Properties of $^{187}$Ta revealed through isomeric decay†

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We report results from the production and separation of a low-energy beam of the neutron-rich tantalum isotope, $^{187}$Ta*$^{14}$, together with its high-spin isomeric state. The production process exploits multi-nucleon transfer (MNT) reactions which have been shown to be effective for making neutron-rich nuclei.† The large angular momentum transfer in MNT reactions is a key aspect for the formation of high-spin isomers.

The experiment was performed at the RIKEN Nishina Center with the recently commissioned KEK Isotope Separation System (KISS) facility.2 This is the first facility of its kind, capable of stopping heavy-ion reaction products in a high-pressure (80 kPa) argon gas cell, performing laser resonant ionization for element (Z) selectivity, and achieving mass (A) separation of the electrostatically extracted, singly charged, 20 keV ions in a dipole magnet with a resolving power $A/\Delta A = 900$.

The $^{187}$Ta ions were produced by MNT reactions of a 50 particle-nA beam of $^{196}$Xe at 7.2 MeV/nucleon, delivered by the RIKEN Ring Cyclotron. The beam was incident on a 5 µm thick natural tungsten target at the entrance to the argon gas cell.

The 20 keV secondary beam of laser-ionized tantalum was mass separated (1.5 ions/s of $^{187}$Ta) and transported to a moving-tape collection point, surrounded by a low-background, 32-element gas proportional counter with 80% of 4π solid angle for $\beta$ particles and conversion electrons3 and four Super Clover germanium $\gamma$-ray detectors with a total absolute full-energy-peak efficiency of 15% at 150 keV. The tape transport was operated with equal beam-on/beam-off periods, with the radioactivity moved to a shielded location at the end of each cycle. The chosen beam-on periods were 30 s, 300 s and 1800 s, with five days of data taking.

An isomer in $^{187}$Ta at 1789(13) keV had been identified in the Experimental Storage Ring at GSI,4 but without observation of the decay radiations. Details of the excited-state structure of $^{187}$Ta have now been revealed by the isomeric $\gamma$-ray emissions, as illustrated in Fig. 1. The isomer is found to have an excitation energy of 1778(1) keV, with a half-life of 7.3(9) s.

Despite the proximity to $N = 116$, which is predicted to be the critical point for a ground-state prolate-oblate shape transition, the reduced hindrance for the 191.7 keV, E2 isomeric decay remains substantial, with $f_{\nu} = 27(1)$, indicating that $K$ is approximately conserved, and therefore that axial symmetry is not strongly violated. Nevertheless, weak violation of axial symmetry is indicated by the observed irregularity in the 9/2[514] rotational band that is populated through the isomer decay. Comparison with the rhenium isotone, $^{189}$Re, supports calculations showing that axial symmetry is better conserved for the lower-Z nuclei, through the $N \approx 116$ shape transition region.

The new capability to produce low-energy beams of neutron-rich tantalum isotopes and isomers demonstrates the power of the gas-stopping technique for nuclear structure studies of exotic neutron-rich nuclei, even with refractory elements. This marks a milestone on the way to the exploration of nuclei predicted to have well-deformed oblate ground states.

References
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