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ABSTRACT

A study has been made of the neutron deficient radioactive isotopes of europium and gadolinium produced by proton, deuteron, and helium ion bombardments of samarium and europium using the 60-inch and 184-inch cyclotrons and the proton linear accelerator. Four new isotopes of europium and one new isotope of gadolinium have been characterized.

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A study has been made of the light europium and gadolinium isotopes produced by bombardment of samarium and europium oxides with energetic protons, deuterons, and helium ions. In addition to the natural oxides, electromagnetically concentrated isotopes of samarium were used as target materials.[1] In some of the bombardments chemical separations of the target materials were not considered necessary because of restrictions on the number of possible isotopes produced due to the use of low energy bombarding particles and enriched isotopes. When necessary, separations of europium and samarium were made using a cation exchange resin column (Dowex-50, pH of citrate = 3.3 - 2.5) at elevated temperatures as described in a recent article by Thompson, et al.[2] Separations of europium and gadolinium were made using a sodium amalgam reduction method[3] to overcome the difficulty of their separation in a cation exchange column. The conversion electron energies were determined from aluminum and beryllium absorption data. A search for positron emission in most of the nuclides studied here was made using a 180° beta ray spectrometer of low resolution (see Table 1).

The decay of europium isotopes with mass numbers 147, 148, 149, was observed after proton bombardments of enriched samarium isotopes (see Table 1). The (p,n) reaction is probably virtually the only nuclear

reaction induced by 8.5 mev protons on samarium. The threshold of the (p,2n) reaction is estimated to be 9 - 10 mev for $Sm^{147-149}$ using neutron binding energies calculated from the semiempirical mass equation[4] and estimated electron capture decay energies. This assumption is borne out by experimental evidence which indicated the formation of only one radioactivity with high yield. The 50 day Eu^{148} mass assignment and the half-life of Eu^{149} are in disagreement with data reported by Marinsky and Glendenin.[5] Eu^{147} showed branching toward decay by alpha particle emission with a particle energy of 2.92 ± 0.1 mev as measured with the differential alpha pulse analyzer[6] and a branching ratio of about $\alpha/E.C. = 10^{-5}$.[7]

Another isotope of europium, Eu^{145}, was observed as recoil nuclei from the alpha decay of Tb^{149}. The terbium was produced in a 150 mev proton bombardment of gadolinium oxide and isolated using a cation exchange column separation. The Eu^{145} has also been produced in a 50 mev proton bombardment of $Sm_2{}^{147}O_3$.

The radionuclide, Eu^{146}, was observed after a helium ion bombardment of $Sm_2{}^{144}O_3$ placed between a series of stacked platinum foils which degraded the energy of the helium ions through a range from 36 mev to 13 mev. Decay of the samples showed the 38 hour activity was formed in greatest abundance with 25 mev helium ions. Therefore, (α,pn) or (α,2n) reactions were considered the predominant mechanisms for the production of the nuclide. The 38 hour period was also observed after a 19 mev deuteron bombardment on enriched $Sm_2{}^{147}O_3$, thus ruling out a possible assignment to Gd^{146} but consistent with an assignment to Eu^{146}.

A gadolinium isotope, Gd^{149}, has been observed as a product in a number of different bombardments. Natural europium oxide was bombarded with protons in a stacked foil arrangement which produced a proton energy range from 32 mev to 8 mev. The Gd^{149} was produced in largest yield with 28 - 32 mev protons and a (p,3n) reaction was assumed as the predominant mechanism in the production of this isotope. This 9 day period, belonging to Gd^{149}, was also produced in a helium ion bombardment of enriched $Sm_2{}^{147}O_3$ also placed between stacked platinum foils. The helium ion energy range through the target was 36 mev to 13 mev. The 9 day activity was produced in largest yield with 28 - 30 mev helium ions and an (α,2n) reaction was assumed as the predominant mechanism for the production of this isotope. Measurements with the differential alpha pulse analyzer showed alpha branching of this isotope with a particle energy of 3.05 ± 0.15 mev.

This work is being continued and a more complete report will be published at a later date.

We wish to express our appreciation to G. B. Rossi and the crew of the 60-inch Crocker Laboratory cyclotron, J. T. Vale and the crew of the 184-inch cyclotron, and R. D. Watt and the crew of the proton linear accelerator for their cooperation. We also wish to thank the Isotope Research and Development of the Y-12 Research Laboratory, Oak Ridge, Tennessee, for making available to us the enriched isotopes which made much of this work possible. It is a pleasure to acknowledge the continued interest of Dr. G. T. Seaborg. This work was performed under the auspices of the U. S. Atomic Energy Commission.

Table 1

Isotope	Type of Radiation	Half-life	Radiation Characteristics	Produced by	Bombarding Particle Energy	Chemical Separation
Eu^{145}	EC, e^-	5±1 days	0.2 mev e^-	recoil nuclei from α decay of Tb^{149}	--	--
				$Sm^{147}(p,3n)Eu^{145}$	50 mev	ion exchange column
Eu^{146}	EC, e^-	38±3 hrs	0.4 mev e^-	$Sm^{147}(d,3n)Eu^{146}$	19 mev	no
				$Sm^{144}(\alpha,2n)Gd^{146}$ $(\alpha,pn)Eu^{146}$	25 mev	no
Eu^{147}	EC, e^-, no β^+	24±2 days	2.92±0.1 mev α 0.2 mev e^- $\alpha/k = 10^{-5}$	$Sm^{147}(p,n)Eu^{147}$	8.5 mev	ion exchange column
Eu^{148}	EC, e^-, γ no β^+	50±2 days	0.38 mev e^-	$Sm^{148}(p,n)Eu^{148}$	8.5 mev	no
Eu^{149}	EC no β^+	>30 days	--	$Sm^{149}(p,n)Eu^{149}$	8.5 mev	no
Gd^{149}	EC, e^-, α, γ	9±1 days	3.05±0.15 mev α 0.35 mev e^-	$Eu^{nat}(p,3n)Gd^{149}$	28-32 mev	sodium amalgam
				$Sm^{147}(\alpha,2n)Gd^{149}$	28-30 mev	no
				$Sm^{nat}(\alpha,xn)Gd^{149}$	36 mev	sodium amalgam

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