

Experimental determination of solubilities of sodium tetraborate (borax) in NaCl solutions, and a thermodynamic model for the Na-B(OH)₃-Cl-SO₄ system to high-ionic strengths at 25 °C

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ABSTRACT

In this study, solubility experiments on sodium tetraborate (NaB₄O₇·10H₂O, borax) are conducted in NaCl solutions up to 5.0 m at room temperature (22.5 ± 1.5 °C). In combination with solubility data of sodium tetraborate in Na₂SO₄ solutions from the literature, the solubility constant (log *K_{sp}*) for sodium tetraborate for the following reaction



is determined as -24.80 ± 0.10 based on the Pitzer model. In conjunction with the relevant Pitzer parameters, based on the above log *K_{sp}* for borax, and log β₁ (0.25 ± 0.01) evaluated from the literature for the following complex formation reaction



a thermodynamic model with high precision is established for the Na⁺-B(OH)₃-Cl⁻-SO₄²⁻ system at high-ionic strengths up to saturation of halite (NaCl), mirabilite (Na₂SO₄·10H₂O), and thenardite (Na₂SO₄). The model is validated by comparison of model predicted equilibrium compositions for the assemblages of borax alone, borax + halite, borax + mirabilite, borax + halite + thenardite, and borax + mirabilite + thenardite in the mixtures of NaCl+Na₂SO₄ to ionic strengths of 8.0 m, with independent experimental values from the literature. The differences in concentrations of major ions, e.g., Na⁺, Cl⁻, and SO₄²⁻, between model predicted and experimental values are generally <0.5%. The difference for total boron concentrations is <0.05 m with an error <25%.

The revised thermodynamic model is applied to the potential recovery of borax from boron-enriched brines via evaporation at 25 °C, using the two brines from China as examples. The reaction path calculations suggest that the brine from the Zhabei Salt Lake in Xizang (Tibet) Autonomous Region, is suitable to recovery of borax via evaporation at 25 °C, whereas the brine from the western Sichuan Province, although it is enriched in boron, is not suitable to extraction of boron as borax, but is suitable to extraction of potassium as sylvite, via evaporation at 25 °C.

Keywords: Pitzer model, borate, actinide solubility, nuclear waste isolation, geological repositories, Waste Isolation Pilot Plant (WIPP), performance assessment (PA), concentrated brines