

Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen

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If the potential for a boom in the global hydrogen economy is realized, there will be an increase in the need for accurate hydrogen thermodynamic property standards. Based on current and anticipated needs, new fundamental equations of state for parahydrogen, normal hydrogen, and orthohydrogen were developed to replace the existing standards. To accurately predict thermophysical properties near the critical region and in liquid states, the Quantum Law of Corresponding States was applied to improve the normal hydrogen and orthohydrogen formulations in the absence of available experimental data. All three equations of state have the same maximum pressure of 2000 MPa and upper temperature limit of 1000 K. The uncertainty in density is 0.04 % in the region between 250 and 450 K and at pressures up to 300 MPa. The uncertainties of vapor pressures and saturated liquid densities vary from 0.1-0.2 %. Heat capacities are generally estimated to be accurate within ± 1 %, while speed of sound values are accurate to within ± 0.5 % below 100 MPa.