

Coprecipitation experiment of various elements with Sm hydroxide using multitracer

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Chemical studies on transactinide elements with atomic numbers $Z \geq 104$ are currently at the frontier in nuclear chemistry. The transactinide elements are produced at accelerators using heavy-ion-induced nuclear reactions. Rapid chemistry on a one-atom-at-a-time basis is applied to these elements because of their low production rates and short half-lives. In addition, for unambiguous identification of these elements, it is necessary to detect α or spontaneous fission decays. Therefore, chemical experiments of transactinides are not abundant. In the ion-exchange chromatography, the fluoride complex formation of Rf ($Z = 104$) was successfully investigated, and the behavior of Rf was reported to be clearly different from those of the homologues Zr and Hf. Chemical studies on transactinides in various chemical systems should be conducted to understand their characteristic chemical properties.

The purpose of the present study is to establish a coprecipitation method as a new method for the chemistry of transactinide elements. Because these elements can be treated as only one atom at a time, we must study their coprecipitation behaviors with a carrier element. For this, a preparation method of coprecipitated samples with Sm hydroxide, which facilitated the α spectrometry with a high energy resolution, was established.¹⁾ We are planning to apply this method to transactinide chemistry and to investigate the coprecipitation behaviors of transactinides. In the chemistry of transactinides, model experiments with their homologues are usually performed to establish the experimental method and to determine the conditions. In this work, we investigated the coprecipitation behaviors of various elements with Sm hydroxide using a multitracer produced by nuclear spallation reactions in RIKEN.

A multitracer was produced by irradiating the ^{nat}Ta foil targets by 135-MeV/nucleon ¹⁴N ions accelerated by RIKEN Ring Cyclotron²⁾. Various nuclides, namely various elements, with $Z < 73$ (Ta) were produced by nuclear spallation reactions. Only the nuclear reaction products recoiling out of the target foils were transported from the reaction chamber to the chemical laboratory by the He/KCl gas-jet system.²⁾ The products collected on a glass filter paper for about 40 h were dissolved in 1 mL of 0.01 M HCl solution, and the solution sample was filtrated with a filter paper to remove the glass chips from the solution.

The Sm standard solution (20 μ L) containing 20 μ g of Sm was added into 220 μ L of the multitracer solution. The solution was stirred, and then 2 mL of the basic solution (dilute and concentrated aqueous NH₃, and 0.1, 1, 6, and 12

M NaOH solutions) was added. The solution was stirred for 10 s or 10 min. Then, the solution containing the precipitate was filtrated by suction with a polypropylene membrane filter (0.1 μ m, ϕ 20, Eichrom). The filtrate was collected in a vial. Both the precipitate and filtrate were dried using a heater at 100°C and then subjected to γ -ray spectrometry with a Ge detector. The precipitation yields (Y_1) were determined from these radioactivities. The reference radioactivities of the radiotracers were also determined. The precipitation yield (Y_2) as a relative value to the reference was also determined to check the accuracy of the obtained precipitation yields.

The product nuclides were identified from the energies and half-lives of the observed γ -ray peaks. We found the following nuclides: ²⁴Na, ⁴²K, ^{82m}Rb, ^{127,129}Cs (alkali metals), ²⁸Mg, ⁴⁷Ca, ¹²⁸Ba (group 2), ^{44,47,48}Sc, ⁸⁷Y (group 3), ^{132,135}Ce, ^{145,146}Eu, ^{146,147,149}Gd, ^{149-153,155}Tb, ^{155,157}Dy, ^{160m}Ho, ¹⁶¹Er, ^{165,167}Tm, ^{166,169}Yb, ^{169,171,172}Lu (lanthanides), ⁸⁹Zr, ^{170,173}Hf (group 4), ⁹⁰Nb, ¹⁷⁶Ta (group 5), ^{93m}Mo (group 6), ⁹⁶Tc (group 7), ^{99m,100}Rh (group 9), ⁶⁵Zn, (group 12), ⁶⁷Ga, ^{110,111}In (group 13), ^{71,72}As, ^{118m,120m}Sb (group 15), ⁷³Se, and ^{119m}Te (group 16).

For these elements, the precipitation yields and their dependences on the composition of the basic solution were obtained. Overall, the yields reflecting the properties of each element in the hydroxide precipitation were observed. For example, the yields of alkali metal elements were almost 0% under all the conditions. The yields of lanthanides were almost 100%, and decreased in the case using 6 and 12 M NaOH. In addition, the precipitation yield of Zn was decreased to almost 0% in adding concentrated aqueous NH₃, indicating the well-known properties that Zn forms a cationic ammine complex in such a solution. The yields of Zr and Hf, the homologues of Rf, were close to 100% and decreased with an increase in the hydroxide-ion concentration, while those of Nb and Ta, the homologues of Db, were always high. In contrast, the yields of Mo, the homologue of Sg, were 0% under all the conditions. It would be interesting to study the precipitation behaviors of these transactinides. The Y_1 values were consistent with the Y_2 values. In comparison between the results with 10-s and 10-min stirring, both the yields agreed with each other for many elements, suggesting rapid chemical reactions; only exception was the result using 12 M NaOH. We believe that the coprecipitation properties of transactinides with Sm hydroxide could be investigated by the present method.

References

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- 2) H. Haba et al., *Radiochim. Acta* **2005**, 93, 539.

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