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PREPARATION OF LONG-LIVED TERBIUM-157 AND TERBIUM-158*

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Previous investigations of the unstable terbium isotopes having mass 157 and 158 have revealed that the mass-157 nuclide has a half life of less than 10 minutes or greater than 25 years[1] while a 111-kev magnetic octupole transition has been attributed to the de-excitation of an isomeric state of the odd-odd 158 nuclide.[2,3] Nuclear spectroscopic investigations indicate that the nuclear ground state of terbium-157 has spin 3/2[4] in accordance with the unified nuclear model,[5] which, in addition, predicts even (positive) parity for this ground state. Investigations using paramagnetic resonance and optical spectroscopy have revealed that stable gadolinium-157 also has nuclear spin 3/2,[6,7] while odd (negative) parity is indicated by the unified nuclear model. The ground state of terbium-158 may be described by assigning the odd proton to the 3/2+ orbital indicated for terbium-157 and the odd neutron to the $3/2^-$ orbital for gadolinium-157. The two states with spins and parities 0- and 3- that arise from these orbitals satisfactorily account for the isomerism observed. On this basis the beta decays of both the terbium-157 and terbium-158 ground states to low-lying states of the respective product nuclei are expected to be at least first-forbidden. Additionally, low energies are expected for these beta-decay processes, since both terbium nuclides lie close to stability; thus it appears reasonable that these isotopes have long lifetimes and have previously remained unobserved.

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In the continuation of a program to identify and study long-lived isotopes in the rare earth region,[8] a 5-mg sample of dysprosium oxide enriched to 13.8% in the mass-156 isotope has been irradiated with neutrons in the Materials Testing Reactor. The sample, contained in a quartz ampoule, received an exposure of 2×10^{21} neutrons/cm^2 over a 3-month interval. Four months after irradiation, mass analysis of the unseparated sample was made by using a 30-cm-radius solid-sample mass spectrometer. The presence of mass peaks at 157, 159, 165, and 166, unobservable in the sample before irradiation, indicated neutron capture in dysprosium-156, -158 and -164. The sample was next chemically fractionated by cation-exchange chromatography to yield pure fractions of the various rare earth elements. The holmium, dysprosium, and terbium fractions were identified by scintillation spectroscopy, which revealed the presence of holmium-166, dysprosium-159, and terbium-160. Mass-spectrometric investigation of the terbium fraction revealed the existence of mass peaks at 157, 158, 159, and 160, indicating the preparation of new long-lived isotopes terbium-157 and -158 in addition to the stable terbium-159 and 76-day terbium-160. The relatively high abundance of terbium-158 produced by the neutron capture of terbium-157 points to a high cross section for this process.

A lower limit for the K-capture half life of both terbium-157 and terbium-158 may be set by observing that the isotopic ratios of terbium-157 and -158 to terbium-160 are approximately 160 and 70, respectively, and also that the K x-ray and gamma-ray spectrum of the terbium fraction is predominantly that of 76-day terbium-160. Assuming that the K radiation due to K-capture of terbium-157 and terbium-158 is less than the K radiation accompanying the decay of terbium-160 (primarily due to the high K conversion of the 84-kv transition in gadolimium-160), we conclude the K-capture half lives of these isotopes are greater than 30 years and 15 years respectively. These isotopes will be further examined to search for evidence of electron-capture processes and to determine pertinent neutron cross sections.

It is a pleasure to acknowledge the cooperation of the staff of the Materials Testing Reactor in carrying out the irradiation.

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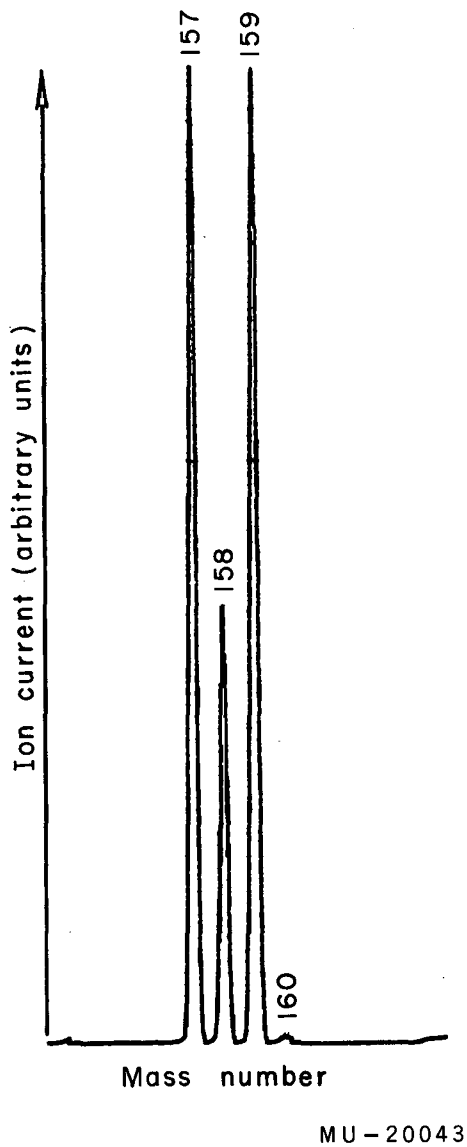
157
159
158
160
Ion current (arbitrary units)
Mass number
MU-20043

Fig. 1.