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ABSTRACT

A series of C^{12} bombardments on Pr^{141} has resulted in the discovery of two new activities. The first, with a 70-min half-life, is believed to be Tb^{148}. The isotope has two gamma rays, 780 and 1120 kev, following its decay. The 780-kev gamma ray is postulated to be the transition from the first excited level to the ground state in the even-even nucleus, Gd^{148}. The second activity has a half-life of 24 min and has a 305-kev gamma ray following its decay. It is probably Tb^{147}, though this has not been clearly established.

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its gamma-ray energies are known.[2] None of the Gd^{147} gamma rays appeared in the gamma spectra taken with the above sample. The gamma rays of Gd^{149} growing in from Tb^{149} were observed. The inability to see any Gd^{147} growing in from a pure terbium fraction certainly indicates that the new activity could not be Tb^{147}. Gd^{148} has a half-life of about 130 years. No gamma rays have been identified in connection with its decay. The isotope is an alpha emitter, and there is also fair evidence that it is beta-stable.[3] Its half life is too long for growth of its activity to be seen with samples containing originally the 70-min activity.

The next experiment performed was a bombardment of Pr^{141} with 100-Mev C^{12} ions. The results from this experiment are discussed more fully in connection with Tb^{147}. Suffice it to say that the gamma spectrum in this case indicated that Gd^{147}, presumably growing in from Tb^{147}, was present in large quantity, while Tb^{149} was definitely absent and the gamma rays assigned to the 70-min activity were present, if at all, to a very limited extent. Essentially the same kind of evidence was obtained from N^{14} bombardments on Pr^{141}. In these experiments no chemical separations were made. Terbium-149 was seen to be present in an 80-Mev bombardment but the gamma rays of the 70-min activity were not. In a 110-Mev N^{14} bombardment the gamma rays of the new activity were very much in evidence, being in greater abundance than the gamma rays of Tb^{149}. Spectra of the same sample taken at later times did not show any Gd^{147} present, while Gd^{149} was seen. A 225-kev gamma ray very prominent in Gd^{147} decay was definitely absent from this experiment. The evidence from the two N^{14} bombardments together with that from the C^{12} experiments indicates that the 70-min activity has a lesser mass number than that of Tb^{149}, but presumably greater than 147. In this manner the 70-min activity was determined to be Tb^{148}.

The gamma spectrum obtained in the 75-Mev C^{12} bombardment is shown in Fig. 1. The two gamma rays assigned to the decay of Tb^{148} have energies of 780 and 1120 kev. The half-lives of the two peaks were determined and found to be about 70 min. The two gamma rays have thus been assigned to Tb^{148} decay, not only on the basis of the variation of their intensities with bombarding energies, but also because of their half-lives. Table I lists the first-excited-level energies of even-even nuclei whose neutron numbers vary from 90 to 82.

Table I

Variation of energy of first-excited-level with neutron number

Neutron Number	Nucleus	Energy of first-excited-level of kev
90	Gd^{154}	123
	Sm^{152}	122
88	Gd^{152}	344
	Sm^{150}	337
86	Sm^{148}	562
	Nd^{146}	460
84	Nd^{144}	694
82	Nd^{142}	1.57
	Ce^{140}	1.596
	Ba^{138}	1.43
	Xe^{136}	1.32

The energies quoted for all these nuclei are well established and have been taken from the new Table of Isotopes.[4] The variation of first-excited-level energies of even-even nuclei with neutron number is readily noted. As the neutron number is decreased going from the region where rotational levels in nuclei are observed toward the 82-neutron closed shell, the energies increase. They begin to decrease again on the other side of the 82-neutron shell, though this is not shown in Table I. Gd^{148}, the nucleus populated in the decay of Tb^{148}, has 84 neutrons, the same number as Nd^{144}. For that reason one would expect that their first-excited-level energies would be somewhat similar in magnitude. The first excited level in Nd^{144} has an energy of 694 kev. When we note another general trend in Table I -- that is, that the energies seem to increase with atomic number for a given neutron number --- it certainly does not seem unreasonable to propose that the 780-kev gamma ray in Tb^{148} decay represents the transition from the first excited level to the ground state in Gd^{148}. The ratio of intensities of the two gamma rays, 780 and 1120 kev, assigned to Tb^{148} is 8:5, after the gamma-ray intensities have been corrected for the efficiency of the 3 X 3-inch NaI(Tl) crystal used to obtain the spectra. We should like to suggest that the two gamma rays may be in cascade, with the 1120-kev gamma ray being the transition from a level at about 1900 kev to the 780-kev first excited state. A somewhat analogous case exists in Nd^{144}, in which a transition of 1490 kev proceeds from a level at 2180 kev down to the first excited level at 694 kev. Coincidence work is needed to test this possibility.

The rest of the gamma rays in the spectrum were found to decay with a 4-hr half-life. A spectrum taken approximately 10 hours after the one displayed in Fig. 1 was obtained showed no peaks at 780 or 1120 kev. Only the gamma rays of Tb^{149} were visible.

The decay curves of the 510-kev and K-x-ray peaks were resolved and found to have 70-min components. Thus the 70-min activity must decay both by positron emission and by electron capture.

Terbium-147

A new activity with a half-life of 24 min was observed in the 100-Mev C^{12} bombardment on Pr^{141}. As mentioned previously, Gd^{147} was known to be certainly present in the sample produced from this bombardment by virtue of the identification of its gamma rays, while Tb^{149} and Tb^{148} were known to be absent. Figure 2 shows the gamma spectrum taken of the sample approximately 10 minutes after the termination of the bombardment. The gamma rays of Tb^{149} and Tb^{148} are not observed in the spectrum. There is a peak at 225-kev which represents the most prominent gamma ray in Gd^{147} decay. There are also two other peaks present, one at 145 and the other at 305 kev. The half-life of the 305-kev gamma ray was found to be 24 min. There was a component of about the same half-life in the decay curve of the 145-kev peak. Spectra taken at later times showed the 225-kev gamma ray increasing in intensity relative to the other two peaks, and at still later times the remainder of the Gd^{147} gamma rays became evident. The same 24-min half-life appeared as the shortest component of both the Geiger-Müller counter and the 510-kev annihilation peak decay curves.

Thus it was established that a new activity with at least one gamma ray (305 kev) had been found. Also the mass number of the isotope had to be less than 148 because the 305-kev gamma ray belonging to its decay was not seen in the 65- and 75-Mev C^{12} bombardments when Tb^{148} was known to be present. We would like to propose that the new isotope is Tb^{147} for the following two reasons:

First, the decay curve of the 225-kev gamma ray was obtained and it was found to have an initial interval of growth which was then followed by the characteristic half-life of Gd^{147}. The half-life of the growth period of the 225-kev gamma ray was found to be between 20 and 30 min, indicating that perhaps the gamma ray had grown in from the 24-min activity.

Second, in Fig. 3, which shows the spectrum taken a day after bombardment time, only the prominent gamma rays of Gd^{147} decay are seen. Their energies are 225, 390, 635, 750, and 900 kev. Smaller peaks are seen at about 110, 120, and 500 kev, which represent undoubtedly some of the less intense gamma rays of approximately the same energies reported for Gd^{147}.[2] The point that we wish to emphasize is that no intense gamma rays, other than those of Gd^{147}, are visible, indicating that the 24-min activity probably does decay to Gd^{147}.

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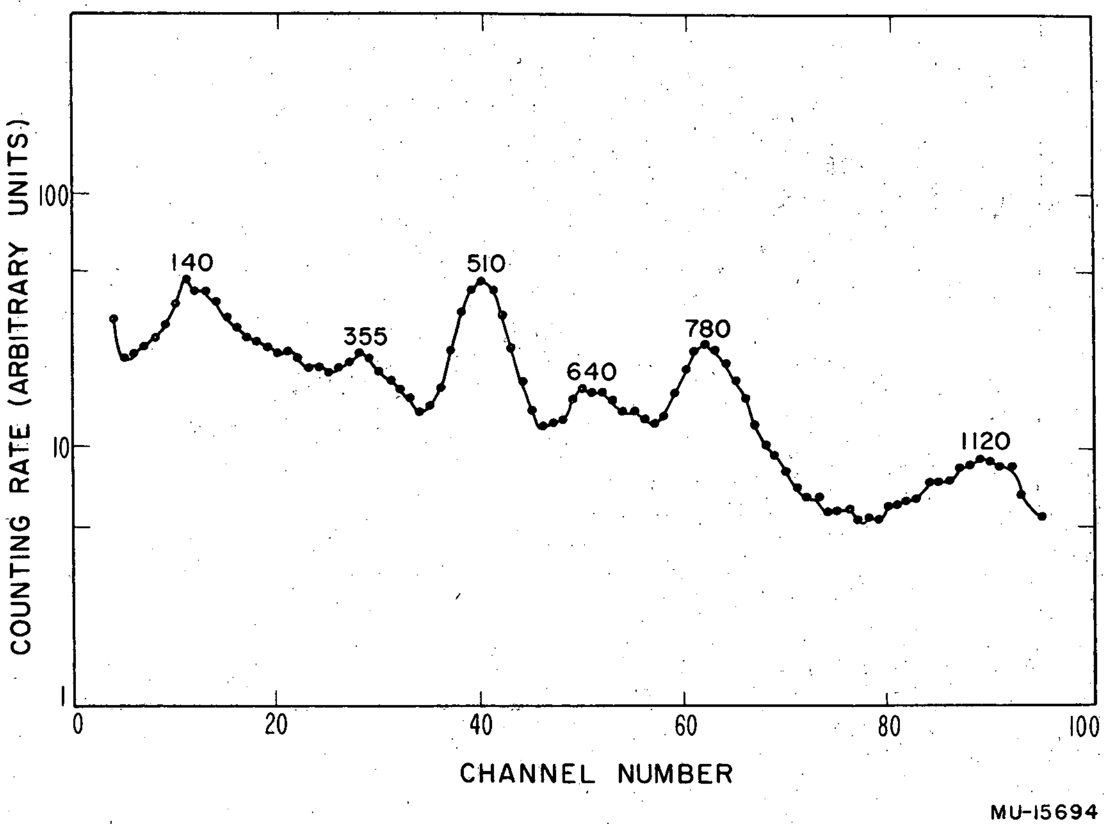

Fig. 1. Gamma Spectrum obtained in the 75-Mev C^{12} bombardment on Pr^{141}.

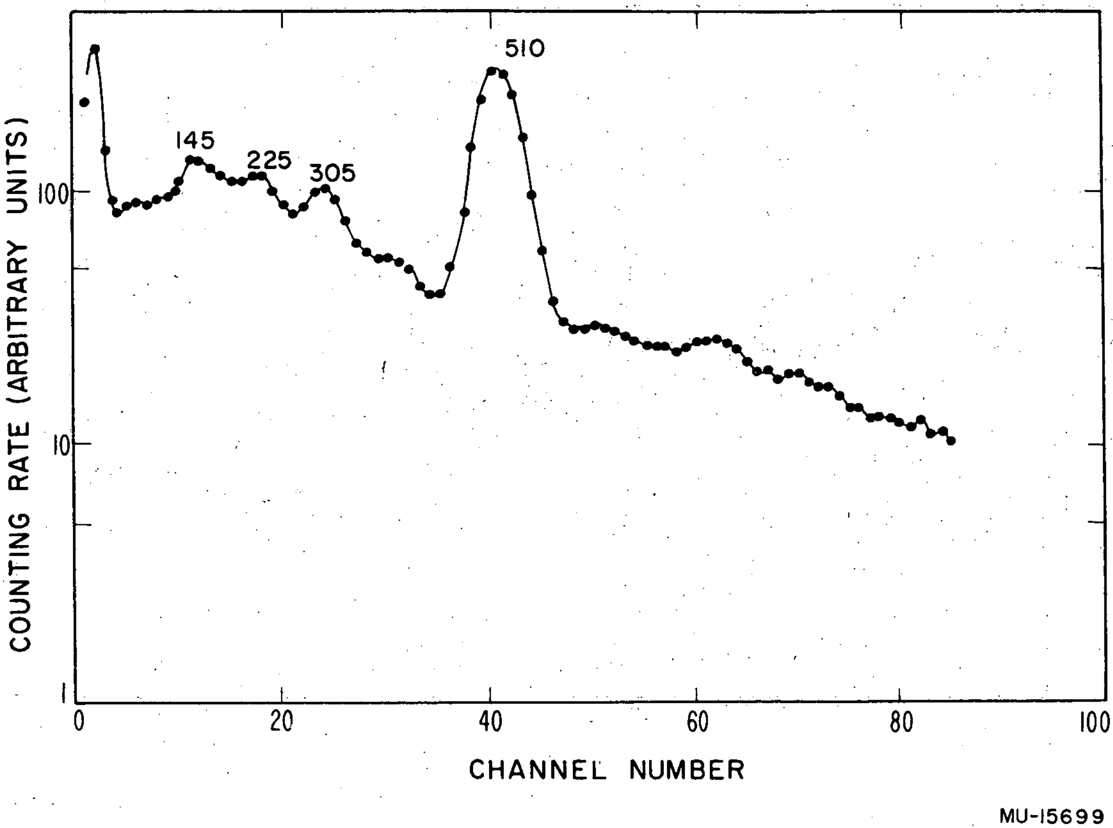

Fig. 2. Gamma Spectrum obtained in the 100-Mev C^{12} bombardment on Pr^{141}. The spectrum was taken approximately 10 minutes after the termination of the **bombardment.**

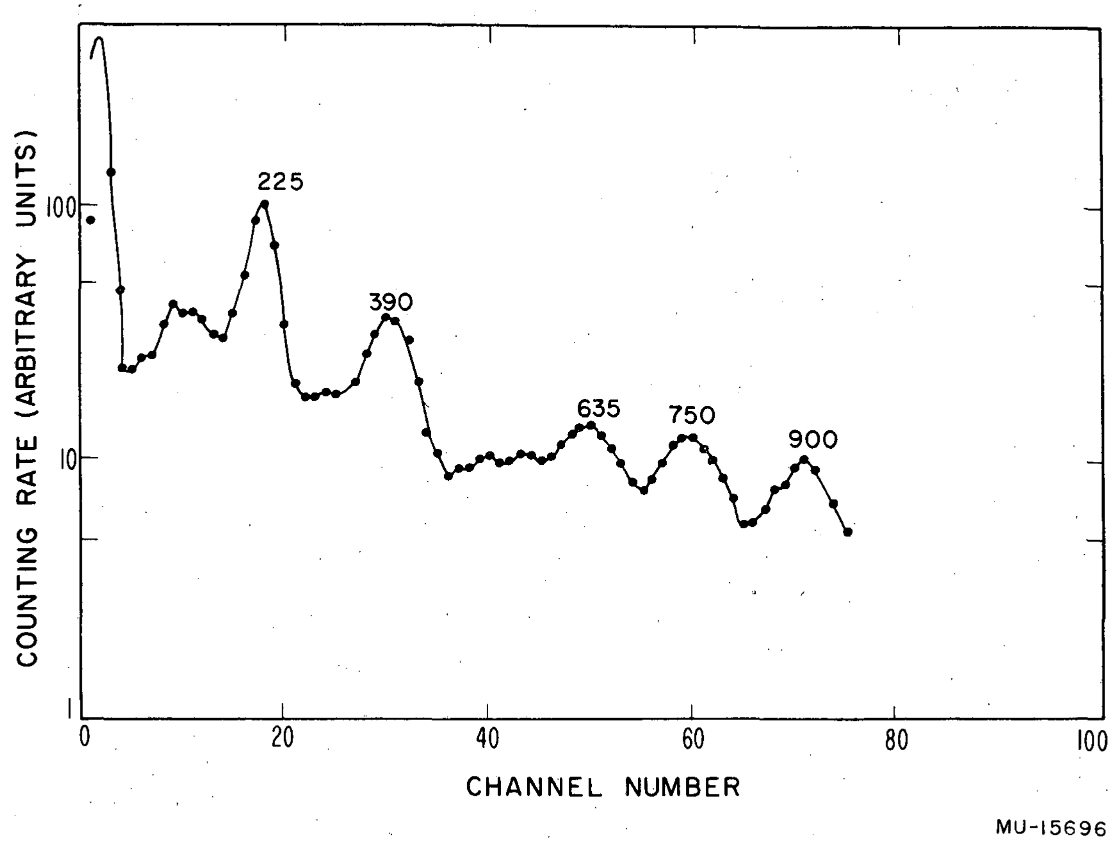

Fig. 3. Gamma Spectrum taken a day after the termination of the 100-Mev C^{12} bombardment on Pr^{141}. The prominent gamma rays in the decay of Gd^{147} are readily observed.