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As a part of a study of rare earth alpha emitters produced by heavy-ion reactions, the $La^{139} + O^{16}$ system giving rise to isotopes up to terbium was investigated. In addition to the 4.1-hr Tb^{149} previously reported,[1] 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 haveeestablished that the activity is due to an isomeric state of Tb^{149}.

Natural lanthanum oxide targets (~2mg/cm^2) were bombarded with 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.[2] 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 bombarding energy of 104 Mev, where the intensities of the 4.1-hr 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 Tb^{149} from the following experimental observations: (a) $Ba + O^{16}$ bombardments did not produce the activity; so it must be due to an isotope of Tb. (b) It was possible to show that the 4.1-hr Tb^{149} was a daughter of the 4-min activity by a recoil-milking experiment.[2] 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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* Work done under the auspices of the U. S. Atomic Energy Commission.

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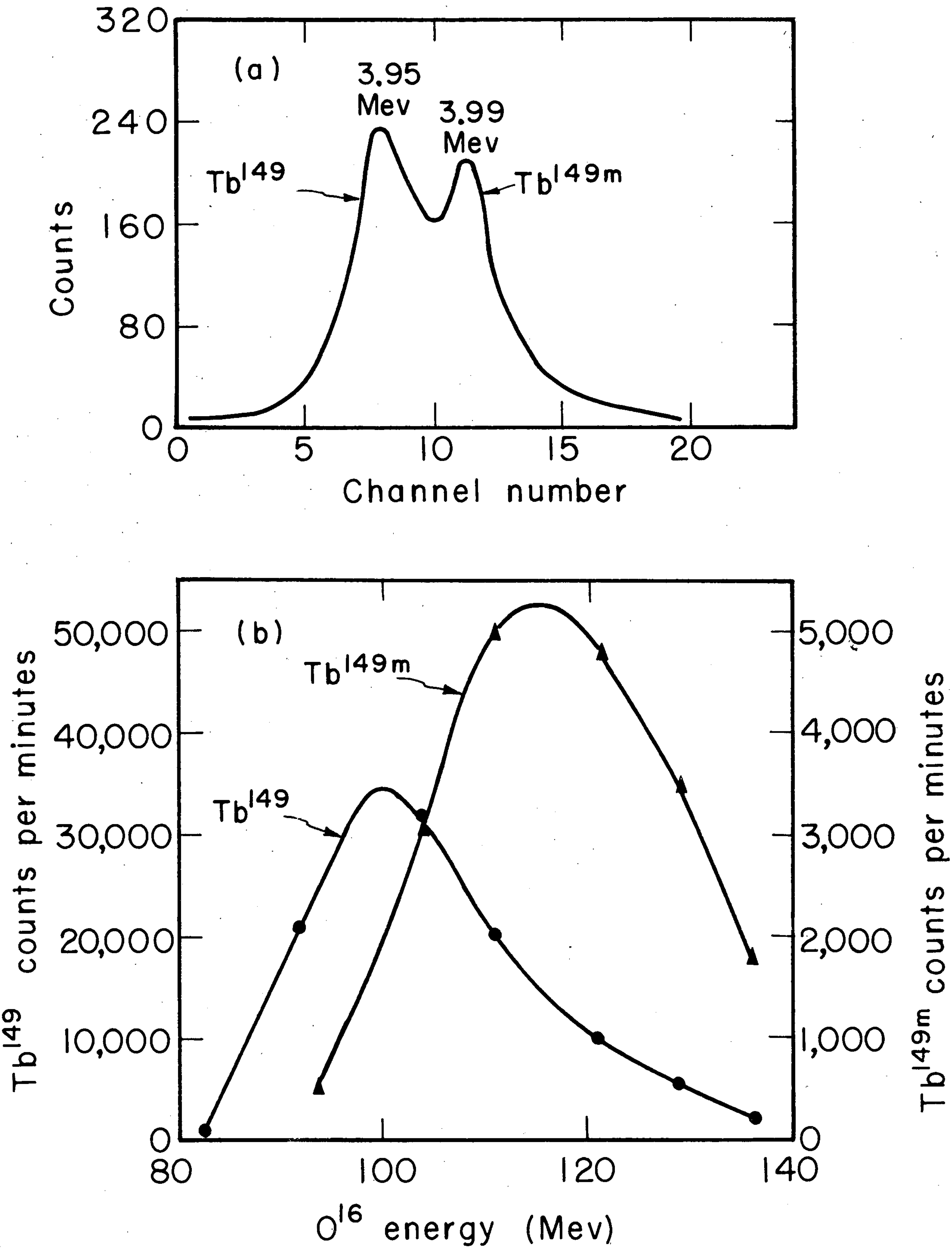
Figure Legends

Fig. 1. (a) Alpha particle spectrum of Tb^{149} and Tb^{149m}. (b) Excitation functions for Tb^{149}(●) 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}.



320
240
160
80
0
Counts
(a)
3.95
Mev
3.99
Mev
Tb149
Tb149m
0
5
10
15
20
Channel number
50,000
40,000
30,000
20,000
10,000
0
Tb149 counts per minutes
(b)
Tb149m
Tb149
5,000
4,000
3,000
2,000
1,000
0
Tb149m counts per minutes
80
100
120
140
O16 energy (Mev)

Fig. 1

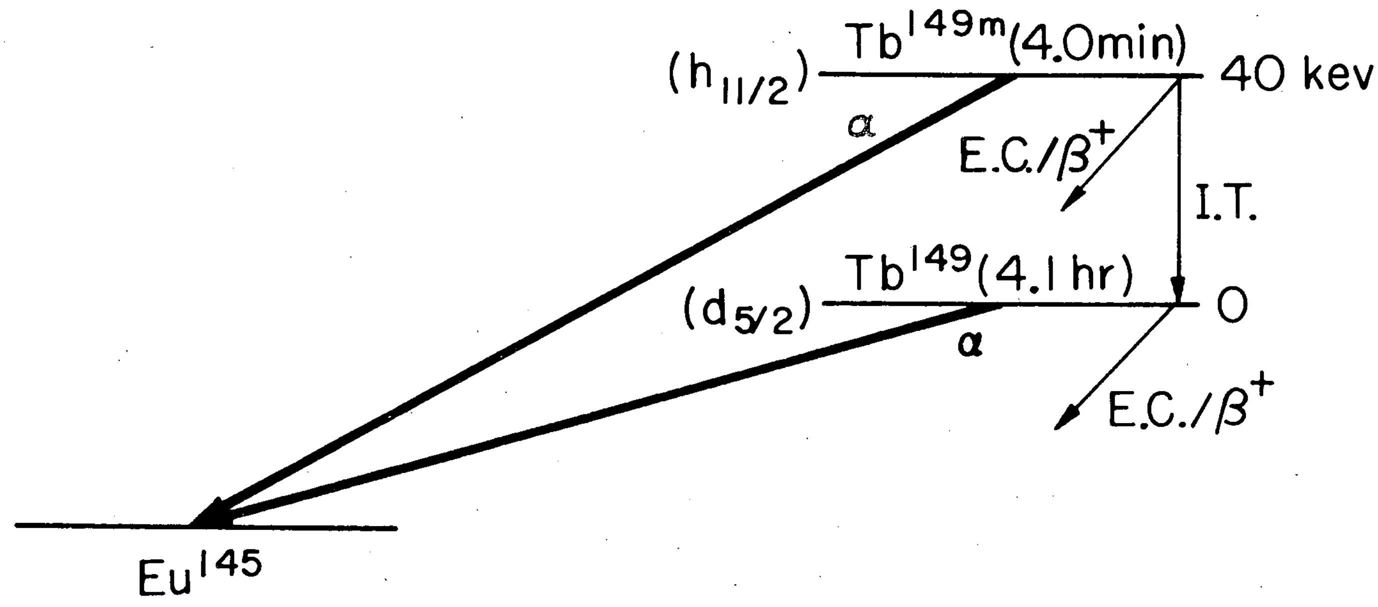


Fig. 2

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