A New Approach to a Comprehensive Formulation of Thermodynamic Properties of Seawater

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Successful formulation of thermodynamic properties of seawater TEOS-10 [1], developed primarily by R. Feistel, models the Gibbs energy for seawater as a sum of Gibbs energy of pure water as given by IAPWS-95, and an excess function depending on temperature, pressure, and salinity. Recently, we performed measurements of density for standard seawater at practical salinity close to 35 in the temperature range from −20°C to 25°C, and in the pressure range from 0.1 MPa to 110 MPa. The data is not yet published. The experimental procedure was similar to that for heavy water measurements [2]. The measured data also cover a significant part of the metastable liquid region. This is a great advantage for studying properties of seawater in the vicinity of the melting line.

Comparisons with TEOS-10 showed significant deviations at the melting line and below it, particularly for properties depending on derivatives. Therefore, we attempted to develop an alternative formulation. The present model uses our experiments and some other recent data [3]. The model is based on the observation that the pressure-volume-temperature surface for seawater at given salinity appears to be similar to that for pure water. We developed a simple salinity-dependent transformation, which maps the seawater surface onto the pure water surface. The formulation incorporates the extended Debye–Hückel model, which ensures proper limiting behavior. As a pure-water reference, the supercooled water standard [4] is used, which provides a more accurate description of cold pure water at elevated pressure than IAPWS-95. The transformation contains only 7 parameters adjusted to experimental data. As a result, volume is obtained as a function of temperature, pressure, and salinity. The function is integrable in pressure, thus providing Gibbs energy and, consequently, all thermodynamic properties of seawater. To this end, a Gibbs function at atmospheric pressure must be added. This can be taken over from TEOS-10 or developed separately. The proposed scaling approach represents an alternative to the additive scheme of TEOS-10.

References

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