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Compatible solutes: thermodynamic properties relevant for effective protection against osmotic stress

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Abstract

Organisms developed very different strategies to protect themselves against osmotic stress. To sustain high salt concentrations of their surrounding some organisms accumulate so-called compatible solutes (CSs), which increase the internal osmotic pressure without disturbing the organism's metabolism. At constant temperature, osmotic pressure is mainly determined by the concentration of the compatible solute and the osmotic coefficient of the aqueous solution, and to a minor extent also by solution densities.

Thus, osmotic coefficients and densities were measured for aqueous CS solutions in a broad range of concentration and at three temperatures (273 K, 310 K, 323 K) at atmospheric pressure. Further, the solubility of CSs in water was measured as function of temperature to determine the maximum CS concentration that can be applied in aqueous solutions. CSs under investigation were trimethylamine N-oxide (TMAO), trehalose, citrulline, N,N-dimethylglycine, DMSO, glycerol, methylglycine, and ectoine. The data was used to calculate real osmotic pressures induced by these CSs. PC-SAFT was applied to model thermodynamic properties and phase equilibria of aqueous CS solutions in quantitative agreement to experimental data.

Among the CSs investigated in this work, TMAO induced the highest osmotic pressure and thus can be considered the best protector against osmotic stress. The data was finally analyzed concerning the influence of CSs molecular size, charge, and hydrophobicity on osmotic pressure. This included also the comparison to incompatible solutes (urea, glycine).