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Thermal Conductivity of Sodium Chloride Aqueous Solutions

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Abstract—Equations representing the thermal conductivity of water as a function of temperature and pressure, as well as the thermal conductivity of sodium chloride aqueous solutions at temperatures from 20 to 325°C and pressures from 0.1 to 100 MPa and concentrations up to 5 mol/kg are obtained.

Keywords: thermal conductivity, aqueous solution, sodium chloride, thermal conductivity equation, solution concentration

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Sodium chloride is among substances dissolved in geothermal waters, seawater, industrial effluents, and many natural waters. Such waters serve as working fluids in the heat exchangers used in many thermal engineering installations; hence, the thermophysical properties of these solutions must be known for designing and operating such installations. The best way of presenting information on these properties as a function of temperature and pressure is to derive it in the form of mathematical expressions convenient for use in computer programs. The purpose of this work is to construct such equation for the thermal conductivity of an aqueous solution of sodium chloride.

The problem of experimentally measuring the thermal conductivity of sodium chloride aqueous solutions was dealt with in many investigations, information of which is given in Table 1. In the majority of these works, measurements were carried out at atmospheric pressure and in a moderate range of temperatures. The measurements carried out at increased pressures [9, 10, 12, 14, 15] cover the temperature range to 200°C, and it is only in [7] that systematic data on the thermal conductivity of solutions with concentrations of up to 5 mol/kg H_2O at temperatures up to 320°C and pressures close to the saturation pressure were obtained. Thermal conductivity at higher temperatures (up to 375°C) was measured in [13], but only for a solution with a single value of its concentration equal to 4 mol/kg H_2O. The error of the thermal conductivity values obtained in all these works is approximately the same and equal to 1.5–2.0%. The results of these works are consistent with one another within this range of accuracy. Work [5] is the only exception: the thermal conductivity values reported in it are perhaps erroneous because they differ from the totality of other data by 5–6%, and so is work [13]. The dependence of thermal conductivity on temperature obtained in [13] has a pattern differing from those observed in all other investigations. According to the data of all works, the thermal conductivity of solutions is always smaller than that of water, whereas according to [13], the thermal conductivity of solutions at high temperatures is higher than that of water. Since such dependence was obtained only in one investigation and for one concentration of solution, it needs verification and was not taken into consideration in the present study.

In generalizing experimental data on thermal conductivity of solutions, it is advisable to consider them in correlation with the data for the thermal conductivity of pure water. Therefore, an equation for thermal conductivity of solutions was sought in the form

$$\lambda_s = \lambda_w(T, p) - \Delta\lambda(T, p, m), \qquad (1)$$

where λ_w is the thermal conductivity of water, λ_s is the thermal conductivity of solution, and $\Delta\lambda$ is the difference of these thermal conductivities as a function of temperature, pressure, and molality.

Thermal conductivity of pure water can be calculated using the equation recommended by the IAPWS [17]. However, this equation is given as a dependence of thermal conductivity on temperature and density, which is frequently inconvenient for engineering calculations. Therefore, a new equation for the thermal conductivity of water as a function of temperature and pressure was constructed in this work:

$$\lambda_w = \sum_{j=0}^{j=3}\sum_{i=0}^{k(j)} a_{ij}\tau^i\pi^j, \qquad (2)$$

where λ_w is the thermal conductivity of water, mW/(m K); $\tau = T/T_0$, T is temperature, K, $T_0 = 404.15$ K; $\pi = (p - p_s)/p_0$; p is pressure, MPa, p_s is the water saturation pressure, MPa, and $p_0 = 1$ MPa.