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COMPETING DECAY MODES OF A HIGH-SPIN ISOMER IN THE PROTON-UNBOUND NUCLEUS $^{158}$Ta

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An isomeric state at high spin and excitation energy was recently observed in the proton-unbound nucleus $^{158}$Ta. This state was observed to decay by both $\alpha$ and $\gamma$ decay modes. The large spin change required to decay via $\gamma$-ray emission incurs a lifetime long enough for $\alpha$ decay to compete. The $\alpha$ decay has an energy of 8644(11) keV, which is among the highest observed in the region, a partial half-life of 440(70) $\mu$s and changes the spin by 11$\hbar$. In this paper, additional evidence supporting the assignment of this $\alpha$ decay to the high-spin isomer in $^{158}$Ta will be presented.

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1. Introduction

The recent observation of an isomer at high spin, $19^-$, and excitation energy, 2809 keV, in the proton-unbound nucleus $^{158}$Ta [1] raised the possibility of a blurring to the limits of the observable nuclear landscape due to the possible existence of isomers. These isomers can be sufficiently long

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to survive a separator flight time and hence be observed at the focal plane. Both $\alpha$- and $\gamma$-decay modes have been associated with this isomer, as shown in Fig. 1. In this paper, additional experimental evidence supporting the previous assignment of a new $\alpha$ decay to this isomer will be presented.

Fig. 1. Partial level scheme of $^{158}$Ta including competing decay branches from the $19^-$ isomer. Both $\alpha$- and $\gamma$-decay branches lead to the population of $^{154}$Lu. Transition energies are in keV.

2. Experimental details

The experiment was performed at the University of Jyv"askyl"a accelerator laboratory. The $^{158}$Ta nuclei were produced in excited states using fusion-evaporation reactions induced by $^{58}$Ni ions, with a beam energy of 255 MeV, incident on an isotopically enriched $^{102}$Pd target of thickness $\sim 1$ mg cm$^{-2}$. The JUROGAM HPGe spectrometer surrounded the target position and was used to measure prompt $\gamma$-ray emissions. The RITU gas-filled separator [2] transported recoiling reaction products to its focal plane and also suppressed unreacted beam. The GREAT spectrometer [3] was situated at the focal plane. Recoiling nuclei that entered GREAT passed through a multiwire proportional counter (MWPC) before being implanted into one of two adja-cently mounted double-sided silicon strip detectors (DSSDs). Subsequent radioactive $\alpha$ decays were detected by the DSSDs but not the MWPC, thus distinguishing between signals associated with recoils and decays. A planar and a Clover Ge detector were used to measure X-rays and $\gamma$-rays from the DSSDs that were emitted during decay processes. Data were recorded using a triggerless data acquisition system [4], time stamped with a precision of 10 ns, and events were built in software [5]. Reaction channels were identified using standard tagging techniques [6, 7].
3. Evidence for the α-decay branch

Gamma-ray transitions observed at the focal plane revealed the presence of the isomer at high spin and excitation energy, which primarily γ decays via a 1002 keV transition [1]. A new α decay (E_α = 8644(11) keV) was observed to decay with a half-life similar to that of this isomer. The decay curves of the α- and γ-decay branches are compared in Fig. 2 (a)–(b). The measured half-life of the α-decay branch is 6.4(4) µs, which is consistent with the 6.1(1) µs half-life associated with the γ-decay branches. The same γ-ray transitions feeding the isomer are observed in association with both the α- and γ-decay branches. Based on this evidence, the new α decay was assigned to the same high-spin isomer.

Further evidence that this α decay originates from $^{158}$Ta can seen in the subsequent decays, which are shown in Fig. 2 (c)–(f). The γ-decay branches of the isomer feed the $^9$+ low-lying metastable state. The decay of this state is the first step in the following decay chain:

$^{158}$Ta$^9_+$ → α(6046) → $^{154}$Lu$^9_+$ → β$^+$ → $^{154}$Yb$^0_+$ → α(5331) → $^{150}$Er$^0_+$.
of which, in this experiment, only the $\alpha$ decays could be observed. The 5331 keV $^{154}$Yb $\alpha$ decay [8] is observed strongly above the background following the decay of the $9^+$ state in $^{158}$Ta. Furthermore, the decay curve reveals the unobserved $\beta$-decay component from $^{154}$Lu. A similar energy and decay curve can be seen following the decay of the 8644 keV $\alpha$ decay, which suggests that it feeds the same decay chain, and thus originates from $^{158}$Ta. A closed $Q$-value loop incorporating the $\alpha$- and $\gamma$-decay branches de-populating the $^{158}$Ta$_{19^-}$ isomer and populating the $^{154}$Lu$_{9^+}$ state is evidence that the 8644 keV $\alpha$ decay is a direct transition between these two states [1]. The total $Q$-values via the $\alpha$-decay branch and via the $\gamma$-ray branch are 8869(11) and 8870(14), respectively. To account for the change in spin and parity, an angular momentum change of 11$\hbar$ occurs as a result of this decay.

4. Summary and acknowledgements

The 8644 keV $\alpha$ decay was previously assigned to the $19^-$ isomer in $^{158}$Ta based on the feeding $\gamma$-ray transitions, the half-life and the $Q$-value, all of which are consistent with observations associated with the $\gamma$-decay branch. The subsequent radioactive decay data presented in this paper is consistent with a decay from $^{158}$Ta, which reinforces the previous assignment.

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