§8. A Conceptual Design of the Blanket with Molten LiF-PbF2

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The National Institute of Fusion Science (NIFS) showed a conceptual design of the blanket with molten LiF-BeF2(flibe) for the coming fusion device. Molten salts show neither phase transition nor radiation damage during neutron irradiation. Moreover, Flibe has been successfully used in the molten salt reactor at ORNL. Thus Flibe is a promising candidate as a blanket material. We proposed the molten LiF-PbF2 as an alternative candidate, since resource of Pb is more plentiful than Be and Pb also generates extra neutron with (n, 2n) reaction. This year we made preliminary discussion of the molten LiF-PbF2 blanket.

The LiF-PbF2 system shows a simple eutectic at 853K and PbF2=60 mol%. Operating temperature may be 50 K over the eutectic temperature, that is, about 900 K, which is much higher than that of the Flibe. Corrosion resistive material was Cu among brass, P-brass, monel, SUS304SS, Ni and Cu. This results was expected by thermodynamics of fluorides of constituent metals. It was pointed out that Cu cannot be structural material at high temperatures, but can be a cladding material.

In order to know the chemical form of tritium evolved from neutron irradiated LiF-PbF2, 1 g of the solidified LiF-PbF2 was irradiated in TRIGA-II reactor at Musashi Institute of Technology. This sample was sealed under He atmosphere in a quartz ampoule. Mass spectrum of this sample were determined by Q-mass at liquid nitrogen temperature and then a t 673 K to release T. At mass number =22 a peak appeared at 673 K. It was concluded that this peak corresponds to TF.

Tritium recovery experiments were carried out in the LiF-PbF2 melt under neutron irradiation at 973 K. Diffusion coefficients of tritium in the LiF-PbF2 melt was estimated to be 1×10^{-9} m^2/s, which is comparable to that in the Flibe.

Measurement of the solubility of HF gas in LiF-PbF2 binary molten salt mixture with its eutectic composition have been carried out over a temperature range between 923 and 1023 K by an elution method. In order to examine the apparatus for the solubility measurement, preliminary experiment to study HCl solubility in the NaCl-KCl melt were carried out. Experimental conditions were almost similar to those of Lukumanova and Vil'nyanskii. It was found that our solubility results shows an agreement with their results. In order to evaluate HF solubility and to obtain values of heat of solution and entropy, density of this system was also measured. The temperature dependence is expressed by the following equation.

$$d/10^3 kgm^{-3} = 4.48 - 9.61\times10^{-4}T$$

The solubility of HF in the molten LiF-PbF2 were listed in Table 1.

Table 1 Solubility of HF in the molten LiF-PbF2 with PbF2 = 60 mol%)

Saturating Temp./K	Solubility/mol/mlx10^6
923	1.02
943	0.57
973	0.26
993	0.25
1023	0.06

This shows that HF solubilities decrease with increasing temperature. The small values of solubilities suggest this dependence to be linear or obey Henry's law. The heat of solution, which is independent of temperature is estimated here by a least-fitting from the van't Hoff relation.

$$\Delta H^s = -Rd(\ln K_p)/d(1/T)$$

In our case the heat of HF solution in the LiF-PbF2 melt is

$$\Delta H^s = -0.205 \pm 0.002 kJ/mol$$

A decrease in HF solubility with increasing temperature and the value of heat of solution suggest that a dissolution is an exothermic chemical process.