Research Group for Superheavy Elements

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The research objectives of this group are to understand chemical and nuclear properties of superheavy elements (SHEs) placed at the uppermost end of the Periodic Table and on the heaviest frontier of the nuclear chart. To clarify the chemical properties of SHEs, we investigate valence electronic structures of SHEs through experimental determinations of ionization potentials, redox potentials, and compound formations of SHEs. To elucidate the limits of stability of the heaviest nuclei, we investigate the shell structure of superheavy nuclei through experimental assignments of proton and neutron single-particle orbitals and through the evolution of nuclear deformation at the highest proton and neutron numbers. To shed light on aspects related to the accident at the Fukushima Daiichi NPP, we have made contributions exploiting our experience in radioactivity measurements. Typical progresses in FY2012 are reported in the following.

First successful ionization and mass-separation of Lr (*Z*=103)

The first ionization potential (IP) is a fundamental physical and chemical property of an element. Information on the IP of the heaviest elements can provide a test and better understanding of relativistic effects which are significantly noticeable for heavy elements. Recently, we successfully ionized and mass-separated Lr ions for the first time toward the IP measurement using a newly developed surface ionization ion-source as part of the JAEA-ISOL [1]. The details of the results are described in the research highlights in this issue.

Ground-state configuration of the *N*=157 nucleus ^{259}No

Although many theoretical studies have predicted the stability and shell structure of superheavy nuclei, the location of proton and neutron shells in the superheavy region have not finally been established [2]. Energy spacings and the order of single-particle orbitals are the most sensitive probes to clarify the shell structure. Thus, experimental assignments of spin-parities and single-particle configurations of the ground states as well as excited states in odd-mass superheavy nuclei provide valuable information on the shell structure of superheavy nuclei. For odd-mass $N \geq 157$ nuclei, nothing is known about spin-parities and single-particle configurations experimentally. In the present work, the ground-state configuration of the *N*=157 nucleus ^{259}No produced in the ^{248}Cm(^{18}O,α3*n*) reaction using the JAEA tandem accelerator and the RIKEN AVF cyclotron has been identified through *α*-*γ* coincidence and *α*-singles measurements [3]. Three *γ* transitions were observed for the first time in the *α* decay of ^{259}No, see Fig. 1, and its decay scheme was established as shown in Fig. 2. The neutron $9/2^+$[615] configuration was assigned to the ground state of ^{259}No as well as to the 231.4 keV level in ^{255}Fm. Ground-state deformations and neutron single-particle energies in *Z*=102 isotopes were calculated with a macroscopic-microscopic model [4]. The $9/2^+$[615] orbital was calculated to be the highest among the five orbitals between the *N*=152 and 162 deformed shell gaps. This is consistent with the experimental one-quasiparticle energies in *N*=153 and 155 isotopes [5,6], but is inconsistent with the present experimental result of the $9/2^+$[615] ground state configuration at *N*=157 [7]. To get the $9/2^+$[615] ground state at *N*=157, the order of the neutron orbitals should be different between the *N*=153 and 157 isotones.

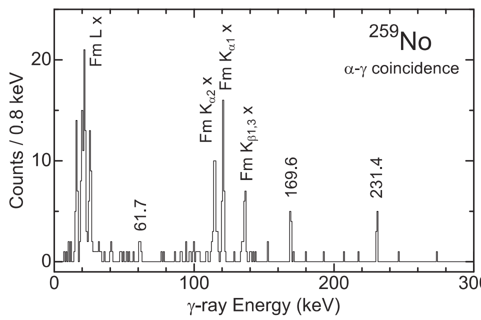

Fig. 1 γ-ray spectrum observed in coincidence with 7260–7810 keV particles which corresponds to the α -energy range of ^{259}No.

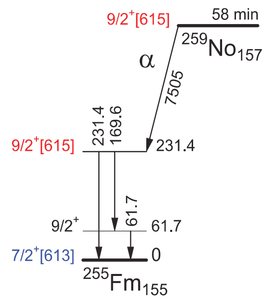

Fig. 2 α-decay scheme of ^{259}No proposed in the present work.

Efficiency calibration of Ge detector in soil samples

We applied our experience in radioactivity measurements, to measure ^{131}I, ^{134}Cs, and ^{137}Cs in soil contaminated by the accident of the Fukushima Daiichi NPP. In addition, efficiency calibrations of Ge detectors and cascade summing corrections for ^{131}I and ^{134}Cs in soil samples which has a large volume and density were performed [8]. Gamma-ray detection efficiencies were determined precisely using standard soil samples spiked with ^{134}Cs, ^{137}Cs, ^{175}Hf, and ^{88}Zr in the laboratory. Cascade summing corrections for γ rays of ^{134}Cs in soil samples were evaluated experimentally. To easily calculate the cascade summing corrections for volume sources, we examined a simplified method using averaged efficiencies, and evaluated its validity through a comparison of the calculated correction factors with the experimental ones. The calculated correction factors agreed very well with the experimental ones, demonstrating the validity of this method.

References

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