

Argon/Helium Refractive Index Ratio for Gas Metrology

James Schmidt^{C,S} and Michael R. Moldover

Process Measurements Division, National Institute of Standards and Technology, Gaithersburg, MD, U.S.A.

To realize a pressure standard based on the values of $n_{\text{He}}(p,T)$ calculated from quantum mechanics and statistical mechanics, we are measuring the refractive index ratio argon/helium $r(p,T) = n_{\text{Ar}}(p,T)/n_{\text{He}}(p,T)$ with the small uncertainty $u(r) < 10^{-8}$. The data extend to pressures of 5 MPa at three temperatures: the triple point of water, the gallium point and the mercury point. The results will also serve as either a check on primary acoustic thermometry or as a test of the controversial prediction that the low-density limit of $r(p,T)$ is temperature-dependent. To achieve uncertainties $u(r) < 10^{-8}$ we filled two quasi-spherical cavities with the test gases and measured the microwave resonance frequencies with relative uncertainties $u_r(f)$ of a few parts in 10^9 . The cavities are maintained at nearly the same temperature ($\Delta T \sim \pm 0.3$ mK) and pressure ($\Delta P/P \sim \pm 1.5 \times 10^{-6}$). For each gas, $n(p,T)$ is computed from: $n(p,T) = [(f_0 + g_0)/(f_p + g_p)] \cdot (1 + k_T p/3)$, where f_0 and g_0 are the frequency and half-width of a resonance mode when the cavity is evacuated; f_p and g_p are the frequency and half-width of the same mode when the cavity is filled with the test gas at the pressure p ; and k_T is the isothermal compressibility of the cavity. Because the two cavities are used simultaneously, the long-term repeatability required of the temperature and pressure measurements is significantly reduced. However, the compressibilities of the two cavities may differ by Δk_T . To account for this, we conduct two sets of measurements: during the first set, one cavity is filled with helium and the second is filled with argon; during the second set, the gases are interchanged. The results of the two sets of measurements are combined to eliminate the dependence of $r(p,T)$ on Δk_T .