# STILL AIR PARAMETERS

**Normals:**  It is useful to have a single source for the value of common atmospheric parameters at some set of meteorological normals.  This paper is intended to fill that need.  I have chosen the value of 1,000 hectopascals ($10^5$ Pascals) as my normal for atmospheric pressure, the value of $10^3$ Pascals as my normal for vapor pressure, and the value of 25°C (298.15K) as my normal for atmospheric temperature.

**Governing Equation:**  The governing equation used throughout this paper is:

$$\bar{p} = \bar{n}k_B\bar{T} = \bar{n}\bar{m}_i\sigma^2 \qquad\qquad\qquad \text{SAP01}$$

Here, $\bar{p}$ is the mean system pressure in Pascals, $\bar{n}$ is the mean number density in number of molecules per cubic meter, $k_B$ is Boltzmann's Constant in joules per molecule per Kelvin, $\bar{T}$ is the mean system temperature in Kelvins, $\bar{m}_i$ is the mean molecular impulse mass in kilograms, and $\sigma$ (*sigma*) is the root-mean-square proximity speed in meters per second.  Sigma is also the **standard deviation** of that distribution, hence the use of the conventional sigma symbol for standard deviation.  Equation SAP01 is a simple combination of Equations GLF10 and GLF11 in Gas Laws in the Free Atmosphere.

**NOTE:**  A *tilde* beneath the parameter symbol ($\underset{\sim}{\bar{n}}$) means that the parameter refers solely to water vapor.  A dot beneath the parameter symbol ($\underset{.}{\bar{n}}$) means that the parameter refers solely to dry air.  The absence of either ($\bar{n}$) means that the parameter refers to humid air.

**COMMON ASSUMPTIONS:**  Certain assumptions are common throughout this paper.  The chief assumption is that the air is still.  There is no net movement of air, no winds and no air currents.  A corollary to this chief assumption is that there are no unbalanced changes of phase taking place.  If a surface of water or ice is present, then that surface is in dynamic equilibrium with the overlying air.  This means that any gross vaporization is exactly equaled by gross condensation; and that any melting of ice is exactly equaled by the freezing of water.  If this were not so, then the volumetric changes consequent on the change of phase would induce airflow.

A second assumption is that the gases of the atmosphere behave essentially as ideal gases at the postulated values and the conditions of zero airflow and no changes of phase.  This means that Equation SAP01 and all other equations of state under conditions of equilibrium will automatically balance.  A moment's thought will show that this concept flows logically and naturally from the

postulation of the temperature and pressure.  By so doing, we have automatically defined the value of the remaining third state parameter, number density.


**CONSTANTS**:  The following constant values have been used in calculations:

**Unified atomic mass unit = u = 1.660 538 921 X $10^{-27}$ kilograms**
**Avogadro's number = $N_A$ = 6.022 141 29 X $10^{23}$ molecules per mole**
**Boltzmann's constant = $k_B$ = 1.380 648 8 X $10^{-23}$ joules per molecule per Kelvin**

All values are from the 2010 CODATA (Mohr, *et al*, 2012).

## TEMPERATURE

**General:**  Temperature measures the mean kinetic energy of translation normal to and relative to the sensing surface of that selected subpopulation of molecules that impacted on that surface during the period of time that affected the measurement.

**Parameter Value**:

$\bar{T}$ = 298.15 Kelvins.

**Data Source**:  Postulated.

**Governing Equation**:     $\bar{T} = \dfrac{\bar{p}}{\bar{n}\mathrm{k}_B} = \dfrac{\bar{m}_i \sigma^2}{\mathrm{k_B}}$

**Universal Temperature Equation**:  $\bar{T} = \dfrac{\bar{u}_i}{\mathrm{k_B}}$                                    SAP02

Here, $\bar{u}_i$ is the mean impulse kinetic energy of translation (measured normal to the sensing surface in joules) of that selected subpopulation of gas molecules that impacted upon that sensing surface during the period of time that affected the measurement.  This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium.  It is even valid for air temperatures sensed by moving objects in moving air.

**Discussion**:  The Nature of Atmospheric Temperatures.

**PRESSURE**

**General:** Pressure measures the simple product of the mean number of molecular impacts per square meter per second and the mean impulse transferred (in newtons) of those impacts.

**Parameter Values**:

$\bar{p} = 10^5$ Pascals

$\bar{p}_{\sim} = 10^3$ Pascals

$\bar{p}_{\cdot} = 9.9 \text{ X } 10^4$ Pascals

Here, $\bar{p}_{\sim}$ is the mean vapor pressure and $\bar{p}_{\cdot}$ is the mean dry air pressure.

**Data Sources**:  Postulated, postulated, and calculated from Dalton's Equation.

**Governing Equation**:  $\bar{p} = \bar{n}k_B\bar{T} = \bar{n}\bar{m}_i\sigma^2$

**Universal Pressure Equation**:    $\bar{p} = \bar{f}_i\bar{\varphi}_i$                    SAP03

Here, $\bar{f}_i$ is the universal molecular flux in the mean number of molecular impacts per square meter per second, and $\bar{\varphi}_i$ is the universal mean molecular impulse per molecular impact in newtons.  This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium.  It is even valid for air pressures sensed by moving objects in moving air.

**Daltons Equation:**  $\bar{p} = \bar{p}_{\sim} + \bar{p}_{\cdot}$                    SAP04

**Discussion**:  [The Nature of Gas Pressures.](#)

## NUMBER DENSITY

**General:** Number density is based on Avogadro's Law that states that for any given combination of temperature and pressure, the number of molecules of any gas or any combination of non-reacting gases is the same.

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

**Data Sources**: Algebraic solutions of the Governing Equation and Avogadro's Identity.

**Governing Equation**:  $\bar{n} = \dfrac{\bar{p}}{k_B \bar{T}}$

**Universal Number Density Equation**:  $\bar{n} = \dfrac{\bar{\rho}}{\bar{m}_p}$                                    SAP05

Here, $\bar{\rho}$ is the mean mass density in kilograms per cubic meter, and $\bar{m}_p$ is the mean molecular mass of the **p-**population of humid air molecules.  This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium.  It is even valid for mass densities in parcels of moving air.

**Avogadro's Identity:**  $\bar{n} = \bar{\underset{\sim}{n}} + \bar{\underset{.}{n}}$                                    SAP06

**Discussion**: Molecular Number Density.

## MOLECULAR MASSES

**General:**  Mean molecular masses are calculated from estimates of the atmospheric abundance of the various isotopes of the most common atmospheric gases and estimates of the various isotopic masses.  The following values were calculated from the forty-four (44) dry air isotopes that are present in parts per billion or greater concentrations and the nine (9) water vapor isotopes.

**Parameter Values**:

$\bar{m}_p = 4.791\ 668 \times 10^{-26}$ kilograms

$\dot{\bar{m}}_p = 4.809\ 851 \times 10^{-26}$ kilograms

$\underset{\sim}{\bar{m}}_p = 2.991\ 505 \times 10^{-26}$ kilograms

$\bar{m}_i = 4.777\ 108 \times 10^{-26}$ kilograms

$\dot{\bar{m}}_i = 4.795\ 145 \times 10^{-26}$ kilograms

$\underset{\sim}{\bar{m}}_i = 2.991\ 450 \times 10^{-26}$ kilograms

**Data Sources**:  *Molecular Masses* and computations from

$$\bar{m} = \frac{(\dot{\bar{m}}\,\dot{\bar{n}}) + (\underset{\sim}{\bar{m}}\,\underset{\sim}{\bar{n}})}{\bar{n}}$$

SAP07

**Discussion:**  Molecular Masses.

## MOLECULAR VELOCITIES

**General:**  At any given temperature, each value of molecular mass ($m$) will have its own distribution of values for the resulting molecular velocities.  Each of these individual distributions will have its own means, modes, medians, and standard deviations.

Nevertheless, the numerical relationships between these consequent parameters will always be the same. For instance, the *functional relationship* between the standard deviation of the proximity velocity distribution ($\sigma$) and the mean molecular proximity velocity ($\bar{v}_p$) and the mean molecular impulse velocity ($\bar{v}_i$) will always be the same ($\sigma = \sqrt{\frac{\pi}{2}}\bar{v}_p = \sqrt{\frac{2}{\pi}}\bar{v}_i$) in the distribution functions for the different masses regardless of the fact the parameters themselves will have different numerical values.

This is true for other molecular velocity parameters as well.  This enables us to use common equations to describe the molecular velocities and velocities of the humid atmosphere despite the fact that this atmosphere is composed of many different molecular velocity distributions.  The parameters in the equations will retain the same denotations and functional relationships, even though the numerical values of the parameters change

**Parameter Values:**

$\sigma$ = 293.55 m sec$^{-1}$
$\underset{\sim}{\sigma}$ = 370.95 m sec$^{-1}$
$\overset{.}{\sigma}$ = 292.99 m sec$^{-1}$

$\bar{v}_p$ = 234.22 m sec$^{-1}$
$\underset{\sim}{\bar{v}}_p$ = 295.98 m sec$^{-1}$
$\overset{.}{\bar{v}}_p$ = 233.78 m sec$^{-1}$

$\bar{v}_i$ = 367.91 m sec$^{-1}$
$\underset{\sim}{\bar{v}}_i$ = 464.92 m sec$^{-1}$
$\overset{.}{\bar{v}}_i$ = 367.21 m sec$^{-1}$

**Data Sources:**   Calculations from governing equation, the equation of equivalence, and the calculated mean molecular masses.

**Governing Equation:**  $\sigma = \left( \dfrac{k_B \bar{T}}{\bar{m}_i} \right)^{1/2}$

**Equation of Equivalence:** $\sigma = \sqrt{\frac{\pi}{2}}\,\overline{v}_p = \sqrt{\frac{2}{\pi}}\,\overline{v}_i = \frac{1}{2}\sqrt{\frac{\pi}{2}}\,\overline{v} = \frac{2}{3}\sqrt{\frac{2}{\pi}}\,\overline{v}_{i'}$            SAP08

**Discussion:**  [Molecular Velocities.](Molecular Velocities.)

### SIGMA

**General:**  Sigma is a speed, is measured in meters per second, and has the dimensions of $LT^{-1}$. Sigma is the root-mean-square speed of the proximity speed distribution, and is the standard deviation of that same distribution.

**Parameter Values**:

$\sigma$ = 293.55 m sec$^{-1}$ in humid air.
$\underset{\sim}{\sigma}$ = 370.95 m sec$^{-1}$ in water vapor.
$\overset{.}{\sigma}$ = 292.99 m sec$^{-1}$ in dry air.

**Data Sources:**  Calculations from governing equation, the equation of equivalence, and the calculated mean molecular masses.

**Governing Equation:**  $\sigma = \left( \dfrac{k_B \bar{T}}{\bar{m}_i} \right)^{1/2}$

**Equation of Equivalence:**  $\sigma = \sqrt{\frac{\pi}{2}}\bar{v}_p = \sqrt{\frac{2}{\pi}}\bar{v}_i = \frac{1}{2}\sqrt{\frac{\pi}{2}}\bar{v} = \frac{2}{3}\sqrt{\frac{2}{\pi}}\bar{v}_{i'}$            SAP08

**Discussion:**  [Sigma](Sigma).

## ATMOSPHERIC DENSITY

**General:**  The mean atmospheric density of a parcel of atmospheric air is the simple product of the mean number density $\bar{n}$ and the mean molecular proximity mass $\bar{m}_p$.  Although widely used in fluid dynamics, it is rarely used at all in either kinetic gas theory or statistical mechanics.  In these two disciplines, it does not appear to be a fertile concept.  Nevertheless, here are the parameter values for whatever they are worth.

**Parameter Values:**

$\bar{\rho} =$ 1.15 904 kilograms per cubic meter

$\underset{\sim}{\bar{\rho}} =$ 7.26 714 X $10^{-3}$ kilograms per cubic meter

$\overset{\cdot}{\bar{\rho}} =$ 1.15 324 kilograms per cubic meter

**Data Sources:**  Solution of the universal equation using calculated values of mean number density and mean molecular mass.

**Universal Equation:**  $\bar{\rho} = \bar{n}\bar{m}$

Here, $\bar{\rho}$ is the atmospheric density in kilograms per cubic meter, $\bar{n}$ is the mean number density in number of molecules per cubic meter, and $\bar{m}_p$ is the mean molecular proximity mass in kilograms. This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium.  It is even valid for the mean specific density of parcels of moving air.

**Discussion:**  Atmospheric Densities.

## MOLECULAR FLOWS

**General:** Molecular flows measure the number of molecules that pass through a plane (real or imaginary) or impact upon a surface (real or imaginary) per square meter per second.

**Parameter Values:**

$\bar{f}_i^e = \sqrt{\frac{1}{2\pi}} \bar{n} \sigma =$ 1.78 864 X $10^{28}$ interactions per square meter per second for humid air.

$\bar{f}_i^e = \sqrt{\frac{1}{2\pi}} \underset{\sim}{\bar{n}} \underset{\sim}{\sigma} =$ 2.25 886 X $10^{28}$ interactions per square meter per second for water vapor.

$\bar{f}_i^e = \sqrt{\frac{1}{2\pi}} \bar{n} \sigma =$ 1.76 630 X $10^{28}$ interactions per square meter per second for dry air.

Here, $\bar{f}_i^e$ is the mean equilibrium flux per square meter per second, $\bar{n}$ is the mean number density in number of molecules per cubic meter, and $\sigma$ is standard deviation of the proximity speed distribution.

**Data Sources:** Derived from the governing equation using mean molecular number density and the mean molecular proximity speed.

**Governing Equation:** $\bar{f}_i^e = \sqrt{\frac{1}{2\pi}} \bar{n} \sigma$

**Universal Flux Equation:** $\bar{f}_i = \bar{n}_p \bar{v}_p = \dfrac{\bar{p}}{\bar{\varphi}_i}$                       SAP09

Here, $\bar{f}_i$ is the mean number of passages or impacts per square meter per second, $\bar{n}_p$ is the mean number of molecules in the **p-**population having a component of motion normal to and toward the surface of interest, $\bar{v}_p$ is the mean molecular proximity speed in meters per second, $\bar{p}$ is the mean gaseous pressure upon the surface of interest in pascals, and $\bar{\varphi}_i$ is the mean impulse per impact in newtons. This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium. It is even valid for the flux upon moving objects in moving air.

**Equilibrium Flux Equation:** $\bar{f}_i^e = \frac{1}{2} \bar{n} \bar{v}_p$                       SAP10

**Discussion:** [Molecular Flows](Molecular Flows).

**MOLECULAR MOMENTA**

**General:** Molecular momentum[1] $\underset{\leftrightarrow}{\rho}$ measures the simple product of an individual molecule's mass and its velocity ($mv$). The **p-**population has both a mean proximity momentum ($\bar{m}_p\bar{v}_p$) and a mean impulse momentum ($\bar{m}_i\bar{v}_i$). Fortunately, only the impulse momentum has any role in statistical mechanics. That is the only momentum that can be transferred from one molecule to another or from a molecule to a surface. Note that at the instant of impact, the momentum ceases to be momentum and becomes **impulse**. Momentum that fails to become impulse plays no role in the kinetic atmosphere.

**Parameter Values:**

$\bar{\underset{\leftrightarrow}{\rho}}_i$ = 1.75 642 X $10^{-23}$ kilogram-meters per second for humid air.

$\bar{\underset{\approx}{\rho}}_i$ = 1.39 078 X $10^{-23}$ kilogram-meters per second for water vapor.

$\bar{\underset{\leftrightarrow}{\rho}}_i$ = 1.76 084 X $10^{-23}$ kilogram-meters per second for dry air.

Here, the mean molecular momentum is that momentum at the instant of initial interaction.

**Data Sources:** Solution of the Governing Equation using the calculated values of the interactive masses and constants and the postulated values of the other variables.

**Governing Equation:** $\quad \bar{\underset{\leftrightarrow}{\rho}}_i = \left( \dfrac{\pi \bar{m}_i \mathrm{k_B} \bar{T}}{2} \right)^{1/2}$

**Universal Equation:** $\quad \bar{\underset{\leftrightarrow}{\rho}}_i = \bar{m}_i \bar{v}_i$ $\hfill$ SAP11

This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium. It is even valid for mean molecular momenta in moving air.

**Other Equation:** $\quad \bar{v}_i = \sqrt{\frac{\pi}{2}}\sigma$ $\hfill$ SAP12

**Discussion:** Molecular Momenta

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[1] The conventional symbol for momentum in physics is "p". However, "p" (in both the upper and lower cases) is used for pressure in the atmospheric sciences. Moreover, pressure is a more important parameter in these sciences than is momentum. Therefore, I am using the Greek lower case **rho** ($\underset{\cdot}{\rho}$) for momentum, with the addition of an underlying double-headed arrow. It looks something like "p", but is different enough not to cause confusion with pressure ($p$). Density ($\rho$) will still use the customary **rho** without the arrow.

## MOLECULAR INTERACTIONS

**General:** 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.

**Parameter Value:**

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

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

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

**Data Source:** Derived from the governing equation using mean molecular number density and the mean molecular proximity speed.

**Universal Equation:**  $\bar{f}_i = \bar{n}_p \bar{v}_p$                                        SAP09

**Discussion:**  [Molecular Interactions](Molecular Interactions)

## INTERMOLECULAR COLLISIONS

**General:**  A molecule may be said to undergo an intermolecular collision if its interaction with another molecule results in a change in either molecule's path or speed.  A forceful contact with another molecule is obviously a collision.  A "near miss" is also a collision if the intermolecular forces result in a change in either molecule's path or speed.  The clear majority of intermolecular collisions do not result from forceful contact.  Nevertheless, those are the collisions that we will measure, since current scientific information on near-miss distances is inadequate to the task.

**Parameter Values:**

$\overline{f}_{\otimes}^{e} \approx 5.11$ X $10^9$ intermolecular collisions per humid air molecule per second

**Data Source:**  Solution of the Universal Equation using the estimated value for the mean molecular surface area of the target molecule.

Here, $\overline{n}$ is the mean number density in number per cubic meter, $\sigma$ is the root-mean-square molecular axial velocity in meters per second, and $\otimes$ is the mean molecular surface area in square meters.

**Universal Equation:**  $\overline{f}_{\overline{\otimes}} = \overline{n}_p \overline{v}_p \, \overline{\otimes}$                        SAP13

Here, $\overline{f}_{\overline{\otimes}}$ is the mean number of intermolecular collisions per cubic meter per second, $\overline{n}_p$ is the mean number of molecules per cubic meter that have a component of movement toward the target molecule and $\overline{v}_p$ is the mean proximity speed of that component.

**Other Useful Equations:**

$\overline{f}_{\Sigma}^{e} = \overline{f}_{\otimes}^{e} \frac{\overline{n}}{2} = 6.21$ X $10^{34}$ total intermolecular collisions m$^{-3}$ sec$^{-1}$                SAP14

$$\overline{f}_{\overline{\otimes}} = \underset{\sim}{\overline{n}}_p \underset{\sim}{\overline{v}}_p \, \underset{\sim}{\overline{\otimes}}$$                        SAP15

This last equation is useful in condensation studies.

**Discussion:**  [Intermolecular Collisions](#)

## MOLECULAR FREE PATHS

**General:**  The mean free path is the average distance that a molecule travels between collisions.  It is usually obtained by dividing the molecules' mean speed by the mean frequency of intermolecular collisions.

$$\bar{\lambda}_i = \frac{\bar{v}_i}{\bar{f}_\otimes}$$                    SAP16

**Parameter Value:**

$\bar{\lambda}_i$ = 2.86 x $10^{-7}$ meters in humid air.

**Data Source:**  Solution of SAP19 using calculated values of mean molecular impulse speed and mean molecular surface area.

**Discussion:**  Molecular Free Paths

**MOLECULAR IMPULSES:**

**General:** When a real air molecule impacts upon a real surface, that impact is not instantaneous. It occupies a real segment of time. During that time, a force is transmitted to that surface by that molecule's impact. That force is impulse, and it is measured in newtons.

$$\varphi_i = \Delta\rho_i = \frac{d\rho_i}{dt} = \int_{initial\ contact}^{final\ contact} m_i v_i \qquad \text{SAP17}$$

Here, $\varphi_i$ is the impulse in newtons, $\rho_i$ is the momentum in kilogram-meters per second, $m_i$ is the molecular impulse mass, and $v_i$ is the impulse speed normal to and toward the surface at the instant of initial contact. The impulse is equal to the change in momentum over the time of impact. Its dimensions are $MLT^{-2}$.

In an ideal gas where all collisions are perfectly elastic the molecule will rebound with a momentum equal in magnitude but opposite in direction to its initial momentum. Thus, the impulse will be:

$$\bar{\varphi}_i = 2\bar{m}_i\bar{v}_i \qquad \text{SAP18}$$

In the real gases of the atmosphere, many collisions are not perfectly elastic. Molecules may adhere to or be absorbed by the surface. They may be ionized by the collision and gain or lose one or more electrons, thereby changing both their mass and their momentum. They may gain or lose velocity by collision with a hotter or colder surface. This is just a sampling of real-world interactions between a molecule and the surface. All of them render equation SAP18 invalid. Although these deviations are common, they are not usually so common as to cause equation SAP218 to be invalid at the normal level of scientific accuracy and precision. Don't expect much more than the proper order of magnitude and three significant figures and you won't be disappointed—unless changes of phase are taking place. If that is the case, then all bets are off. Equation SAP18 will not be valid.

**Parameter Value:** 2.20 X $10^{-23}$ newtons per impact

**Data Source:** Solution of the Governing Equation using calculated values of mean molecular impulse mass and *sigma*.

**Governing Equation:** $\bar{\varphi}_i = \sqrt{2\pi}\bar{m}_i\sigma$

**Universal Equation:**  $\bar{\varphi}_i = \dfrac{\bar{p}}{\bar{f}_i}$                                   SAP19

Here, $\bar{\varphi}_i$ is the mean molecular impulse in newtons, $\bar{p}$ is the mean gaseous pressure upon the surface of interest in Pascals, and $\bar{f}_i$ is the mean frequency of impact in number of impacts per square meter per second.  This equation is valid for ideal gases and for real gases, under conditions of equilibrium and under conditions of non-equilibrium.  It is even valid for the mean molecular impulse felt by moving objects in moving air.


**Discussion:** <u>Molecular Impulses</u>

## MOLECULAR KINETIC ENERGIES OF TRANSLATION

**General:**  Classical mechanics defines kinetic energy of translation as the energy that a body possesses while going from place to place.  When evaluated, the kinetic energy of translation ( $u$ ) of a body in motion is equal to one-half the product of that body's mass ( $m$ ) and the square of that body's speed ( $v$ ) over its path.  That is,

$$u = \tfrac{1}{2}mv^2 \qquad\qquad\qquad \text{SAP20}$$

For the mean molecular kinetic energy of translation of our $p$-population of gaseous molecules, Equation SAP20 can be rewritten as:

$$\bar{u}_p = \tfrac{1}{2}\bar{m}_p\overline{v_p^2} = \tfrac{1}{2}k_B\bar{T} \qquad\qquad\qquad \text{SAP21}$$

For the subpopulation of molecules that are actively interacting with the surface of interest, we can write:

$$\bar{u}_i = \tfrac{1}{2}\bar{m}_i\overline{v_i^2} = k_B\bar{T} \qquad\qquad\qquad \text{SAP22}$$

**Parameter Values:**

$\bar{u}_p = \tfrac{1}{2}k_B\bar{T}$ = 2.06 X $10^{-21}$ joules per molecule

$\bar{u}_i = k_B\bar{T}$ = 4.12 X $10^{-21}$ joules per molecule

**Data Sources:**  Solution of the Governing Equation using postulated values of Boltzmann's constant and system temperature.

**Governing Equation:**  $\bar{u}_i = k_B\bar{T}$

**Equations of Kinetic Energy of Translation Equivalence:**

$$\bar{u}_p = \tfrac{1}{2}\bar{u}_i = \tfrac{1}{2}k_BT = \tfrac{1}{2}\bar{m}_i\sigma^2 = \tfrac{1}{2}\bar{m}\overline{v_p^2} = \tfrac{1}{4}\bar{m}_i\overline{v_i^2} \qquad\qquad \text{SAP23}$$

$$\bar{u}_i = 2\bar{u}_\sigma = 2\bar{u}_p = k_BT = \bar{m}_i\sigma^2 = \bar{m}\overline{v_p^2} = \tfrac{1}{2}\bar{m}_i\overline{v_i^2} \qquad\qquad \text{SAP24}$$

**Discussion:**  [Kinetic Energies of Translation](Kinetic Energies of Translation)