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A Twenty-First Century Molar Mass for Dry Air

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The audience for this paper includes researchers, educators, and engineers in the fields of air conditioning, atmospheric physics, meteorology, psychrometrics, standards, and thermodynamics. This paper provides a brief history of the molar mass of dry air, M_{da}*, followed by the composition of Earth's atmosphere for the year 2008 and the calculation of* M_{da}*. A single equation is given to calculate* M_{da} *based on the actual abundance of* CO_2 *in the atmosphere, which is currently increasing at an annual rate of 1.9 μmol·mol*$^{-1}$*. This causes an increase in the value of* M_{da} *at a rate of 0.0001 kg·kmol*$^{-1}$ *(lb·lbmol*$^{-1}$*) for every 8.33 μmol·mol*$^{-1}$ *increase in the abundance of* CO_2*. It is practical for many calculations to use the average projected* M_{da} *value over a period of a half-century, during which time the value of* M_{da} *will increase by approximately 0.0010 kg·kmol*$^{-1}$ *(lb·lbmol*$^{-1}$*). For most psychrometric calculations, the authors recommend an* M_{da} *value of 28.966 kg·kmol*$^{-1}$ *(lb·lbmol*$^{-1}$*), which is projected for the year 2036. This value will be correct when rounded to three decimal places through 2058 if* CO_2 *increases at its current rate.*

INTRODUCTION—M_{da} VALUES FROM 1945 TO 2005

Researchers, practitioners, and educators in the fields of agricultural and food science engineering, air conditioning, atmospheric physics, drying and dehumidification, gas turbines, compressors and expanders, meteorology, psychrometrics, and standards make numerous psychrometric (moist air) calculations that are based in part on the molar mass of dry air. Dry air is a mixture of nitrogen, oxygen, argon, CO_2, and eight or more minor constituents called *trace gases*. The molar mass of dry air is calculated as the sum of the products of the mole ratio of each gas times its molar mass.

In the last half of the twentieth century, the following changes took place that resulted in an increase in the molar mass of dry air:

- The scientific community changed from the Oxygen-16 to the Carbon-12 reference for the molar mass of elements and compounds in 1960.
- The molar masses of the basic chemical elements were updated by the International Union of Pure and Applied Chemistry (IUPAC) (Wieser 2005).
- CO_2 in the atmosphere has increased from 314 μmol·mol^{-1} (~1955) to 379 μmol·mol^{-1} (Keeling and Whorf 2005a, 2005b). The 65 μmol·mol^{-1} increase in CO_2 in this time span is accompanied by a decrease in O_2 because combustion and respiration processes combine a carbon atom with O_2 from the atmosphere to produce CO_2 (Park et al. 2004).
- The stated argon mole fraction in air has changed from 9340 μmol·mol^{-1} at the start of the

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