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β-γ spectroscopy of neutron-rich nucleus ^{195}Os

(中性子過剰核 ^{195}Os の β-γ 分光)

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Summary

One of the fundamental problems of astrophysics is an origin of chemical elements. Observed abundance of the elements in the universe is a fingerprint to trace back pathways of nucleosyntheses in terms of astrophysical parameters. A reliable description underlying astrophysical scenarios depends crucially on the knowledge of the nuclear properties. Approximately a half of the nuclei in nature beyond the iron is considered to be synthesized in the rapid neutron capture process (r-process). The astrophysical environment of the r-process is characterized by a neutron density higher than 10^{20} cm^{-3} and a temperature higher than 10^{9} K. The r-process proceeds through a region of very neutron-rich nuclei under such explosive environment. The 3rd peak at the mass number of 195 on the solar r-abundance distribution is considered to be originated from waiting point nuclei with neutron number (N) of 126 on the r-process path. Understanding of the 3rd peak formation is a key issue to elucidate the astrophysical environment of the r-process and to reveal its astronomical site. For the sake, nuclear properties of the waiting point nuclei such as β-decay half-lives, neutron separation energies and β-delayed neutron emission probabilities are necessary. However, the waiting point nuclei for the 3rd peak are too far from the β-stability line to experimentally access them, remaining the stellar environment for the 3rd peak formation still unknown. In the current r-process calculations, nuclear properties of waiting point nuclei for the 3rd peak are based on the theoretical predictions. The region of neutron-rich nuclei with N = 126 is, particularly, predicted as a competitive region of the first-forbidden

(FF) and allowed Gamow-Teller β-decays. Such competition makes it difficult to predict lifetimes of the waiting point nuclei, giving large deviations of the input parameters for the r-process calculations from model to model.

The experimental investigation of nuclear structures for the neutron-rich nuclei around N = 126 is quite important. It would provide crucial inputs to a theoretical model to improve its predictability for the β-decay half-lives of the waiting point nuclei at N = 126. In this work, we have performed the β-γ spectroscopy of ^{195}Os as one of such nuclei around N = 126, whose β-decay schemes are unknown. The radioactive isotopes around N = 126 were produced by the multi-nucleon transfer reactions of ^{136}Xe beams and ^{198}Pt target. The isotope of interest is separated and extracted using the KEK isotope separation system (KISS), which is an argon-gas-cell based laser ion source with a mass separator. Those extracted isotopes are implanted into an aluminized Mylar tape, which is surrounded by the Multi-Segmented Proportional Gas Counter (MSPGC) and four Super Clover High-Purity Germanium (SC-HPGe) detectors for measurements of the β-γ spectroscopy. Twenty-eight γ-ray peaks were observed in coincidence with β-rays, internal conversion electrons and X-rays detected by the MSPGC.

Twenty-two of them were identified as β-delayed γ-rays of the ^{195}Os ground state, where the energies of twenty γ-ray peaks agree with the literature values of observed transitions in ^{194}Ir(n, γ) reactions and two γ-ray peaks were newly found. Two γ-ray peaks were identified as β-delayed γ-rays of the ^{195}Ir ground state. Four γ-ray peaks were associated with the half-life of 47(3) s, which is shorter than the half-life of the ^{195}Os ground state. The cascade transitions among those four γ-rays and the characteristic K X-rays of osmium were found in all γ-γ coincidence spectra, indicating that those transitions belong to a previously unknown isomeric state of ^{195}Os.

The β-decay branching ratios of the ^{195}Os ground state were deduced from the β-γ spectroscopy data. The range of obtained log ft values is from 5.98(4) to 7.63(26), indicating all β-transitions are the first forbidden ones. Systematically assumed spin-parity of ^{195}Os ground state, $3/2^-$, is consistent with an expected one based on the observed log ft values and spin-parities of the β-decay final states. The β-decay half-life of the ^{195}Os ground state was evaluated to be 6.5(4) minutes, which agrees well to the previously known value 6.5(11) minutes. The experimental half-lives of the osmium isotopes including this work are compared with several theoretical predictions. It is found that the systematic trend of the half-lives of the osmium isotopes is not reproduced by any single model. It encourages the improvement of the treatment for FF transitions in any model to reproduce the experimental trend of the Os ground state lifetimes.