Online solid-liquid extraction of ^{255}No with the polymer-supported crown ether

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Nobelium (No) is an actinide element with an atomic number of 102. In aqueous solutions, No is considered to form a +2 valence state stably, while other f-block elements are stable at +3 or higher valence states. Previous ion-exchange experiments have reported that No exhibits similar chemical behavior to that of Ca^{2+} and Sr^{2+}.[1] Our group has recently demonstrated that No^{2+} shows different coprecipitation behavior from alkaline earth metal ions, using the samarium hydroxide coprecipitation method.[2] Further systematic studies are needed on No^{2+} compared with the group II elements from the viewpoint of molecular structure in the solution and its electronic structure.

We focus on solid-liquid extraction using the polymer-supported crown ether. The Sr resin (Eichrom Inc.) contains 4,4′ (5′)-di-tert-butylcyclohexano-18-crown-6 ether (DtBuCH18C6) and has strong extraction selectivity for Sr^{2+}. The selectivity of alkaline earth ion is affected by a changes in the acidity of a liquid phase and its concentration.[3,4] In the extraction in HNO_3 system, the extracted species of Sr is deduced to be $Sr(NO_3)_2$DtBuCH18C6.[5] Previously, we found that the extraction reaction of alkaline earth elements with the Sr resin rapidly (∼1 min) reached the equilibrium state and the solid-liquid extraction is suitable for ^{255}No experiment. We have obtained the distribution coefficients (K_d) of Ca, Sr, Ba, and Ra with the Sr resin in HNO_3, HCl, and $HClO_4$ as comparison data for No.

In this work, we performed online solid-liquid extraction experiments with ^{255}No to obtain its K_d values and to investigate the complexation between No^{2+} and DtBuCH18C6. To obtain the K_d values of No under equilibrium state, we used a batch-type solid-liquid extraction apparatus called AMBER.[6]

We produced ^{255}No ($T_{1/2}$ = 211 s) and ^{162}Yb ($T_{1/2}$ = 18.9 min) by the ^{248}Cm(^{12}C, $5n$)^{255}No and ^{nat}Gd(^{12}C, xn)^{162}Yb reactions with the AVF cyclotron at RIKEN. The reaction products were transported by the He/KCl gas-jet system to the chemistry room and dissolved in 3.5 MHNO_3 or 7.6 M HCl solutions. The solution sample was injected into a chemical reaction container containing the Sr resin. After shaking the container for 60 or 180 s, only the solution phase was discharged from the container through a PTFE filter. Subsequently, the discharged sample was evaporated to dryness and subjected to alpha particle measurement by the automated rapid α/SF detection system.

After α-particle measurement, we measured γ-ray activities of ^{162}Yb in the samples with Ge detectors to calculate the chemical yield of each extraction.

We carried out 48 extraction and 24 control cycles and observed a total of 173 α events from the decay of ^{255}No, as shown in Fig. 1. The production cross-section of ^{255}No was estimated to be approximately 500 nb, and the value is consistent with that determined in the previous report.[7] The half-life of ^{255}No was estimated to be 212±24 s, which is in good agreement with the previously reported value (211 ± 11 s).[8] The K_d value of ^{154,155}Er and ^{254,255}Fm (byproduct α-emitters) is ∼1 mL g^{-1}, which is within the value of other f-block elements previously reported.[4] Thus, it was demonstrated that the α events in the region of interest for ^{255}No in the α-particle spectrum properly originate from only ^{255}No and that reliable K_d values were obtained in the present solid-liquid extraction experiments using AMBER. The K_d values of No are under estimation.

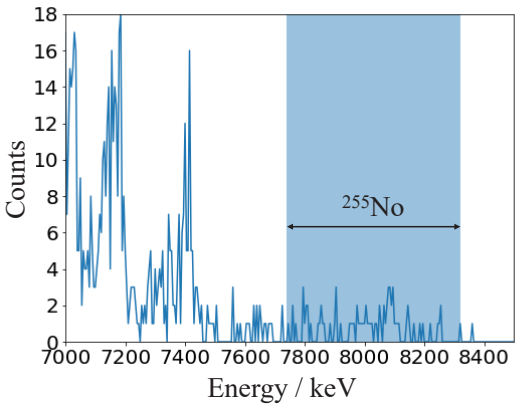

Fig. 1. α-spectrum for ^{255}No obtained in control experiment without the resin with 60-s shaking.

In the future, we will discuss the extraction behavior of No based on the comparison of the K_d values of ^{255}No with those of alkaline earth metal ions. Additionally, we will perform relativistic quantum chemical calculations and analyze the electronic states of extracted species of No.

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