MOLECULAR NUMBER DENSITY

The System of Study: Let us postulate a system of study consisting of a ***p***-population of gaseous atmospheric molecules in random motion in proximity space. The surface of interest is the intangible surface of an imaginary sphere surrounded by the ***p***-population.

Definition of Molecular Number Density –Let us postulate that our population of atmospheric gas molecules contains N gas molecules and occupies V cubic meters of volume. The mean molecular number density is very simply derived, and is:

$$\bar{n} = \frac{N}{V} \qquad \text{NUM01}$$

Here, the mean number density $\bar{n}$ has the dimensions of NL^{-3}, and is measured in terms of number of molecules per cubic meter.

Number Density in Ideal Gases – If our air was still and its constituent gases were ideal gases, we could also derive the mean number density from the thermodynamic version of the *Ideal Gas Equation of State* (see Gas Laws in the Free Atmosphere). That would give us:

$$\bar{n} = \frac{\bar{p}}{k_B \bar{T}} \qquad \text{NUM02}$$

Here, $\bar{p}$ is the mean air pressure in Pascals, $\bar{T}$ is the mean temperature in Kelvins, and $\mathbf{k_B}$ is Boltzmann's Constant in joules per molecule per degree. This equation does not always work for real gases, especially at high densities. However, it works well enough for still air at the temperatures and pressures normally found in our free atmosphere.

Number Density in the *p*-Population: The two sub-populations of the ***p***-population are not necessarily equal in molecular number values. There are any number of common atmospheric situations where they would not be equal. However, regardless of equality or inequality:

$$\bar{n}_p + \bar{n}_{-p} = \bar{n} \qquad \text{NUM03}$$

In both ideal gases and real gases, under conditions of equilibrium and under conditions of non-equilibrium, in still air and in moving air, when the object of interest is moving and when it is not, the two sub-populations of the ***p***-population must total that ***p***-population.

Under conditions of equilibrium—and only under conditions of equilibrium—we can say that the number densities for our two ***p***-subpopulations along the proximity axis are the same. That is,

$$\bar{n}_p = \bar{n}_{-p} = \tfrac{1}{2}\bar{n} \text{ (at equilibrium only)} \qquad \text{NUM04}$$

In the free atmosphere, both natural phenomena and the mathematics of probability make sure that equilibrium rarely happens.

These two sub-populations will not even be in quasi-balance under normal atmospheric conditions. Whenever heating or cooling is taking place, the two sub-populations will be unequal. Whenever either net evaporation or net condensation is taking place, the two sub-populations will be unequal. Wherever we have sources or sinks of atmospheric gases, the two sub-populations will be unequal. Whenever there is the slightest wind, the two sub-populations will be unequal.

For most atmospheric situations, the safest assumption is,

$$\bar{n}_p \neq \bar{n}_{-p} \qquad \text{NUM05}$$

Number Density in the Interactive Population: Molecular number density is not used to denote those molecules that are temporarily interacting with the surface of interest (***i*** subscript). We have a better term, the mean molecular flow rate:

$$\bar{f}_i = \bar{n}_p \bar{v}_p \qquad \text{NUM06}$$

Here, $\bar{f}_i$ is the mean molecular flow rate in number of interactions per square meter per second and $\bar{v}_p$ is the mean molecular translational speed at interaction, measured normal to and toward the surface of interest.

Molecular Number Density in Moving Air: When the wind blows, the values of many atmospheric parameters change significantly. These changes will be functions of the wind speed and the wind direction relative to the surface of interest. Phenomena related to fluid flows are discussed in advanced papers in this collection.

Still Air Parameters: The essay Still Air Parameters gives the following values for still air with no net evaporation or condensation. The system temperature is 25° C, and the system pressure is 1,000 hectopascals. The system vapor pressure is 10 hectopascals.

$\bar{\boldsymbol{n}}$ = 2.429 305 X 10^{25} humid air molecules per cubic meter.
$\underset{\sim}{\bar{\boldsymbol{n}}}$ = 2.429 305 X 10^{23} water vapor molecules per cubic meter.
$\underset{\cdot}{\bar{\boldsymbol{n}}}$ = 2.405 012 X 10^{25} dry air molecules per cubic meter

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REFERENCES

Internal References: References to other essays in this collection are linked in the essay text by hyperlinks. You may follow these hyperlinks or ignore them, as you choose.

General References: These are works that I have read carefully and whose views have helped to shape the views presented in this collection. None of these authors are have any responsibility for my many unconventional views and opinions.

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