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## Development of a Thermodynamic Model for Swelling Stress of Bentonite: Measurements of Thermodynamic Data of Water in Na-Bentonite

Haruo Sato<sup>1,\*</sup>

<sup>1</sup>*Faculty of Environmental, Life, Natural Science and Technology, Okayama University*

*\*E-Mail: [sato.haruo@cc.okayama-u.ac.jp](mailto:sato.haruo@cc.okayama-u.ac.jp) / [ph3c5tsu@s.okayama-u.ac.jp](mailto:ph3c5tsu@s.okayama-u.ac.jp)*

### Abstract

Buffer material composing engineered barrier in the geological disposal of a high-level radioactive waste develops swelling stress by penetration of groundwater from the surrounding rock mass. In previous studies, we measured the activity of water and the Gibbs free energy of water in Na-montmorillonite which is the major component of Na-bentonite by vapor pressure method, and proposed a model to analyze the swelling stress of bentonite based on thermodynamic theory. However, data for the vapor pressure of water in bentonite are limited. In this study, we determined the activities of water and the Gibbs free energy by measuring relative humidity (RH) for water in Na-bentonite and Na-montmorillonite. We also analyzed the swelling stress of bentonite based on the thermodynamic model and compared to the measured data.

Kunigel-V1 and Kunipia-F (Kunimine Industries Co. Ltd.) were used as a Na-bentonite. The montmorillonite contents of both bentonites are approximately 51% and 99%, respectively. Bentonite powder dried was placed in a polyethylene bottle in an amount of 3.00g each, and adsorbed water vapor in a vacuum chamber. Next, RH and temperature sensors and bottles with bentonite were placed in the vacuum chamber, and the chamber of which inside pressure was reduced to -95kPa or less was submerged in a water bath at 25°C. The RH and temperature in the chamber were measured after 24 hours and the weight of the bentonite was measured. This operation was repeated every about 24 hours. Thus, RH and temperature were measured versus water content (ca. 10-100%).

The activities of water and the Gibbs free energies for both bentonites decreased with decreasing water content below approximately 40%. This trend is the same as in the past studies. The swelling stresses of bentonite calculated using thermodynamic data obtained in this study were generally in good agreement with the measured values.