

## MOLECULAR INTERACTIONS

**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 surface of a tangible plane surrounded by the *p*-population.

**Definition of Molecular Interaction:** Whenever any force or object causes a molecule to change either its speed or its direction of movement, a molecular interaction takes place. Whenever a molecule passes through an imaginary place without any change in speed or direction of movement, a molecular interaction takes place.

**Molecular Interactions in the *p*-Population:** The molecules of our *p*-population interact frequently. They pass through imaginary surfaces and they impact upon real ones. They collide with one another. During these interactions, their parameter subscripts remain *p*-subscripts—except during interaction with the surface of interest. During those surface-of-interest interactions, and only during those surface-of-interest interactions, their *p*-subscripts change temporarily to *i*-subscripts. This concept is discussed in detail in [Proximity Space](#). If you are still confused, I suggest that you re-read that essay.

**Molecular Interaction with Forces:** Whenever the force of gravity causes a gas molecule to accelerate or decelerate or change its path, that molecule is interacting with the force of gravity. Whenever an atmospheric molecule has its direction or speed relative to the surface of the earth by the Coriolis force, that molecule is interacting with those forces. Whenever, an atmospheric ion has its speed or direction changed by the forces of ionic attraction, that molecule is interacting with those forces. Such molecular interactions are ubiquitous with the free atmosphere.

Whenever water vapor condenses into water droplets, those vapor molecules are interacting with the forces of surface tension. Whenever a vaporizing water or ice molecule has its kinetic energy of departure reduced by the forces of surface attraction, that molecule is interacting with those forces. Whenever a condensing vapor molecule has its approach speed to a water or ice surface accelerated by the forces of surface attraction, that molecule is interacting with those forces. The list goes on.

**Molecular Interaction with Objects:** Molecules [collide with one another](#) and they collide with real and imaginary surfaces. A molecule may be said to have undergone a “collision” if its interaction with another object results in a change in either molecular speed or direction.

A forceful contact with a surface or another molecule is obviously a collision. A “near miss” is also a collision if either molecule or both undergo any change in either speed or direction. The clear majority of intermolecular collisions do not result from actual contact. Gaseous air molecules repel one another. That is why they are gases, and not liquids or solids.

**Molecular Impacts with Objects:** The [Universal Flux Equation](#) tells us that the number of molecules impacting upon one square meter of surface in one second is,

$$\bar{f}_i = \bar{n}_p \bar{v}_p \quad \text{MIA01}$$

Some of these molecules may impact upon the surface and rebound. Some may be absorbed either physically or chemically by the surface. Some may simply adhere to the surface. We don’t know; and, at this point, we don’t care. We are simply interested in the flux. What happens to the flux once it reaches a surface is the subject of other essays.

**Molecular Interactions with a Moving Object:** The number of molecular interactions with an object remains the same as shown in MIA01 whether the object is moving or not. This may seem counter-intuitive, but nevertheless it is true.

Let us postulate an object moving through still air with a speed of  $v_{mo}$ . Since the distribution of molecular proximity speeds has the characteristics of a [probability density curve](#), we can evaluate the number of air molecules interacting with the leading surface of our object as the error function of that object expressed in terms of the standard deviation of that distribution.

$$\bar{f}_i^{leading} = \bar{f}_i \operatorname{erf} \left( \frac{v_{mo}}{\sigma} \right) \quad \text{MIA02}$$

The number of molecular interactions with the trailing surface will be:

$$\bar{f}_i^{trailing} = \bar{f}_i \operatorname{erfc} \left( \frac{v_{mo}}{\sigma} \right) \quad \text{MIA03}$$

Since,

$$\operatorname{erf}(x) + \operatorname{erfc}(x) = 1 \quad \text{MIA04}$$

the total number of molecular interactions is unaffected by the moving object’s speed.

**Molecular Impulse Magnitudes:** In contrast, the magnitudes of these two sets of molecular impulses are strongly affected by the moving object’s speed. The impacts upon the leading surface will have an impulse speed of:

$$\bar{v}_i^{leading} = \bar{v}_i + v_{mo} \quad \text{MIA05}$$

Whereas the impacts upon the trailing surface will have an impulse speed of:

$$\bar{v}_i^{trailing} = \bar{v}_i - v_{mo} \quad \text{MIA06}$$

Because the relative speeds at collision of these two sub-populations change, so do the momenta, the impulses, and the kinetic energies transferred during collisions.

This change in the speeds of the air molecules relative to a moving object is extremely important in understanding frictional forces on moving bodies, and the ability of rising air to “suspend” cloud droplets and other particulates. We will deal with those situations in more advanced discussions.

**Unbalanced Interactions:** There is a tendency to assume that the number of molecules impacting upon a surface is the same as the number leaving that surface in any reasonable period. This is a false assumption in many cases. Evaporation and condensation are probably the leading examples of unbalanced molecular flows in the atmosphere. The absorption of carbon dioxide and other atmospheric gases by water bodies (and their subsequent—but not always equal—outgassing) are almost as common. Green plants are always absorbing and releasing atmospheric gases—but again, not always equally. The list is endless.

Sometimes the two flows are essentially the same, sometimes they are not. It is never safe to assume. Always check.

**Still Air Parameters:** The essay [Still Air Parameters](#) gives the following values for molecular interactions in 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.

$$\bar{f}_i = \sqrt{\frac{1}{2\pi}} \bar{n} \bar{\sigma} = 2.8449 \times 10^{27} \text{ interactions per square meter per second for humid air.}$$

$$\bar{f}_i = \sqrt{\frac{1}{2\pi}} \bar{n} \bar{\sigma} = 3.5951 \times 10^{25} \text{ interactions per square meter per second for water vapor.}$$

$$\bar{f}_i = \sqrt{\frac{1}{2\pi}} \bar{n} \bar{\sigma} = 2.8111 \times 10^{25} \text{ interactions per square meter per second for dry air.}$$

## 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.

**External References:** These are papers by other authors that contain statements or data that are specifically incorporated into this essay. This paper has no external references.

**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.

Arthur Brown; **Statistical Physics**; Elsevier, New York, 1970.

D. Tabor; **Gases, Liquids, and Solids**; Third Edition; Cambridge University Press, 1991.

Charles Kittel; **Thermal Physics**; John Wiley & Sons, New York, 1969.

R. R. Rogers, M. K. Yau; **A Short Course in Cloud Physics**; Third Edition; Elsevier, New York, 1989.

William D. Sellers, **Physical Climatology**; University of Chicago Press, Chicago, 1965.