Radioactive Europium 150 and Gadolinium 150

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The enriched isotopes of samarium were bombarded with 6.7-Mev protons. A well-defined 13.7-hour activity was measurable in all of the enrichments. Comparison of relative initial saturation intensities clearly indicated that the activity should be assigned to Eu^{150}. The activity is the result of negatron emission. The negatron spectrum has maximum energy of 1.07 Mev, and is classified as a first-forbidden transition on the basis of the $\log(ft)$ value.

The Eu^{150} activity enables one to place a lower limit of 10^5 years on the half-life of the alpha-decay which has been assigned to Gd^{150}.

I. INTRODUCTION

An early investigation of Eu^{150} indicated a 27-hour positron activity as a consequence of a fast neutron bombardment of europium.[1] Later, a 15-hour activity, with the nature of the decay not given, was reported as a result of irradiating europium with 23-Mev gamma-rays.[2] A still more recent investigation indicated a 15-hour half-life resulting from a 1.8-Mev positron transition. The activity was produced by a $Sm^{150}(p,n)Eu^{150}$ reaction.[3]

Several attempts to reproduce these activities in this laboratory resulted in agreeing approximately with the half-life measurements but not with the sign of the emitted radiation.

II. ASSIGNMENT OF THE Eu^{150} ACTIVITY

The enriched isotopes of samarium, with mass numbers 144, 147, 148, 149, 150, and 154,[4] were bombarded with 6.7-Mev protons from the cyclotron. Table I shows the percent enrichment. A half-life of about 13.7 hours was measurable in the samples samarium 144, 147, 148, 149, 150, and 154, with relative initial saturation intensities of 15, 13, 18, 45, 400, and 17, respectively. As is evident from Table I, the initial intensities are in reasonable agreement only with the abundances of Sm^{150} contained in the various samples. In the Sm^{150} sample the activity was followed through 6 half-lives, which showed clearly that the half-life was 13.7 ± 0.25 hours. Since a (p,γ) reaction leads to stable Eu^{151}, a (p,α) reaction leads to Pm^{147} with half-life of 2.26 years, and a (p,n) reaction is certainly more likely than a $(p,2n)$ reaction (6.7-Mev protons were used), it follows that the reaction is of the type Sm^{150}-$(p,n)Eu^{150}$. Thus, the assignment of the 13.7-hour activity to Eu^{150} can be made with certainty.

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[1] M. L. Pool and L. L. Quill, Phys. Rev. **53**, 437 (1938).

[2] F. D. S. Butement, Proc. Phys. Soc. (London) **A64**, 395 (1951).

[3] G. Wilkinson and H. G. Hicks, Phys. Rev. **80**, 491 (1950).

[4] Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

III. THE BETA-SPECTRUM

The 13.7-hour activity was examined in a 180-degree spectrometer. The negatron spectrum and Kurie plot are shown in Figs. 1 and 2. No positrons were detectable.

Examination of six such spectra taken over a 20-hour interval indicated that two independent spectra were involved, the higher energy spectrum (1.88 Mev) decayed with about a 9-hour half-life, and the lower energy spectrum with about a 13-hour half-life. The 9.2-hour activity associated with the 1.88-Mev spectrum has been assigned to Eu^{152}, and would be expected to appear in view of the abundance of Sm^{152} contained in the Sm^{150} enrichment.

After subtraction of the Eu^{152} spectrum, the Kurie plot representation of the Eu^{150} spectrum was found to be nonlinear, as is shown in Fig. 2. The spectrum can be resolved into three component spectra with end-points at 0.79, 0.96, and 1.07 Mev, and relative abundances of 40, 32, and 28 percent, respectively. However, an analysis of the activity on a gamma-ray scintillation spectrometer did not show the gamma rays which would be associated with the transitions between these levels. Also, internal conversion electrons were not observed. It seems more reasonable, therefore, to assert that the disparity from linearity results because the transition is of a forbidden type. The $\log(ft)$ value is about 6.4, which is generally classified as a first-forbidden transition.[5] Further, the spectrum shape is very similar to the shape of the RaE beta-ray spectrum which has been considered.[6] It is concluded that the

TABLE I. Isotopic constitution of the enriched isotopes of samarium.

Isotope Sample	144	147	148	149	150	152	154
	Percent of various isotopes contained in each enrichment						
Sm^{144}	58.9	13.46	5.31	3.19	1.39	3.77	13.95
Sm^{147}	0.35	78.35	9.07	7.94	1.65	1.72	0.914
Sm^{148}	0.522	6.05	76.01	10.72	2.54	2.76	1.4
Sm^{149}	0.547	5.09	11.88	71.53	3.98	4.85	2.13
Sm^{150}	0.191	2.02	1.96	7.02	74.09	11.84	2.89
Sm^{154}	0.034	0.362	0.361	1.7	1.2	4.25	92.10

[5] E. Feenberg and G. Trigg, Revs. Modern Phys. **22**, 399 (1950).

[6] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).

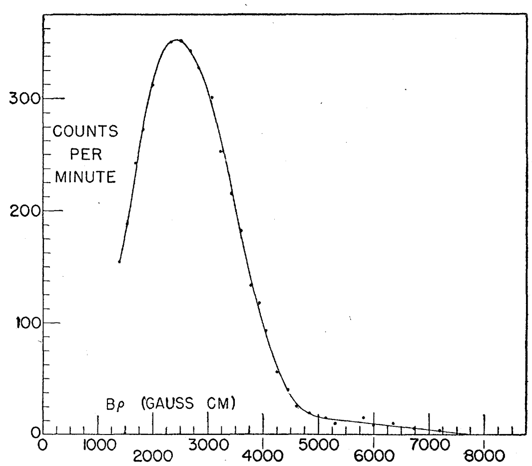

FIG. 1. The β spectrum (of Eu^{150} and Eu^{152}) observed as a result of bombarding the Sm^{150} enrichment with protons.

13.7-hour, Eu^{150} activity results from a first-forbidden negatron transition with maximum energy of 1.07 Mev.

IV. GADOLINIUM 150

Since Eu^{150} decays by the emission of negatrons it seems reasonable to conclude that Gd^{150} is either stable or a long-lived alpha emitter. The stability of Gd^{150} has been investigated, with the findings that if this isotope exists as a stable isotope, then the abundance is less than 0.005 percent[7] or 0.0005 percent.[8] Further, it has been reported that Gd^{150} has a long half-life and emits an alpha particle of 2.7 Mev.[9]

To determine whether or not alpha-particles were present, the 13.7-hour activity was examined on an alpha-ray scintillation counter both during decay and after the disappearance of the activity. The counting rate of this sample was compared with the counting rate obtained using a sample of unbombarded Sm^{150}. Alpha particles, if present, were not observed. The bombarded sample was also examined in a cloud chamber, and again, no alpha particles were detected.

V. DISCUSSION

Because previous reports have indicated that Eu^{150} decays by positron emission,[1,3] the Eu^{150} activity, as reported in this paper, was investigated on four separate occasions. In no case were positrons detectable.

The fact that no alpha particles were detected does not necessarily indicate that alpha particles were not present. In view of the limitations of the counting apparatus, and the amount of Gd^{150} made in the decay process, it is conceivable that no alpha particles would be detected, even if present, if the half-life of Gd^{150} exceeded some definite value. Since the Gd^{150} available was produced from the parent Eu^{150}, and since the initial intensity of the Eu^{150} activity is a known quantity, it is possible to determine a lower limit for the half-life of Gd^{150}. The computation shows that a half-life greater than 10^5 years could not have been detected. Thus, if Gd^{150} is an alpha emitter its half-life is greater than 10^5 years. It is of interest to note that the value

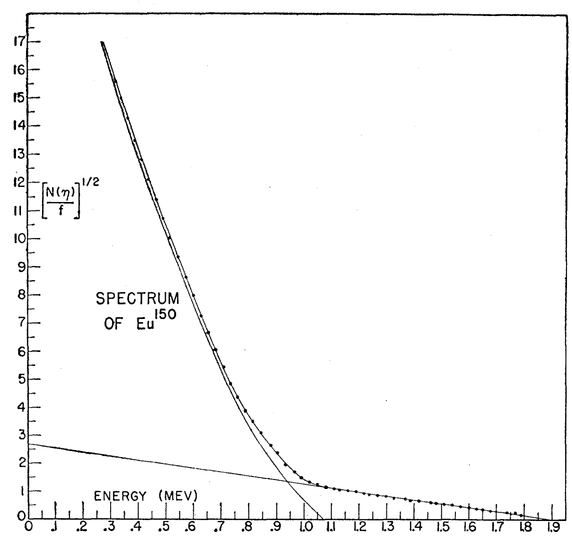

FIG. 2. The Kurie plot representation of the spectrum shown in Fig. 1, and the resulting Kurie plot representation of the Eu^{150} spectrum. We used the $f(Z,\eta)$ values from the preliminary copy of the Fermi Function Table, by I. Feister, National Bureau of Standards.

of the Gd^{150} half-life obtained by using the Geiger-Nuttall relation, the reported energy for the Gd^{150} alpha particle, and the energy and half-life of the Sm^{147} natural alpha emitter, is also of the order of 10^5 years. Apparently a somewhat longer bombardment of Sm^{150} would result in a detectable amount of alpha activity.

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[7] D. C. Hess, Jr., U. S. Atomic Energy Commission Report MDDC-1687 (unpublished); Phys. Rev. **74**, 773 (1948).
[8] W. T. Leland, Phys. Rev. **77**, 634 (1950).
[9] Rasmussen, Thompson, and Ghiorso, Phys. Rev. **89**, 33 (1953).