Equilibrium Approach for Modelling a Smelting Process of the Advanced Spent Fuel Conditioning Process

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As a unit process of the advanced spent fuel conditioning process (ACP) at the Korea Atomic Energy Research Institute (KAERI), a smelting process is employed for the purpose of transforming a metal product from an electrolytic reduction process into an ingot form. An additional purpose of the process is to distillate a salt electrolyte from the metal product, containing alkali metal chloride, alkaline earth metal chloride, lithium oxide and lithium chloride. The salt electrolyte adopted in the electrolytic reduction process is composed of lithium chloride and lithium oxide which accounts for up to 3 wt% of the salt mixture. The alkali and alkaline earth metal chlorides are the products between their oxides with the lithium chloride by chemical reactions taking place during the electrolytic reduction process.

The melting points of the chlorides are lower than that of the metal product whose main constituent is uranium metal. However, a removal of the salt can not be attained unless the process is operated under a vacuum condition. After the distillation of the salt, the operation condition of the smelting process should be changed for smelting the metal product. In the case of the smelting, the vacuum condition is not adequate since an evaporation of the metal components such as Am could take place. It is, therefore, required to develop a distillation and smelting model describing the operation condition of the process.

In practice, two principal methods may be applied to the modelling. The first one is an equilibrium approach which assumes that the vapor being evolved from a solution is in equilibrium with the residual liquid. The other method is a kinetic approach which describes a rate of distillation from the surface. The equilibrium models are very useful to predict the final state with respect to the operation conditions while the kinetic models are available for estimating the evaporated amount of the volatile compounds at a certain time. In this study, an equilibrium model is used since it could suggest the operation conditions which are of significance at the stage of a process development.

An equilibrium model based on the Rayleigh equation and phase equilibrium relation equations is proposed and examined by using published data. The model fits the data by more than 99% for the uranium metal basis. The model is also used to suggest the operation conditions for the smelting process of the ACP. The system of interest contains LiCl, Li_2O, $BaCl_2$, CsCl, RbCl, and $SrCl_2$ for the salt distillation step and it includes U, Am, and Pu for the smelting step. Combined with the design characteristics and experiment results such as the surface area and the rate of a distillation, the model will be developed to describe the kinetic behavior.