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AN ALPHA-EMITTING ISOMERIC STATE OF Td$^{149}$

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As a part of a study of rare earth alpha emitters produced by heavy-ion reactions, the \( \text{La}^{139} + \text{O}^{16} \) system giving rise to isotopes up to terbium was investigated. In addition to the 4.1-hr \( \text{Tb}^{149} \) previously reported, a new alpha activity was observed with an alpha-particle energy of 3.99±0.02 Mev and a half-life of 4.0±0.2 min. Additional experiments have established that the activity is due to an isomeric state of \( \text{Tb}^{149} \).

Natural lanthanum oxide targets (2 mg/cm\(^2\)) were bombarded with \( \text{O}^{16} \) ions at energies ranging from 80 to 140 Mev from the Berkeley heavy-ion linear accelerator (Hilac). Recoils ejected from the target were slowed down in a helium atmosphere and collected on a charged platinum plate. Alpha-particle spectra of the activity on the plates were obtained within 2 min from the end of the bombardment by using a Frisch-grid ionization chamber connected to standard amplifiers and a 100-channel pulse-height analyzer.

Figure 1(a) shows an alpha-particle spectrum of a sample obtained at a bombardment energy of 104 Mev, where the intensities of the 4.1-hr \( \text{Tb}^{149} \) and the new alpha group are comparable. Excitation functions were obtained for both activities and are shown in Fig. 1(b). The 4-min activity was assigned to an isomeric state of \( \text{Tb}^{149} \) from the following experimental observations:

(a) \( \text{Ba} + \text{O}^{16} \) bombardments did not produce the activity; so it must be due to an isotope of \( \text{Tb} \). (b) It was possible to show that the 4.1-hr \( \text{Tb}^{149} \) was a daughter of the 4-min activity by a recoil-milking experiment. Recoils from...
decay were electrostatically collected in vacuum from a plate containing the 4-min and 4.1-hr activities onto a second plate at two different time intervals. Alpha-pulse analysis of the collecting plates showed only the presence of the 4.1-hr Tb$^{149}$ and that it was the daughter of an activity with a half-life of a few minutes.

No alpha groups of an energy higher than 3.99 Mev were found, so that alpha decay probably proceeds to the ground state of Eu$^{145}$. That the ratio of the 4-min to the 4.1-hr activity increases with bombarding energy, suggests that the 4-min activity is the high spin state. A proposed decay scheme for Tb$^{149}$ is shown in Fig. 2.

Terbium-149, with 84 neutrons, lies close to the 82-neutron closed shell and most likely possesses a stable spherical shape. The existence of a long-lived isomeric state can possible be explained, then, by a consideration of shell-model proton states with zero deformation. Above the 50-proton closed shell, the proton-level sequence suggested by Mottelson and Nilsson$^3$ is $\g _{7/2}^\$, $\d _{5/2}^\$, $\h _{11/2}^\$, $\d _{3/2}^\$, and $\s _{1/2}^\$. If the order of filling is according to this sequence, the sixty-fifth proton (Tb) should begin the filling of the $\h _{11/2}^\$ level. If the $\h _{11/2}^\$ level is only filled by pairs of nucleons as is observed with the $\h _{11/2}^\$ neutron shell in the region around Z=50,$^4$ then the ground state of Tb$^{149}$ would probably be $\d _{5/2}^\$ and the isomeric state $\h _{11/2}^\$. This would give rise to an E3 isomer. Terbium-149 is probably not a unique case in this region. The other spherical isotopes of Tb and higher members in the rare earth region which fill the $\h _{11/2}^\$ state may also show the same kind of isomerism.

The peak of the excitation function for Tb$^{149m}$ is shifted upward approximately 15 Mev relative to Tb$^{149}$. This shift is probably because the high spin isomer is formed primarily from compound nuclei having a large angular momentum, where deexcitation by gamma emission is known to compete with nucleon evaporation.$^5$
The low spin isomer is formed from the fraction of compound nuclei having low angular momentum, where de-excitation by gamma emission is comparatively small.5

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REFERENCES

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Figure Legends

Fig. 1. (a) Alpha particle spectrum of Tb$^{149}$ and Tb$^{149m}$. (b) Excitation functions for Tb$^{149}$(e) and Tb$^{149m}$(▲). Counting rates are corrected for decay and length of bombardment but not for alpha branching ratios.

Fig. 2. Proposed alpha decay scheme of Tb$^{149}$. 
(a) Channel number

Counts

Channel number

(b) 0\(^{16}\) energy (Mev)

Tb\(^{149}\) counts per minutes

Tb\(^{149}\) counts per minutes

Tb\(^{149m}\)

Tb\(^{149}\)

Fig. 1