Isomer spectroscopy using multi-nucleon transfer reaction on ^{248}Cm

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The Island of Stability, which is linked to the predicted doubly closed proton and neutron shells in superheavy nuclei, is still an unexplored region in nuclear physics. Owing to low expected cross sections with current experimental techniques, the region has not been accessible for detailed decay studies. Excited states in actinide nuclei can have an important role in characterizing the stability of the island, as part of degenerate orbitals above predicted energy gaps at $Z = 114$ and $N = 184$ can appear as excited states owing to the systematic development of quadrupole deformation. Pioneering studies[1,2] identified a large component of high-j quasiparticle states originating from the $\nu k_{17/2}$ orbital above the gap in ^{249}Cm. Thus, data around this region can provide benchmarks for theoretical calculations of the location and properties of the Island of Stability.

One method to study the region of heavy actinides is to produce them via the transfer reactions of heavy ions onto radioactive actinide targets. The difficulty of using actinide targets lies in their strong radioactivity. An experimental method, called the isomerscope method,[3] is one of measurements to avoid this problem with the space-time separation. This method was originally developed at JAEA to investigate isomeric states via deep inelastic collisions. The combination of γ-ray detectors and absorbers significantly enhanced the peak-to-background ratio of the delayed γ-ray component. We applied this method to perform isomer spectroscopy of nuclei produced via multi-nucleon transfer reactions on actinide targets.

The experiment was performed at the JAEA tandem accelerator facility in May 2021. An actinide target of ^{248}Cm was prepared via electrodeposition onto a 1.8 μm aluminium backing. The target was irradiated using a ^{18}O beam with an energy of 96.5 MeV with an intensity of approximately 2.0 particle nA. The beam energy was set to detect the light ejectiles identified at backward angles. The produced nuclei were identified via specific transfer channels using an array of ΔE-E telescopes. The selection of the beam energy enabled us to place the telescope at the backward angles, which effectively reduced the radiation damage on the silicon detectors. An ejectile passing through one of the four ΔE detectors (20 μm thick) was stopped in the E detector (300 μm thick) to measure the residual energy. Heavier nuclei were scattered in the forward direction and stopped in a catcher foil. Four germanium and four $LaBr_3$ detectors were placed close to the foil to detect the delayed γ rays. A tungsten shield was placed between the target and γ-ray detectors to absorb the strong γ-radiation around the target.

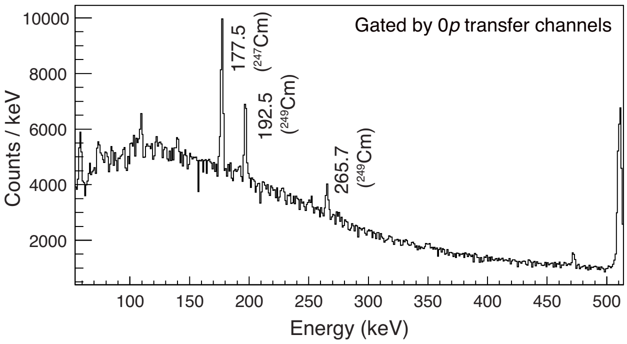

Fig. 1. Delayed γ-ray spectrum gated using 0p transfer channels by the ΔE-E silicon telescope. The 177.5- and 265.7-keV peaks resulted from the isomeric state of ^{247}Cm with a half-life of 100.6 ns.[4] The 192.5- and 265.7-keV peaks resulted from the isomeric state of ^{249}Cm with 19-ns half-life.[2]

Several known isomers belonging to nuclei in the region of ^{248}Cm were successfully observed in this study. An example of the delayed γ-ray spectrum is shown in Fig. 1. The 178-keV peak correspond to the γ-ray transition from the isomeric state of ^{247}Cm.[4] The half-life value deduced by the preliminary analysis agreed well with the literature value of 100.6 ns.[4] The 192.5- and 265.7-keV peaks corresponded to transitions from an isomeric state in ^{249}Cm.[2] This short-lived 19-ns isomer was successfully identified in this experimental setup. Further analysis to identify new isomeric states is in progress.

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