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New Isotope ^{150}Pr†

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Irradiation of enriched ^{150}Nd with fast neutrons was found to produce a new radioactivity which was assigned to the (n,p) product ^{150}Pr. The following radiation characteristics were observed to belong to ^{150}Pr: half-life 6.1 ± 0.3 sec, γ-ray energy 131.0 ± 0.8 keV, and maximum β^--ray energy 5.7 ± 0.3 MeV.

INTRODUCTION

There has been no previous report of the radionuclide ^{150}Pr even though it can be expected to be produced through the (n,p) reaction on stable ^{150}Nd. Yamada and Matumoto[1] have estimated the β^--decay Q value to be approximately 5.5 MeV, which indicates a half-life of a few seconds. Hoffman and Daniels[2] have assigned ^{147}Ce, the ^{150}Nd-(n,α) product, a β^- decay half-life of 65 sec. The β^--decay Q value of ^{147}Ce is estimated[1] to be approximately 3.45 MeV.

In the present investigation, a new 6.1-sec β^-- and γ-ray activity was observed from the fast-neutron bombardment of enriched ^{150}Nd metal and was assigned to ^{150}Pr based on its decay characteristics.

EXPERIMENTAL

The radioactive sources were produced by fast-neutron bombardment of a 164-mg sample of enriched ^{150}Nd metal obtained from Union Carbide, Stable Isotopes Division, Oak Ridge National Laboratory. The isotopic composition and percentage impurities present of the enriched sample are given in Tables I and II. Calculations on the amounts of impurities present revealed that the activities produced from them are below the range of detection. The 14.7-MeV neutrons were generated through the T(D, n)^{4}He reaction using the University of Arkansas 400-kV Cockroft-Walton positive-ion accelerator. The neutron flux during irradiation varied from 1×10^9 to 5×10^9 neutrons/sec cm^2.

The ^{150}Nd sample described above was sealed in a polyethylene "Marlex" capsule, and was transported from the accelerator to the detection system by means of a fast pneumatic transport system (transient time = 0.4 sec). Typically 20–30 bombardments of the enriched sample were required for each experiment.

γ radiation was studied using an 8-cm^3 coaxial ORTEC Ge(Li) detector in conjunction with a Canberra 1416 amplifier and a 4096-channel Nuclear Data 3300 series analyzer system. β spectra were measured using a 3.8-cm-diam by 2.1-cm-high cylindrical plastic detector in conjunction with a Canberra 1417 amplifier and the ND 3300 analyzer. The plastic β detector was calibrated using ^{207}Bi (0.975 MeV), ^{90}Sr-^{90}Y (2.271 MeV), ^{144}Ce-^{144}Pr (2.989 MeV), ^{34m}Cl (4.460 MeV), and ^{16}N (4.291 MeV). The secondary standards of ^{34m}Cl and ^{16}N were produced through the ^{35}Cl$(n,2n)$ and ^{16}O(n,p) reactions, respectively. β-γ coincidence measurements were obtained using the plastic β detector and a 7.6-cm × 7.6-cm NaI(Tl) detector in conjunction with a Canberra 1417 amplifier and a Canberra 800 series coincidence unit (delay time = 1 μsec) and the ND 3300 analyzer. The total γ yield of the 131-keV γ ray was obtained by analyses of the activity under that photopeak in four successive singles spectra obtained by the Ge(Li) detector described above. The total β^--yield coincidences were obtained simultaneously with the β-γ coincidence measurements on the 131-keV γ ray by employing a 512-channel ND 1100 series analyzer in the time mode.

RESULTS AND DISCUSSION

Successive single γ-ray spectra obtained through

TABLE I. Isotopic composition of the enriched ^{150}Nd metal sample. (Total weight 164 mg.)

Isotope	% abundance
142	1.04±0.05
143	0.53±0.05
144	1.20±0.05
145	0.45±0.05
146	1.10±0.05
148	0.92±0.05
150	94.75±0.05

the Ge(Li) detector revealed only one short-lived photopeak of 131 keV. In Fig. 1 are shown four successive spectra of 10 sec each (top to bottom) with the first one starting 0.4 sec after the end of bombardment of the sample. The γ-ray region shown is 105–165 keV; the spectra were obtained from 30 bombardments of the enriched ^{150}Nd. The duration of each bombardment was 10 sec.

The 114.3-, 138.6-, and 155.6-keV γ rays can be assigned[3] to the 1.73-h ^{149}Nd produced through the ^{150}Nd(n, $2n$)^{149}Nd reaction. Those γ rays assigned to ^{149}Nd were used as internal γ-ray energy standards since their energies are known[3] to within 0.2 keV. The uncertainty of the γ-ray energies reported here is ± 0.8 keV. This is an upper-limit uncertainty to a computerized program incorporating an efficiency curve for the Ge(Li) detector (that was fitted by an equation using a least-squares-analysis method). The derived equation fits the experimental values within ± 0.5%. Given the background for a specific peak, the program calculates the net counts per channel, then uses the established efficiency curve, to derive the total activity per channel, and finally derives

TABLE II. Spectrographic analysis.

Element	%	Element	%
Al	<0.05	Sn	<0.05
Ba	<0.02	Ti	<0.02
Be	<0.001	V	<0.02
Ca	<0.05	Y	<0.008
Co	<0.05	La	<0.02
Cr	<0.05	Ce	<0.4
Cu	<0.02	Pr	<0.2
Fe	<0.01	Sm	<0.2
K	<0.01	Eu	<0.01
Li	<0.02	Gd	<0.02
Mg	<0.02	Tb	<0.1
Mn	<0.05	Dy	<0.2
Mo	<0.01	Ho	<0.1
Na	<0.05	Er	<0.01
Ni	<0.1	Tm	<0.02
Pb	<0.05	Yb	<0.01
Si	<0.05	Lu	<0.004

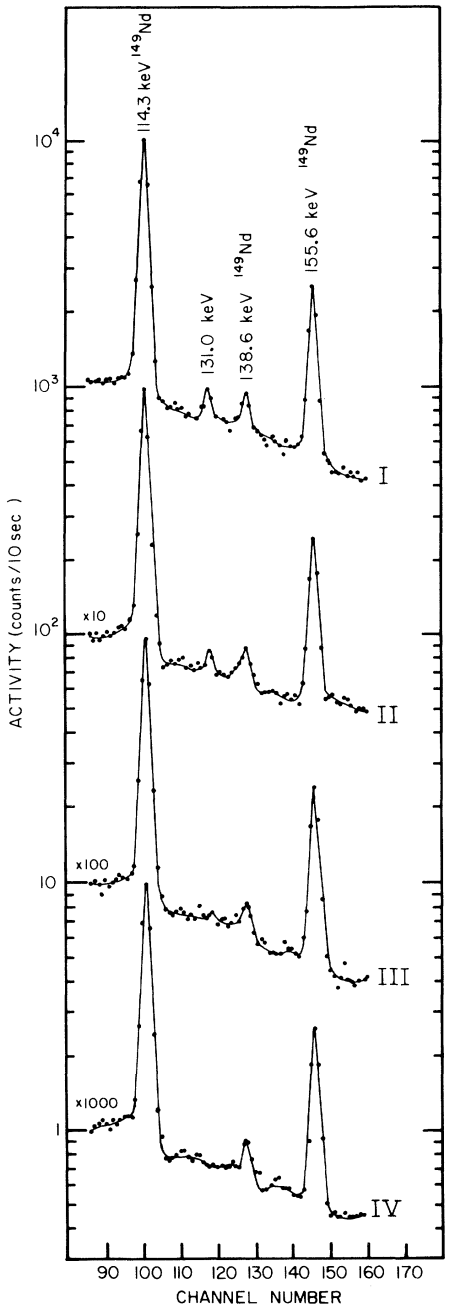

FIG. 1. Four successive (top to bottom) 10-sec singles Ge(Li) spectra of the energy region 105–165 keV. The spectra were obtained from thirty 10-sec bombardments of enriched ^{150}Nd metal. The γ rays of 114.3, 138.6, and 155.6 keV are assigned to 1.73-h ^{149}Nd produced through the ^{150}Nd(n, $2n$) reaction.

the geometric centroid of that peak. The energy of a given peak is derived by introducing into the program the calibration peaks which are also treated in a similar manner, and a least-squares analysis method is used to derive an energy cal-

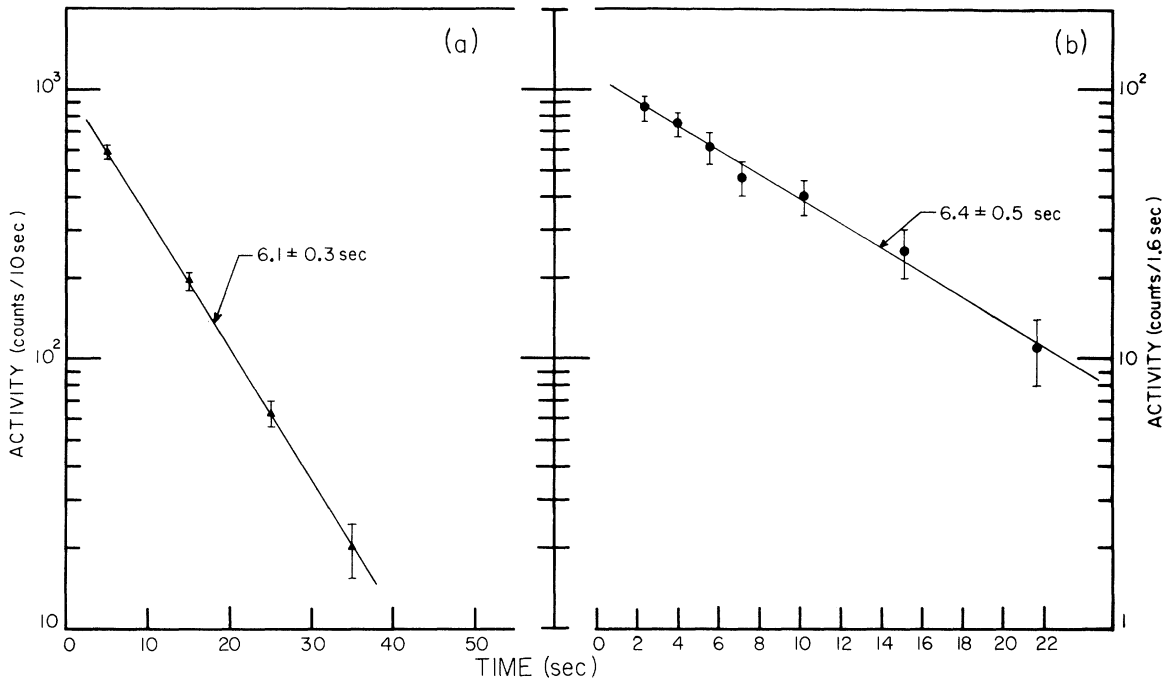

FIG. 2. Half-life measurements of the 131-keV γ ray. (a) Decay of 131-keV γ ray observed in singles Ge(Li) spectra. (b) Gross β decay of the β-γ coincidences on the 131-keV γ ray (β bias >2.0 MeV).

ibration curve through the centroids of the calibration peaks; hence we attribute an error of ± 0.8 keV to our derived energies. Least-squares analysis of the half-life of the 131-keV γ ray consistently yielded 6.1 ± 0.3 sec as shown in Fig. 2(a).

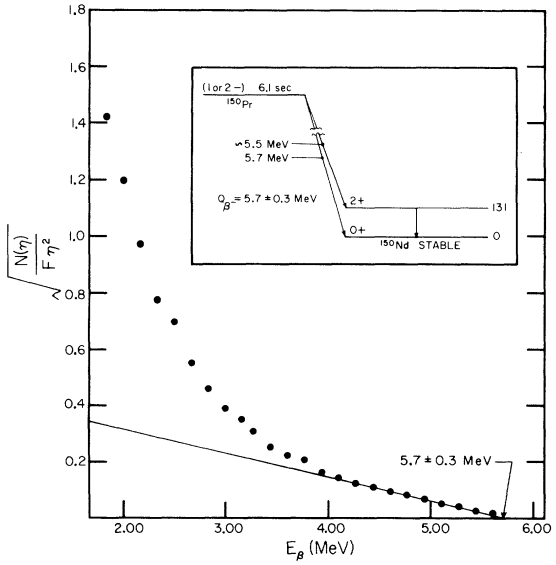

FIG. 3. Fermi-Kurie plot of the β spectrum of ^{150}Pr obtained from 30 10-sec bombardments of the enriched ^{150}Nd sample. A small amount of ^{16}N (4.291 and 10.422 MeV) contamination was subtracted. The nitrogen activity was produced from oxygen impurities in the fast-transport capsule. The *inset* shows the tentatively proposed decay scheme of ^{150}Pr.

The beta spectrum was observed to have a 5.7 ± 0.3-MeV end point after a small amount of 7.1-sec ^{16}N contamination was subtracted. The ^{16}N was produced from oxygen impurities in the fast-transport capsule. A typical singles β^--ray spectrum (after subtraction of ^{16}N contamination) is shown in Fig. 3. A half-life of the high-energy β^- rays could not be determined due to the nitrogen contamination. β-γ coincidences on the 131-keV γ ray revealed a 5.5 ± 0.5-MeV β^- end-point energy. Total β^- yield of the coincident β^- rays biased more than 2 MeV (in order to eliminate ^{149}Nd contributions) decayed with a 6.4 ± 0.5 sec (least-squares-analysis method) half-life as shown in Fig. 2(b).

The new 6.1-sec activity was assigned to ^{150}Pr based on the following facts: (a) The 131-keV γ ray was found in coincidence with a 5.5 ± 0.5-MeV β ray and can only be assigned to ^{150}Pr, since all other fast-neutron reaction products of Nd have β- decay Q values of less than 4.9 MeV (^{148}Pr) and half-lives ≥55 sec (^{139m}Ce); (b) the 131-keV γ ray can be assigned to the 2+ → 0+ ground-state γ transition in ^{150}Nd [4]; and (c) the β-decay Q value of 5.7 ± 0.3 MeV for the 6.1-sec activity is in agreement with the value estimated [1] for ^{150}Pr.

The region of 88–90 neutron number is known [5] to be a transitional region between the shell model and the collective model. The ground-state spins of several nuclei in this region cannot be ade-

quately described by filling the appropriate single-particle levels. The Pm isotopes with two more odd protons than Pr are observed to have either a $\frac{5}{2}$+ or $\frac{7}{2}$+ odd-proton assignment with the 91st odd neutron assigned a spin parity of $\frac{3}{2}$−. If one assumes a slight deformation of $\epsilon \sim 0.1-0.2$, then the 59th odd proton of ^{150}Pr would fall in either the $\frac{5}{2}$+ [413] or $\frac{7}{2}$+ [404] Nilsson orbits and the 91st odd neutron in the $\frac{3}{2}$− [521] orbit.[6-8] From the coupling rules given by Gallagher and Moszkowski[9] for odd-odd nuclei, a ground-state spin-parity of (1 or 2−) is expected for ^{150}Pr. In the inset of Fig. 3 is shown a tentative decay scheme of ^{150}Pr. The assignment of a (1 or 2−) ground-state spin-parity is very tenuous. However, comparison of the β^- and β^--γ measurements supports either a (1 or 2−) spin-parity, since one does not expect to populate individual particle levels of the same parity for both odd nucleons in this region.

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