Coprecipitation experiment with Sm hydroxide using a multitracer produced by nuclear spallation reaction: A tool for chemical studies with superheavy elements†

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The chemical properties of superheavy elements (SHEs) are expected to deviate from the periodicity of their lighter homologues in the periodic table because of the strong relativistic effects on the valence electronic shells of the heavy atoms. However, it is difficult to perform chemical experiments of SHEs because these nuclides are short-lived and their production rates by nuclear reactions are quite low. These conditions create the need for rapid chemical experiments on a one-atom-at-a-time basis. In addition, for unambiguous identifications of these elements existing as single atoms, it is necessary to detect α particles with characteristic energies. These experimental difficulties limit the variety of chemical investigations of SHEs. So far, most of the methodologies in aqueous chemistry were limited to the ion-exchange method or solvent extraction. The purpose of the methodologies in aqueous chemistry were limited to these radioactivities. The product nuclides were identified based on their characteristic γ-ray energies and corresponding half-lives. In total, we identified 34 elements containing more than 60 nuclides as follows: 24Na, 42K, 82Rb, 127Cs {group 1}, 24Mg, 47Ca, 128Ba {group 2}, 44,47Sc, 86,87Y {group 3}, 72La, 132,133Ce, 145,146,147Eu, 146,147,148Gd, 149-153Tb, 152,155,157Dy, 160Ho, 161Er, 165,166,167Tm, 166,169Yb, 169,170,171,172Lu {group 3 (lanthanides)}, 90Zr, 170,173Hf {group 4}, 90,170Ta {group 5}, 93Mo {group 6}, 96Tc {group 7}, 99m,100,101Rh {group 9}, 65Zn {group 12}, 67Ga, 110,111In {group 13}, 71,72As, 118,120Sn {group 15}, 73Se, and 119,120Te {group 16}. The nuclides listed in parentheses are ones for which the coprecipitation yields could not be determined. Various elements belonging to various groups in the periodic table were included in the multitracer used. The presently prepared multitracer contains the homologues of various (nine) SHEs (group 4–18), and thus, this study is beneficial for the model experiment toward the chemical study on the SHEs.

The coprecipitation yields of radionuclides of groups 1–7, 9, 12, 13, 15, 16 elements with Sm hydroxide and their dependence on the kind and concentration of the prepared basic solutions qualitatively reflect the hydroxide precipitation properties (formation of ammine and hydroxide complexes) of the elements in macro amounts. This finding suggests that the coprecipitation behavior of an element whose chemical properties are unknown can be investigated using the present method, and we can discuss its general hydroxide precipitation properties based on the results obtained for coprecipitation. In addition, the chemical reactions of the majority of the elements in the coprecipitation are sufficiently fast to reach equilibrium within 10 s of stirring although for Mo and Se, relatively slow chemical reactions were observed. Based on the results in the present experiment, we can say that the present coprecipitation method with Sm hydroxide is applicable to SHE chemistry. This methodology will open new chemistry routes (various precipitates) for SHEs.

Reference

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