

## Online solid-liquid extraction experiments of $^{255}\text{No}$ in the Sr resin/HDEDTP system

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Element 102, nobelium (No), is the second element from the back of the actinide series. Unlike all other lanthanides and heavy actinides, No exists as a divalent cation rather than trivalent cation in aqueous solutions. A previous study on ion-exchange experiments have reported that No exhibits similar chemical properties to those of alkaline earth metals.<sup>1)</sup> Our group has demonstrated that No exhibits different co-precipitation behavior compared to alkaline earth metal ions using the samarium hydroxide co-precipitation method.<sup>2)</sup> Subsequently, we focused on solid-liquid extraction using a polymer-supported crown ether resin (product name: Sr resin, made by eichrom Inc.). A recent online solid-liquid extraction experiment involving  $^{255}\text{No}$  in the Sr resin/ $\text{HNO}_3$  system was successfully achieved<sup>3)</sup> using an automated batch-type solid-liquid extraction apparatus (AMBER).<sup>4)</sup> Further extraction investigation of No in various extraction systems is required to systematically understand the chemical properties of No.

In this work, we focus on diethyldithiophosphate (HDEDTP) as a new ligand for Sr resin solid-liquid extraction with  $^{255}\text{No}$  to obtain its distribution coefficients ( $K_d$ ) and to investigate the complexes in the Sr resin. Previously, we determined the  $K_d$  values of alkaline earth metals (Ca, Sr, Ba, and Ra) in the Sr resin/HDEDTP system and found that the extraction reactions reached equilibrium within 1 min, thereby indicating the suitability of this system for the  $^{255}\text{No}$  experiment. A series of extraction experiments for  $^{255}\text{No}$  were conducted using AMBER to determine the  $K_d$  values and investigate the properties of No.

$^{255}\text{No}$  ( $T_{1/2} = 211$  s) and  $^{162}\text{Yb}$  ( $T_{1/2} = 18.9$  min) were produced by the  $^{248}\text{Cm}(^{12}\text{C}, 5n)^{255}\text{No}$  and  $^{nat}\text{Gd}(^{12}\text{C}, xn)^{162}\text{Yb}$  reactions by using the AVF cyclotron at RIKEN. The nuclear-reaction products were transported to the chemistry laboratory using a He/KCl gas-jet system and deposited on the collection site of AMBER for 450 s. Subsequently, the products were dissolved in 250  $\mu\text{L}$  of 320 mM HDEDTP solution and loaded into a chemical reaction container containing the Sr resin. After shaking the container with a vortex mixer for 30–180 s, only the liquid phase was pushed out of the container through a PTFE filter by compressed air. The solution samples were evaporated

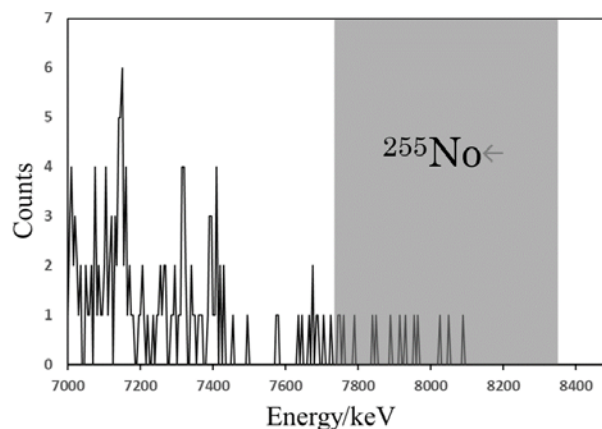


Fig. 1.  $\alpha$  spectrum of  $^{255}\text{No}$  was obtained in control experiments with a shaking time of 60 s.

to dryness and subjected to  $\alpha$  particle measurement by the automated rapid alpha/SF detection system.

After the  $\alpha$  particle measurement, we performed  $\gamma$ -ray measurement for  $^{162}\text{Yb}$  (163.35 keV) in samples with Ge detectors to calculate the chemical yield of each extraction.

We performed 68 and 21 times experiments for extraction and control, respectively. As shown in Fig. 1, a total 28 times of  $\alpha$  events from the decay of  $^{255}\text{No}$  were observed. The half-life of  $^{255}\text{No}$  was estimated to be  $226 \pm 17$  s, which is consistent with the previously reported value ( $211 \pm 11$  s).<sup>5)</sup>

The  $K_d$  values were determined using

$$K_d = A_r V / A_s w = (A_1 - A_s) / A_s w, \quad (1)$$

where  $A_r$ ,  $A_s$ , and  $A_1$  represent the radioactivities of  $^{255}\text{No}$  in the resin, solution, and control solution, respectively;  $V$  represents the volume of the aqueous phase (mL); and  $w$  represents the mass of the dry resin (g).

The  $K_d$  values of Er, Fm, and Yb were consistent with those observed in the Sr resin/ $\text{HNO}_3$  system.<sup>4)</sup> In addition, the  $K_d$  values of No were constant for all different shaking times of 30, 120, and 180 s, which implies that the extraction reactions reached equilibrium within 30 s of shaking.

We plan to discuss the extraction behavior of No based on the comparison of the  $K_d$  values of alkaline earth metal ions. In addition, we will conduct theoretical studies on No complexes in the Sr resin using relativistic quantum chemical calculations (DFT) to

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analyze the electronic states of these complexes.

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