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Discovery of a new 2.3 s isomer in neutron-rich ^{174}Tm

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Abstract. A new program of K-isomer research has been initiated with the 8π spectrometer sited at the ISAC facility of TRIUMF. We discuss in this paper the identification of a new 2.3 s isomer in ^{174}Tm and its implications.

PACS. 21.10.Tg Lifetimes – 23.20.Lv γ transitions and level energies – 27.70.+q $150 \leq A \leq 189$

1 Experiment and results

The detection and study of high-K isomers is an active area of current nuclear structure research. In particular, one of the goals of a future study involving neutron-rich nuclei in the Dy-Hf region is to search for the possible existence of an "island" of β-decaying high-K isomers [1]. The close proximity of high-K states to the Fermi surface in neutron-rich $A = 170$–190 nuclei makes this region very attractive to search for high-K isomers [1,2]. In the present work, nuclei far from stability are produced at the ISAC facility sited at TRIUMF, using 500 MeV proton-induced reactions on Ta targets, extracted using a surface ionization source, and accelerated to an energy of 30 keV. A high-resolution mass analyzer separates species with different mass number, which are then transported to the experimental stations such as the 8π spectrometer. This spectrometer is an array of 20 Compton-suppressed high-purity germanium detectors [3] which is used to detect γ-rays from the implanted nuclei. The detection system has been augmented with a moving tape transport facility, to reduce the contaminating activity present in an isobaric beam.

In two sets of experiments several of the known high-K isomers in the Dy-Hf region, with half-lives ranging from a few ms to several minutes could be accessed [4]. We report here the discovery of a new isomer in the neutron-rich nucleus ^{174}Tm. The $A = 174$ isobaric beam was implanted onto a moveable tape transport facility, with

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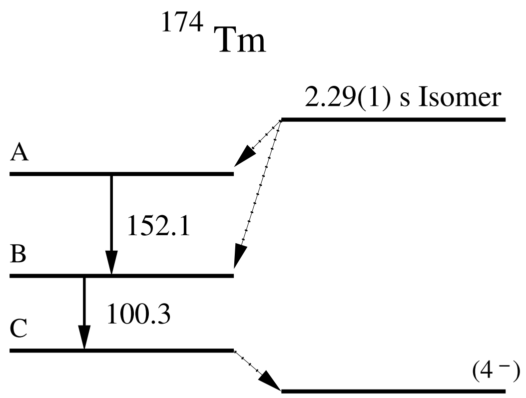

Fig. 1. Partial level scheme of ^{174}Tm. Dotted transitions have not been observed in the present experiment.

beam-on/beam-off cycling times of 2s/2s, 3s/3s ("short"), 10s/10s and 100s/50s. The accumulated γ-ray data were dominated by the ground-state β-decay of ^{174}Tm (with a half-life of 5.4 min). In addition, two known coincident γ-rays with energies of 100.3 and 152.1 keV were observed (fig. 1). These two γ-ray transitions are known to be present in the ground-state β-decay of ^{174}Er, which has a half life of 3.3 min [5]. In the present experiment we found no evidence for the production of ^{174}Er. This important argument is based on the non-observation of other strong γ-ray transitions from the β-decay of ^{174}Er [5].

In the present experiment, a half life of 2.29(1) s was deduced from γ-time matrices gated by the 100 and

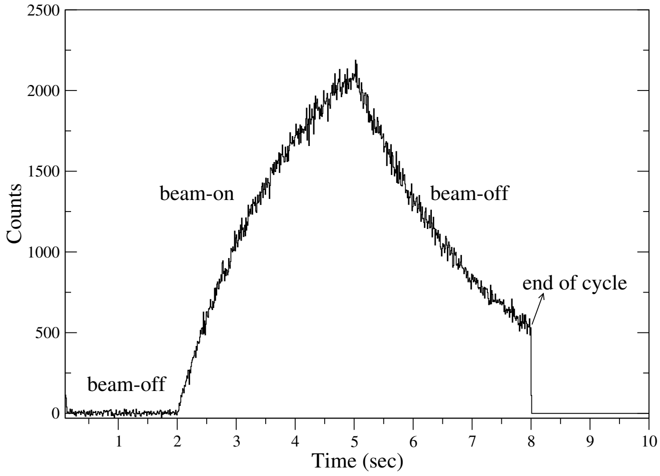

Fig. 2. Time spectrum gated by the 100.3 keV γ-ray transition. The beam-off/beam-on/beam-off tape-cycling times correspond to 2s-3s-3s.

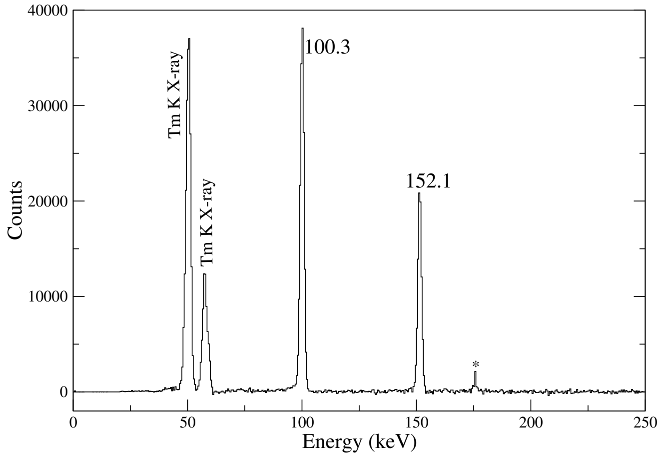

Fig. 3. Singles spectrum in the "short"-cycling time of 2s-3s-3s corresponding to the beam-off/beam-on/beam-off periods. The dominant component due to the longer-lived ^{174}Tm β-decay ($T_{1/2} = 5.4$ min) has been subtracted. The peak marked by the asterisk is a remnant of the subtraction procedure.

152 keV γ-ray transitions (fig. 2). A "short" time-gated singles spectrum, obtained by subtracting out the long-lived β-decays, shows prominently only the Tm K X-rays and the 100 and 152 keV γ-ray transitions (fig. 3). Based on the singles and the coincidence data, a new isomer in ^{174}Tm with a half life of 2.29(1)s is established unambiguously. From the coincidence data the K-conversion coefficients for the 100 and 152 keV γ-ray transitions were deduced to be 3.1(1) and 1.13(6) respectively, suggesting mainly $M1$ multipolarity with a $E2$ admixture. The new data are in close agreement with the theoretically expected values of 2.69 and 0.82 for $M1$ multipolarity, respectively, but differ from the values 1.7(3) and 0.54(6), respectively, reported in [5].

A careful analysis of the "singles" spectrum (fig. 3) did not yield any new γ-ray transitions that could be candidate γ-ray transitions between the isomer and the known excited states (labeled in fig. 1 as "A", "B", "C"), as well as between the excited states and the ground state. These data suggest the possibility of the existence of very low-energy and highly-converted transitions in the decay of the isomer and the excited states. It is to be noted that we prefer to identify the *isomeric level as a new excited state* in ^{174}Tm as opposed to the excited state "A" itself being isomeric. This is based on, a) a large intensity difference between the two observed γ-ray transitions (γ 100 $\sim$ four times γ 152), indicating direct feeding of the excited state "B" by a cascade of low energy γ-ray transitions and/or highly converted transitions, and b), anomalously large hindrance factors if the level "A" itself were to be the isomeric state. Furthermore, if the origin of isomerism is presumed to be partly due to K-hindrance (in line with several known examples in this mass region) then this level could possibly have a high K value. Based on systematics and Nilsson model calculations of the single-particle levels in ^{174}Tm [5], the isomer is tentatively assigned to have a $K^\pi = (8^-)\pi 7/2^-[523] \otimes \nu 9/2^+[624]$ Nilsson configuration, while the other excited states ("B" and/or "C") may be based on $K^\pi = ((4/5)^+)\pi 1/2^+[411] \otimes \nu 9/2^+[624]$ configurations. Thus the levels involved in the isomer decay may have spins greater than the low values suggested from the previous works [5]. The present interpretation would be consistent with the earlier data only if the decay through the 100 and 152 keV transitions originates from a high-spin β-decaying isomer in ^{174}Er instead of the ground-state β-decay of ^{174}Er. In addition, the absence of ^{174}Yb X-rays/γ-ray transitions in the 'short' time-gated singles spectrum (fig. 3) rules out significant β-decay of the 2.3 s isomer in ^{174}Tm.

2 Summary

A new isomeric state with a half-life of 2.29(1) s has been identified in the neutron-rich odd-odd nucleus ^{174}Tm. If the isomer exists because of K-hindrance, then the levels populated in the decay have spins higher than the ones deduced by the earlier ^{174}Er β-decay studies, and could possibly imply the existence of a high-spin β-decaying isomer in ^{174}Er.

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