

Improved *Ab Initio* Values of the Thermophysical Properties of Helium as a Standard

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Since the year 2000, several groups, using diverse approximations, have improved the *ab initio* calculations of the helium-helium interaction energies $U(r)$. We constructed a new pair potential $U_{06}(r)$, that: represents the improved theory and also has smaller uncertainties than the potentials used in our previous work [1]. For example, near 4 bohr, where $U(4 \text{ bohr}) \sim 293 \text{ K}$, the uncertainty decreased from 1.0 K to 0.1 K. Near the minimum of the potential well, where $U(5.6 \text{ bohr}) \sim -10 \text{ K}$, the uncertainty decreased from 0.07 K to 0.02 K. Using the new potential U_{06} , we recalculated the zero-density thermophysical properties of helium from 1 K to 1000 K, and assessed the uncertainty of the results. At 300 K, the relative uncertainty of the second virial coefficient was reduced from 22×10^{-4} to 6×10^{-4} , and the relative uncertainty of the viscosity was reduced from 6×10^{-4} to 2×10^{-4} . The lower uncertainties have significant contributions from the remaining uncertainty of $U_{06}(r)$ and from the adiabatic approximation, despite improvements in the calculation of the adiabatic and relativistic corrections. In this work, the calculations were independently coded by two of the authors (JJH and JBM), and compared to each other to discover and repair errors in the algorithms and coding. The uncertainties resulting from our numerical approximations are negligible. The present *ab initio* results are consistent with the measurements of the first acoustic virial coefficient of helium between 7 K and 293 K reported by Pitre *et al.* at this meeting (the relative experimental uncertainties range from 4×10^{-4} at 273 K to 3×10^{-3} at 7 K). The *ab initio* value for the viscosity of helium at 298 K differs from that reported by May *et al.* (at this meeting) by 0.1 %, which is twice the combined uncertainty. Our results for the thermophysical properties of helium will be published in user friendly tables.

[1] J.J. Hurly and M.R. Moldover, *J. Res. Natl. Inst. Stand. Technol.* **105**, 667 (2000).