

I think there is little question that a molar-based analysis departs from the Newtonian definition of motion. In the opening paragraphs of *Philosophiæ Naturalis Principia Mathematica*, Newton was explicit on three key points:

1. The quantity of matter (*quantitas materiae*) is measured by mass;
2. The quantity of motion (*quantitas motus*) is measured as the product of mass and velocity, now termed momentum; and
3. The motion of the whole equals the sum of the motions of its constituent parts.

The paper by Maxwell (1867)—openly available at <https://doi.org/10.1098/rstl.1867.0004>—marks a point of divergence in the treatment of multicomponent systems. At first, the Newtonian definition of motion is retained. On pages 51–52, Maxwell writes:

If we suppose an imaginary plane drawn through a vessel containing a great number of such molecules in motion, then a great many molecules will cross the plane in either direction. The excess of the mass of those which traverse the plane in the positive direction over that of those which traverse it in the negative direction, gives a measure of the flow of gas through the plane in the positive direction.

This mass-based measure of flow is consistent with the *Principia*. However, in the following paragraph Maxwell continues:

If the plane be made to move with such a velocity that there is no excess of flow of molecules in one direction through it, then the velocity of the plane is the mean velocity of the gas resolved normal to the plane.

This shift from a barycentric (mass-based) description to one based on molecule number or moles departs from the classical-mechanical framework without explicit justification. For air, it neglects the differing inertias of water-vapour molecules (18 g mol^{-1}) and dry-air molecules (29 g mol^{-1}), treating them equivalently despite their unequal resistance to changes in motion. The resulting specification of air motion therefore differs from that implied by classical mechanics. Because water-vapour diffusion is defined relative to the motion of air, this also affects the definition of diffusion itself.

This Maxwellian framework underlies the derivation of Curtiss and Hirschfelder (1949), which treats the mass-average fluid velocity as an “arbitrary” parameter that may be “varied at will”. Their derivation does not recognize that a diffusive exchange—in which two molecules exchange positions—necessarily alters the mass-average fluid velocity when the molecules have different masses.

As shown in my reply to Dr. Roderick, the choice between a molar-based and mass-based framework has important consequences for how net transport is partitioned into diffusive and non-diffusive components. These differences become increasingly significant as water vapour ceases to behave as a trace gas, which occurs not far above 35°C over humidifying surfaces. Consequently, transport above high-temperature hydrological surfaces in the Earth system, such as

Yellowstone's hydrothermal features, is substantially mischaracterized by the molar-based framework.