THE STATE OF A GAS

Definition of State: The state of a gas or of a mixture of gases is defined by the pressure of the gas, the volume of the gas, and the temperature of the gas. An equation of state is a formula that describes the mathematical relationship between those three parameters of a gas or mixture of gases.

A good example of such an equation is the ***Ideal Gas Equation of State*** from Gas Laws in the Free Atmosphere:

$$PV = RT \qquad \text{SOG01}$$

Here, P is the gas pressure in Pascals, V is the volume of one mole of the gas in cubic meters, R is the universal gas constant in joules per mole per degree, and T is the absolute temperature of the gas in Kelvins. This formula is essentially a laboratory formula, and cannot be applied to the free atmosphere in its present form because of the volume stricture. If you restrain the volume of any portion of the free atmosphere, you no longer have a free atmosphere.

This is not a serious problem, because SOG01 may easily be rewritten. The universal gas constant is defined as:

$$R = N_A \mathbf{k}_B \qquad \text{SOG02}$$

Here, N_A is **Avogadro's Number** in number of molecules per mole, and k_B is **Boltzmann's Constant** in joules per molecule per Kelvin. The molar units are easily removed by the equivalence:

$$\bar{n} = N_A / V \qquad \text{SOG03}$$

In this expression, $\bar{n}$ is the mean number density of the gas in number of molecules per cubic meter. We know that the value is a mean value because there is a bar over the parameter character. The bar is there because—even in an ideal gas—the number density will vary from place to place and time to time.

We should view the system pressure P and the system temperature T in Equation SOG01 as mean values for much the same reasons. After making these changes, SOG01 may now be rewritten as:

$$\bar{p} = \bar{n} \mathbf{k}_B \bar{T} \qquad \text{SOG04}$$

Here, $\bar{p}$ is the mean gas pressure in Pascals, $\bar{n}$ is the mean number density in molecules per cubic meter, $\mathbf{k}_B$ is Boltzmann's Constant in joules per degree per molecule, and $\bar{T}$ is the mean temperature in Kelvins. This version of the equation of state is easily applied to the free atmosphere. This version is sometimes called the thermodynamic equation of state because it features $\mathbf{k}_B \bar{T}$, often called "the thermal term".

