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 α and γ decay modes. The large spin change required to decay via γ-ray emission incurs a lifetime long enough for α decay to compete. The α decay has an energy of 8644(11) keV, which is among the highest observed in the region, a partial half-life of 440(70) μs and changes the spin by 11$\hbar$. In this paper, additional evidence supporting the assignment of this α 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 α- and γ-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 α decay to this isomer will be presented.

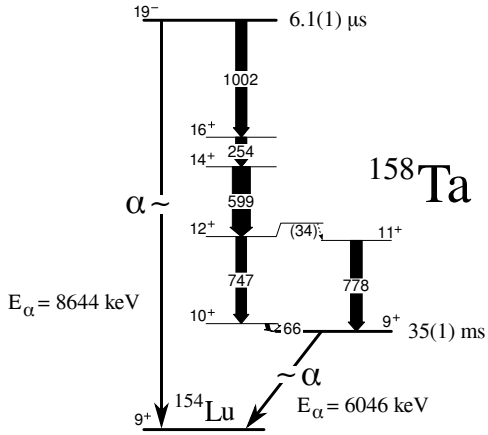

Fig. 1. Partial level scheme of ^{158}Ta including competing decay branches from the 19^- isomer. Both α- and γ-decay branches lead to the population of ^{154}Lu. Transition energies are in keV.

2. Experimental details

The experiment was performed at the University of Jyväskylä 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 γ-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 adjacently mounted double-sided silicon strip detectors (DSSDs). Subsequent radioactive α 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 γ-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.

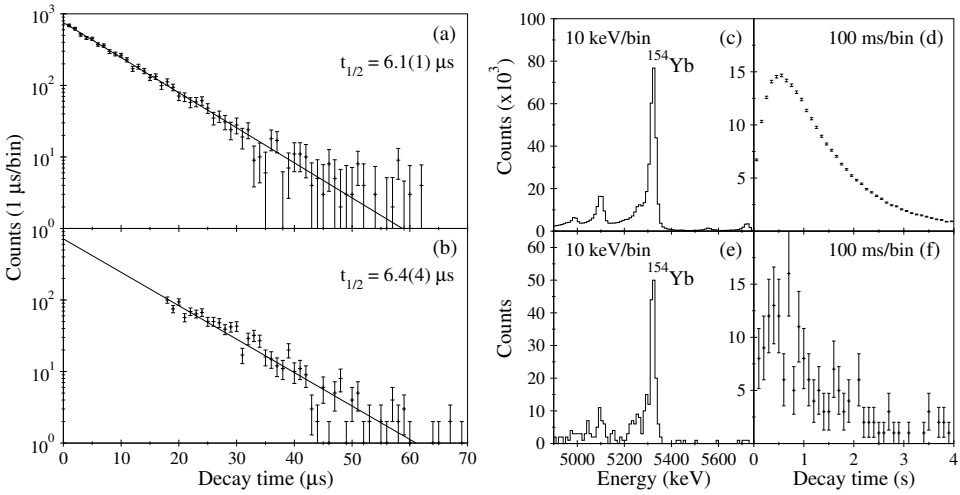

Fig. 2. Decay curves for (a) the 1002 keV γ-ray transition and (b) the 8644 keV α decay, which have consistent half-lives. (c) The energy and (d) decay time of decays following the α decay of the 9^+ state in ^{158}Ta. (e) The energy and (f) decay time of decays following the 8644 keV α decay from the high-spin isomer in ^{158}Ta. The 5331 keV ^{154}Yb peak appears strongly above the background in both (c) and (e). The ^{154}Yb decay times in (d) and (f) reveal the unobserved β decay of ^{154}Lu, completing the decay chain from ^{158}Ta$\rightarrow^{154}$Lu$\rightarrow^{154}$Yb$\rightarrow^{150}$Er, and have consistent peaks. These similarities reinforce the assignment of the 8644 keV α decay to the 19^- isomer in ^{158}Ta.

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:

$$^{158}\mathrm{Ta}_{9^+} \rightarrow \alpha(6046) \rightarrow^{154} \mathrm{Lu}_{9^+} \rightarrow \beta^+ \rightarrow^{154} \mathrm{Yb}_{0^+} \rightarrow \alpha(5331) \rightarrow^{150} \mathrm{Er}_{0^+} ,$$

of which, in this experiment, only the α decays could be observed. The 5331 keV ^{154}Yb α 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 β-decay component from ^{154}Lu. A similar energy and decay curve can be seen following the decay of the 8644 keV α decay, which suggests that it feeds the same decay chain, and thus originates from ^{158}Ta. A closed Q-value loop incorporating the α- and γ-decay branches depopulating the $^{158}\mathrm{Ta}_{19^-}$ isomer and populating the $^{154}\mathrm{Lu}_{9^+}$ state is evidence that the 8644 keV α decay is a direct transition between these two states [1]. The total Q-values via the α-decay branch and via the γ-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 α decay was previously assigned to the 19^- isomer in ^{158}Ta based on the feeding γ-ray transitions, the half-life and the Q-value, all of which are consistent with observations associated with the γ-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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