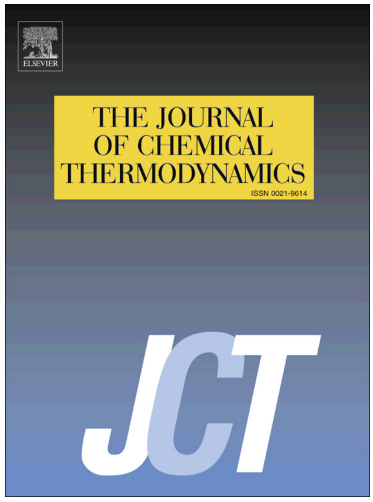

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PII: S0021-9614(16)30336-6
DOI: http://dx.doi.org/10.1016/j.jct.2016.10.028
Reference: YJCHT 4858

To appear in: *J. Chem. Thermodynamics*

Received Date: 4 August 2016
Revised Date: 4 October 2016
Accepted Date: 20 October 2016

Please cite this article as: J.P. Martin Trusler, E.W. Lemmon, Determination of the thermodynamic properties of water from the speed of sound, *J. Chem. Thermodynamics* (2016), doi: http://dx.doi.org/10.1016/j.jct.2016.10.028

Determination of the thermodynamic properties of water from the speed of sound

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Abstract

Thermodynamic properties of compressed liquids may be obtained from measurements of the speed of sound by means of thermodynamic integration subject to initial values of density and isobaric specific heat capacity along a single low-pressure isobar. In this paper, we present an analysis of the errors in the derived properties arising from perturbations in both the speed-of-sound surface and the initial values. These errors are described in first order by a pair of partial differential equations that we integrate for the example case of water with various scenarios for the errors in the sound speed and the initial values. The analysis shows that errors in either the speed of sound or the initial values of density that are rapidly oscillating functions of temperature have a disproportionately large influence on the derived properties, especially at low temperatures. In view of this, we have obtained a more accurate empirical representation of the recent experimental speed-of-sound data for water [Lin and Trusler, J. Chem. Phys. 136, (2012) 094511] and use this in a new thermodynamic integration to obtain derived properties including density, isobaric heat capacity and isobaric thermal expansivity at temperatures between (253.15 and 473.15) K at pressures up to 400 MPa. The densities obtained in this way are in very close agreement with those reported by Lin and Trusler, but the isobaric specific heat capacity and the isobaric expansivity both differ significantly in the extremes of low temperatures and high pressures.

Keywords: equation of state; speed of sound; thermodynamic integration; water.