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, $^{187}Ta_{114}$, 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.[1)] 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 $A/\varDelta A = 900$.

The ^{187}Ta ions were produced by MNT reactions of a 50 particle-nA beam of ^{136}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 β particles and conversion electrons[3)] and four Super Clover germanium γ-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 γ-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.

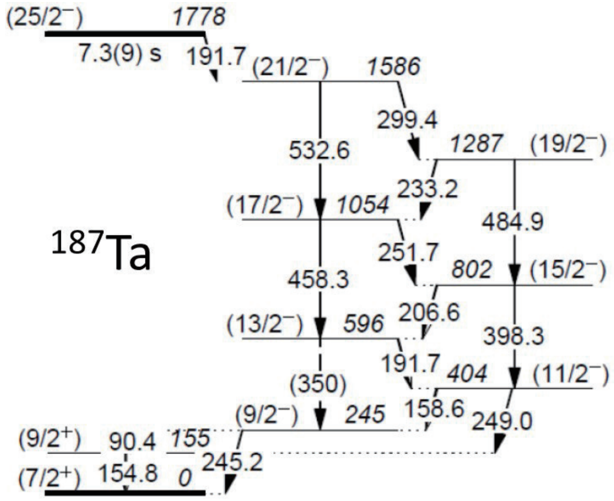

Fig. 1. Level scheme for ^{187}Ta based on γ-ray transitions observed following the decay of a $T_{1/2} = 7.3(9)$ s isomer.

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.

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