

## Thermodynamic Properties of Helium-4. a New Wide Range Reference Equation of State

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A multiparametric and fundamental equation of state is presented for the fluid thermodynamic properties of helium. The equation is valid for temperatures from the  $\lambda$ -line ( $\sim 2.17$  K) to 1500 K and for pressures up to 2000 MPa. . The formulation can calculate all thermodynamic properties, including density, heat capacity, speed of sound, energies, entropy and saturation properties. A new equation of state is necessary to overcome difficulties associated with the current standard in the asymptotic region between the I-line and 3 K and also difficulties related to lack of data, extrapolation performance, and accuracy at higher temperatures. The uncertainty in density is 0.3 % at pressures up to 10 MPa below 50 K. From 50 K to 200 K the uncertainty decreases to 0.1 % at pressures up to 50 MPa. At higher temperatures the uncertainty in density is 0.05 % up to pressures of 20 MPa. At all temperatures and at pressures higher than those listed here, the uncertainty increases to 0.8 % in density. The uncertainties in the speed of sound are 0.03 % for the vapor phase and 0.1 % for the liquid phase. The uncertainty in vapor pressure is less than 0.05 % , in excellent agreement with the T90 temperature scale. The uncertainty for the heat capacities is about 5 %. Uncertainties in the critical region are higher for all properties except vapor pressure.