§6. System Design Study of Hydrogen Isotope Recovery from Molten-Salt Blanket of Fusion Reactor

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Molten salt Flibe ($2LiF+BeF_2$) as an advanced blanket has several attractive advantages of simple self-cooled blanket system, easy maintenance, a stable salt, low MHD effect and so on. The largest disadvantage is chemical control of TF to be generated in the blanket. Relating with tritium behavior in the molten salt Flibe blanket of FFHR-2 including physical or chemical properties on tritium recovery and tritium leak, to control chemical form of tritium in Flibe becomes a critical issue. Therefore, it has being intensively investigated in the JUPITER-II program [1,2]. When the chemical state of tritium in Flibe is successfully controlled by the use of Be, the tritium chemical form is considered T_2 or HT in Flibe. In this NIFS collaboration study, a design of a tritium recovery apparatus and an effective way to control of tritium leak were investigated closely relating with the FFHR-2 design. In this report we focused on the expected TF concentration in the Flibe blanket and impurity effects because of the limit of paper length.

The generation of tritium fluoride (TF) can cause corrosive action to Flibe-facing materials. In the Flibe blanket, Be is used for the neutron multiplier and is also expected as a redox-control agent as follows:

$$Be + 2TF = BeF_2 + T_2$$

Based on the experimental study of JUPITER-II, we obtained the Be dissolution rate and the saturated Be concentration in Flibe. Their values were as follows:

Be dissolution rate: 1.8×10^{-3} mol/m^{2}s at 530°C
Saturated Be concentration: 4×10^{-3} Be/Li_2BeF_4

The dynamic behavior of redox control by Be in the Flibe blanket was analyzed using two material balance equations on tritium and Be and a tritium generation rate. As the first approximation, it was assumed that the tritium chemical form immediately after the nuclear reaction is TF. As the second assumption, the bulk tritium concentration is constant throughout the self-cooled blanket under the complete mixing condition. In this analysis, we focused on the overall material balance of TF and T_2 in the self-cooled Flibe blanket. Variations of the TF and T_2 concentrations in the Flibe blanket with time were determined using two material balance equations in terms of the reaction rate constant, k_{BeF2}. The reaction rate may decrease with the decrease of the TF concentration in the blanket. The reaction order was assumed of the second-order. From fitting the numerical simulation to the experimental data, the reaction rate constant was determined. The value was 1×10^9 mol/m^{3}s at the HF partial pressure of 10^2 Pa.

Under steady-state operation, the concentration of TF in Flibe was calculated using the three parameters, the Be dissolution rate, the saturated concentration and the

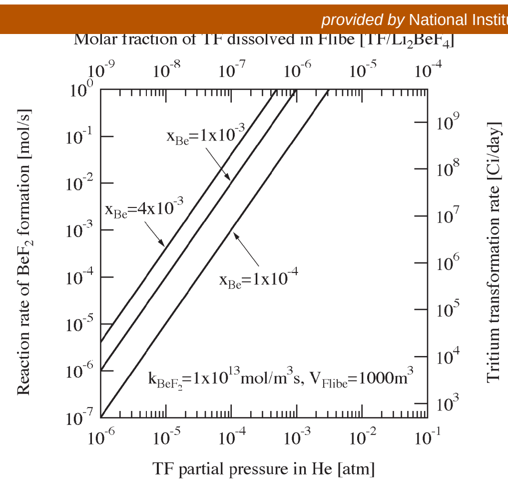

Fig. 1 TF-to-T_2 conversion rate as a function of HF

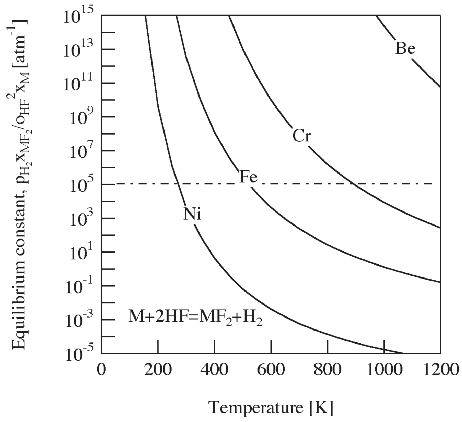

Fig. 2 Concentration ratio of metallic impurities in Flibe as a function of temperature

reaction rate constant. **Fig. 1** shows the TF concentration expected in the Flibe blanket of FFHR-2. If k_{BeF2} is independent of the TF concentration, the calculated TF concentration was estimated 10^{-2} in molar fraction. The concentration is sufficiently low, and, therefore, we can expect that Be can act as a redox agent as well as neutron multiplier.

Fig. 2 shows the concentration ratio of metallic impurities in Flibe as a function of temperature. Ferritic steel or Ni alloy such as Hastelloy is expected for the structural material of Flibe blanket. In this case, Ni, Fe and Cr are impurity metals expected in Flibe. Thermodynamic calculation and the reaction rate equations showed us that iron is the most influential one for the redox control by Be. Therefore we need to remove Fe in the Flibe blanket loop.

References

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