kmol$ or g/mol, therefore the unit of R is:

$$\frac{kJ}{kmol \cdot K} \cdot \frac{kmol}{kg} = \frac{kJ}{kg \cdot K} \tag{10}$$

Take air as an example. The molar mass of air is about $29 kg/kmol$, therefore R for air is:

$$\frac{8.314}{29} \frac{kJ}{kg \cdot K} \approx 287 \frac{J}{kg \cdot K} \tag{11}$$

2.3 Boltzmann's Constant

The Boltzmann constant is a physical constant that relates the average kinetic energy of particles in a gas to the temperature of the gas.

$$k_B = \frac{\bar{R}}{N_{AV}} = 1.3806 \times 10^{-23} J/K \tag{12}$$

Where N_{AV} is the Avogadro's number:

$$N_{AV} = 6.0221 \times 10^{23} molec/mol \tag{13}$$