



Co-precipitation of single atoms of element 104 rutherfordium with samarium hydroxide

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Abstract

All superheavy elements (SHEs), with atomic numbers (Z) ≥ 104 , have been artificially synthesized one atom at a time and their chemical properties are largely unknown. Because these heavy nuclei have short lifetimes and their production rates are extremely low, chemical experiments need to be carried out on single atoms and the methodologies have mostly been limited to adsorption and extraction. We have now investigated the precipitation properties of the SHE Rf ($Z = 104$). A co-precipitation method with samarium hydroxide previously established had shown that the co-precipitation behavior of a range of elements reflected these elements' tendency to form hydroxide and ammine complexes. Here, co-precipitation behavior of Rf was investigated in basic solutions (NH_3 and NaOH solutions). Comparisons between the behavior of Rf with that of Zr and Hf (lighter homologues of Rf) and actinide Th (a pseudo-homologue of Rf) showed that Rf does not coordinate strongly with NH_3 , but forms a hydroxide (co)precipitate as the group 4 elements form $\text{M}(\text{OH})_4$ precipitates.

Background & Results

In heavy atoms, the relativistic effects caused by the high nuclear charge are strong, and the strong effects stabilize the inner orbital electrons (s and $p_{1/2}$) and destabilize the outer orbital electrons (d and f) of SHEs, which would result in characteristic chemical properties among their homologues in the periodic table. Therefore, the chemical properties of SHEs attract many scientists. However, it is difficult to realize the chemical experiments on SHEs due to single atom situation in SHE experiments and short half-lives of the heavy nuclei.

For co-precipitation experiment on element 104, Rf, we previously studied co-precipitation behaviors of its homologous elements, Zr and Hf, and pseudo homologue, Th. In addition, we developed an apparatus for rapid and repetitive preparation of co-precipitated samples. In this work, we performed online co-precipitation experiments using the apparatus for the ^{261}Rf isotope produced in the $^{248}\text{Cm}(^{18}\text{O}, 5n)^{261}\text{Rf}$ reaction with the AVF cyclotron at RIKEN. Co-precipitation yields of Rf were determined as relative values to standard samples. The values of Rf were around 100% and similar to those of Zr, Hf and Th, which represents that Rf would have the property to form hydroxide precipitate. In high hydroxide ion concentration solution, the yield of Rf was different from those of Zr and Hf but similar to that of the pseudo homologue Th.

Significance of the research and Future perspective

Chemical properties of SHEs may be characteristic in the periodic table due to strong relativistic effects. However, the relativistic effects are not well understood. The relativistic effects influence the orbital electrons in all elements though negligibly small for light elements, and understanding these relativistic effects, as well as the Coulomb interactions (nucleus-electron and electron-electron

interactions) and quantum electrodynamics, is crucial for a complete understanding of the element properties. Full-relativistic calculations on various chemical behaviors of SHEs that are strongly influenced by the relativistic effects would advance research on the relativistic effects. To experimentally observe their new chemical behaviors and to provide such data for the latest relativistic calculations are of significant importance. By using the presently developed co-precipitation method, we are planning to investigate various precipitation behaviors for SHEs.

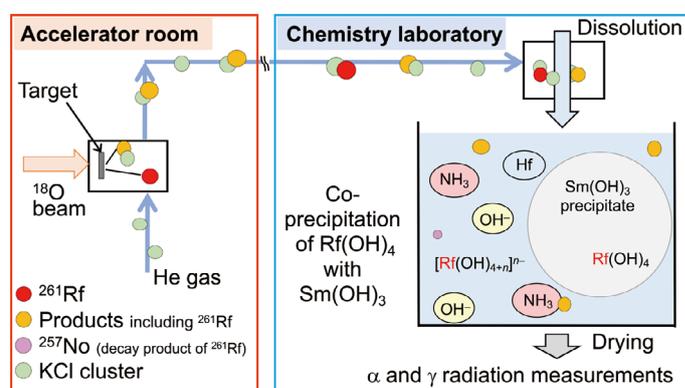


Fig. 1 Schematic figure of online co-precipitation experiment of ^{261}Rf .

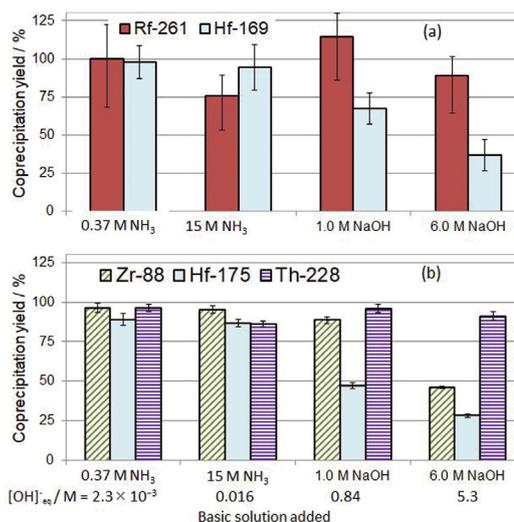


Fig. 2. Co-precipitation yields of Zr, Hf, Th, and Rf with samarium hydroxide.

Patent

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URL

Keyword

Kasamatsu, Yoshitaka; Toyomura, Keigo; Haba, Hiromitsu et al. Co-precipitation behaviour of single atoms of rutherfordium in basic solutions. *Nature Chem.* 2021, 13, p. 226-230, doi: 10.1038/s41557-020-00634-6

superheavy element, rf, co-precipitation, precipitate, samarium hydroxide