Thermodynamic Properties of Seawater: Extensions to High Temperatures, Pressures and Salinities

Javid Safarov [C, S]
University of Rostock, Lehrstuhl für Technische Thermodynamik, Rostock, MV, Germany
javid.safarov@uni-rostock.de

Silvia Berndt
University of Rostock, Lehrstuhl für Kolbenmaschinen und Verbrennungsmotoren, Rostock, MV, Germany

Frank Millero
University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL, U.S.A.

Rainer Feistel
Leibniz-Institut für Ostseeforschung, Sektion Physikalische Ozeanographie und Messtechnik, Warnemünde, MV, Germany

Andreas Heintz
University of Rostock, Abteilung für Physikalische Chemie, Rostock, MV, Germany

Egon Hassel
University of Rostock, Lehrstuhl für Technische Thermodynamik, Rostock, MV, Germany

The majority of water on earth is seawater, a solution of salts of nearly constant composition dissolved in water. For scientific investigations and design of many natural and technical processes which have to do with seawater, it is of great importance to have a reliable base of thermodynamic data. The most recent standard formulation for seawater (Equation of State 1980) is restricted in its range of applicability due to a lack of density measurements at higher temperatures and elevated pressures. This equation needs the dependence between seawater properties and the more accurate recent international standards for temperature (ITS-90) and for properties of pure water (IAPWS-95). As a result, the International Association for the Properties of Water and Steam endorsed a new joint seawater formulation on the occasion of its 15th International Conference on the Properties of Water and Steam in September 2008 in Berlin. This formulation is also expected to be adopted internationally for oceanography. The present work therefore fills an essential data gap. The main purpose of the investigations described in this presentation is to relate the thermodynamic equilibrium properties to seawater composition, temperature and pressure. The following topics will be presented:

· A thorough evaluation of the state-of-the-art standard equations for seawater thermodynamic equilibrium properties and a recommendation for improvement of these equations.

· Thermodynamic properties of seawater with various salinities over the parameter range of interest by using existing data and new data already measured.

· A comprehensive and accurate thermodynamic equation of state over a well specified range of parameters which are of interest in oceanographic research, underwater technology and land-based industrial plants running on seawater.

The constructed equation of state are used for the calculation of the thermal properties, such as isothermal compressibility, isobaric thermal expansibility, differences in isobaric and isochoric heat capacities, thermal pressure coefficient, internal pressure, secant bulk modulus etc. Another important parameter for the analysing of quality of constructed equation of state is fit of apparent molar volume and compressibility of seawater to the Pitzer equation, analysis of the Debye-Hückel limiting slopes for the sea salts and evaluation of the infinite-dilution apparent molar volume of sea salt. Using the density values of seawater in a various salinities and pure water at the high temperatures and pressures, apparent molar volumes and compressibility of sea salt in water were defined. Derived apparent molar volumes of sea salt fitted to the Pitzer's ion-interaction relation to accurately calculate of apparent molar volumes of sea salt at infinite dilution. The osmotic coefficients and activity of solvent are calculated from the vapor pressure results of seawater. The obtained results are tabulated for use for practical purposes in the oceanographic research.