High-Accuracy Measurements of the Electric and Magnetic Susceptibilities of O_2 and H_2 Using a Quasi-Spherical Resonator and a Cross Capacitor

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We used a cross capacitor and a quasi-spherical microwave resonant cavity to measure simultaneously the relative dielectric permittivity ε_r and the (complex) refractive index $\boldsymbol{n}$ of molecular oxygen and molecular hydrogen at 273 K, 293 K and 323 K, at pressures up to 6.5 MPa. The capacitance ratios and frequency ratios were measured with a resolution of 1×10^{-8} or better; however a hysteresis of 1×10^{-7} was observed along each isotherm. Helium was used as a reference fluid to calibrate the deformation of the cross capacitor and the resonator under hydrostatic pressure. Our results for the molar dielectric polarizability A_ε of hydrogen will provide a sensitive test of *ab initio* calculations of A_ε. Our values for the small, complex magnetic susceptibility χ_m of O_2 have an uncertainty of less than 1 % at pressures above 2 MPa. Extrapolating these values of χ_m to zero-frequency and zero-pressure yield the static magnetic susceptibility $\chi_M(0) = (43.08 \pm 0.25) \times 10^{-9}$ m^3 mol^{-1} at 293.15 K, which is in excellent agreement with the theoretical value of 43.09×10^{-9} m^3 mol^{-1} calculated using Van Vleck's formalism. This is the first measurement of $\chi_M(0)$ for O_2 that has not used $\chi_M(0)$ of water as a susceptibility standard.