§9. Prediction Study of Hydrogen Transport Properties for Molten Salt Flinabe

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Flibe ($LiF+BeF_2$ mixed molten salt) is a promising liquid tritium breeder and coolant for fusion reactors, because of low reactivity with oxygen, moderate viscosity and high neutron multiplication. Its defects, on the other hand, are generation of corrosive TF and high melting point (459°C). The former defect has already been solved by the redox control technique using Be[1]. If the latter is removed, the molten salt becomes the most attractive tritium breeder. Recently, a new fluoride Flinabe ($LiF+NaF+BeF_2$ mixture) is focused on because of its potential lower melting point. However, there were few studies because of large freedom due to the tertiary-component system. Before initiating detailed experimental studies on this fluoride, preliminary investigation is made to predict physical or chemical properties of Flinabe as a function of composition along with Flibe, Fnabe ($NaF+BeF_2$) and Flinak (LiF+NaF+KF), on which prior studies have already been presented[2].

Viscosity and melting point are the most important properties when the fluoride is used for liquid breeder or coolant. Li_2BeF_4 ($2LiF+BeF_2$) and eutectic Flinak have a moderate viscosity near to H_2O. However, its viscosity becomes large when the BeF_2 content becomes rich. Fig. 1 shows estimations and measurements of fluorides viscosity. When the molar fraction of BeF_2 is smaller than 0.4, its viscosity is lower than 0.01 Pas. Previous measurements of Flibe and Fnabe are almost equal to the estimations. The equation to estimate the viscosity of the tertiary-component Flinabe from that of each pure component, η_i, is given as a function of mole fraction, x_i, as follows:

$$\eta_{Flinabe}^{-0.25} = x_{LiF}\eta_{LiF}^{-0.25} + x_{NaF}\eta_{NaF}^{-0.25} + x_{BeF_2}\eta_{BeF_2}^{-0.25} \quad (1)$$

The above equation can be applied under any temperatures as long as the mixture is in liquid state. When the content of BeF_2 increases, the viscosity also increases exponentially. The behavior is well simulated by the correlation.

The melting temperatures of Flibe, Fnabe and Flinak are estimated based on the thermodynamic properties of mixing enthalpy and entropy. The Gibbs free energy of a mixed fluoride is estimated by the following equation:

$$\sum_{i=1}^{n} x_i G_{i,liq}^0 + R_g T \sum_{i=1}^{n} x_i \ln(x_i) + \sum_{i \neq j}^{n} \Omega_{ij} x_i x_j = G_{k,sol}^0 \quad (2)$$

where $G_{i,liq}{}^0$ is the standard Gibbs free energy of each pure component (i=LiF, NaF, BeF_2, KF) and x is its molar fraction. Ω_{ij} is an interaction parameter determined by electro-chemical measurements independently. The above equation is used to estimate properties of relating mixed fluorides such as Flibe, Fnabe and Flinak, because the interaction parameters are already available in previous references. A comparison of Flibe is shown in Fig. 2. Comparatively close agreement is obtained in the melting temperature and the binary-component phase diagram between experiment and estimation. The interaction parameter is available for Flibe, Fnabe and Flinak. However, that for Flinabe is not obtained. At present, two methods of the interaction enthalpy model and chemical reaction one are investigated. Further experiment and analysis are necessary. When a new phase of Li_2BeF_4, Na_2BeF_4 or $LiNaBeF_4$ in each phase diagram is formed in the tertiary-component Flinabe system, the chemical reaction model developed in the present study is useful for the estimation.

Experiment using a mixed fluoride with low viscosity and low melting point will be performed in the near future.

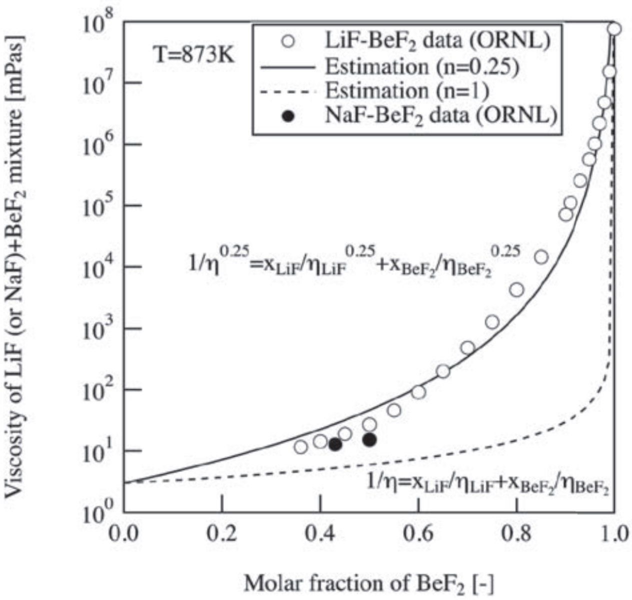

Fig. 1 Prediction of $LiF-BeF_2$ or $NaF-BeF_2$ viscosity

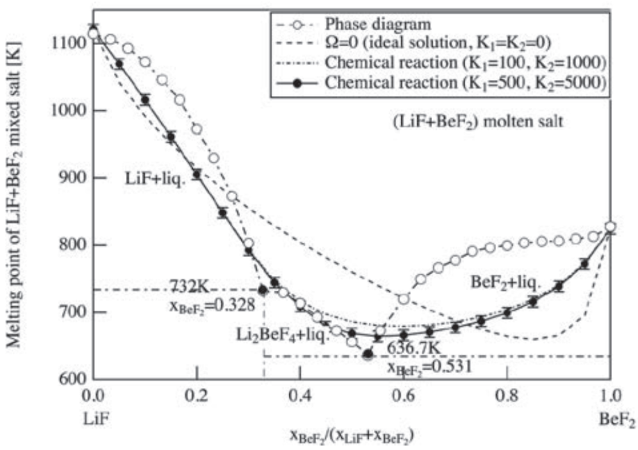

Fig. 2 Prediction and measurement of phase diagram and melting point of the binary-component $LiF+BeF_2$ system

1) Fukada, S. *et al.*: J. Nucl. Mater., **367-370** (2007) 1190.
2) Fukada, S. *et al.*: Fus. Sci. Technol. in contribution.