total of 100% for the electron capture transitions to the five levels of Yb^{173}. The percentages of electron capture to the 633-, 351.1-, 179.5-, and 78.7-kev levels and the ground state of Yb^{173} are thus approximately 4, 35, 24, 37, and 0, respectively.

DISCUSSION

The discrepancies enumerated in the introduction are now considered. The 625-day half-life of Lu^{173} is closest to the originally assigned value of 500 days. The 273-kev transition is not to the ground state of Yb^{173} but originates from 351-kev level. Transitions of energy greater than 351-kev do exist in the activity of Lu^{173} and their positions in the energy level scheme are shown in Fig. 2. The 22-, 113-, 145-, and 335-kev gamma rays mentioned in the introduction are not observed by in the gamma-ray spectrum of Lu^{173} nor have any of them been observed by conversion electron measurements. A 22-kev gamma ray was shown not to exist in an amount greater than two percent of the K x-ray by absorption measurements with a scintillation spectrometer. Peaks at about 113 and 335 kev are observed in the gamma-ray spectrum of Lu^{173} when a geometry is used which allows coincidence summation to occur but these two peaks disappear rapidly when the K x-ray is absorbed. The conclusion is that the 113-kev peak is the coincidence sum peak of two K x-rays, and the 335-kev peak is that of a 273-kev gamma ray and a K x-ray. The results of this investigation show that few if any electron capture transitions of Lu^{173} occur to the ground state of Yb^{173}.

The gamma-gamma coincidence information obtained in this investigation agrees with that mentioned in the introduction[10] for the cases where the gamma rays of the two investigations correspond. In particular, the 172- and 273-kev peaks were each in coincidence with themselves and the 556-kev gamma ray was in coincidence with the 79-kev gamma ray only.

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Isomeric States of Nd^{141} and Sm^{143}†

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Two previously unreported nuclear isomers which belong to the series having 81 neutrons and even numbers of protons have been found and studied. These are Nd^{141m} (half-life 63.7 seconds, gamma-ray energy 0.76 Mev) and Sm^{143m} (half-life 137 seconds, gamma-ray energy 0.68 Mev). The observed properties agree with the assignment of $h_{11/2}$ and $d_{3/2}$ to the upper and lower states, respectively, as predicted by the single particle model.

INTRODUCTION

SEVERAL isomers having even Z and 81 neutrons are known: Te^{133m}, Xe^{135m}, Ba^{137m}, and Ce^{139m}. All of these decay by $M4$ transitions involving the transition $(11/2,-)\rightarrow(\frac{3}{2},+)$. The energies of these transitions have a regular dependence on Z and their comparative lifetimes[1] ($T_{\frac{1}{2}\gamma}A^2E^9$) are very nearly equal. Predictions based on these facts indicated that Nd^{141m} and Sm^{143m} should also be easily observable. These predictions are verified by the work reported here.

EXPERIMENTAL

Targets of praseodymium metal, Pr_2O_3, La_2O_3, Sm_2O_3, and $Sm_2{}^{144}O_3$ were bombarded in the internal beam of the U.C.L.A. cyclotron. The powdered samples ranging in weight from 10 to 50 mg were wrapped in tantalum foil and bombarded for periods of 30 seconds to 5 minutes. Protons of 16 Mev were used for (p,n) reactions and of 20.6 Mev for the (p,pn) reaction.

The targets were removed from the cyclotron and placed in an aluminum container situated approximately 2 inches from a 2-in.×2-in. NaI(Tl) crystal coupled to a Du Mont 6292 photomultiplier tube and cathode follower preamplifier, followed by a linear amplifier (Baird-Atomic Model 215). The output from the amplifier was fed into a 100-channel pulse-height analyzer and, simultaneously, into a single-channel

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[1] M. Goldhaber and A. W. Sunyar, *Beta- and Gamma-Ray Spectroscopy*, edited by Kai Siegbahn (North Holland Publishing Company, Amsterdam, 1955), Chap. XVI.

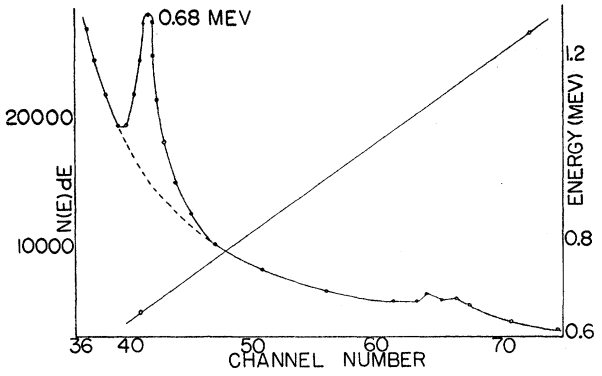

FIG. 1. Scintillation spectrum of Sm^{143m}.

analyzer (Baird-Atomic Model 510). The multichannel analyzer was biased to record the gamma-rays having energies greater than annihilation radiation. The integral discriminator of the amplifier was set to pass all pulses above annihilation radiation and, after suitable scaling, these pulses were recorded on one pen of a two pen Sanborn Recorder. The second pen of the recorder was connected to the channel output of the single channel analyzer to record the decay of pulses having energies within the channel.

RESULTS

1. Nd^{141m}

The gamma-ray spectrum from the praseodymium bombardments exhibited a relatively small "gamma background" extending beyond 1 Mev (probably caused by bremsstrahlung originating from high-energy positrons in activities formed in the oxide coating on the metal), and a very prominent peak at 0.76±0.01 Mev. A small peak at 1 Mev was attributed to an annihilation "sum peak." For both the integral and channel (0.76 Mev) decay curves the half-life obtained was 63.9 ±1.1 seconds. The similarity of the energy and half-life to those reported[2] for Ce^{139m} led to a confirmatory investigation of Ce^{139m}. By similar methods, using La_2O_3 as the target material, the energy and half-life of Ce^{139m} were determined to be 0.74±0.01 Mev and 54.2±1.1 seconds, respectively, in agreement with the reported values for Ce^{139m}.

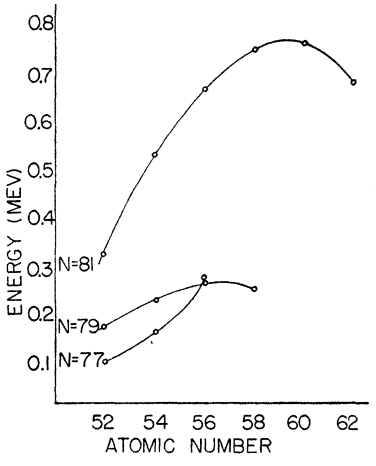

FIG. 2. Isomeric transition energies of some $M4$ transitions.

2. Sm^{143m}

The gamma-ray spectrum for the $Sm_2{}^{144}O_3$ bombardments is shown in Fig. 1. Subtraction of the large bremsstrahlung background (broken line) yielded a peak from which the energy was determined to be 0.68±0.01 Mev. Subtraction of the long-lived activity in the differential decay (channel set at 0.68 Mev) produced a curve which was resolved into activities of 137±2 seconds and *ca* 30 seconds half-lives. A plot of the area under the 0.68-Mev peak as a function of time showed that the 0.68-Mev gamma-ray has a half-life of 137 seconds. No other peaks which could be assigned to the 30-second activity were observed in the spectrum out to 1.4 Mev. The 30-second activity may be attributed either to Eu^{143} produced by a $(p,2n)$ reaction or to a combination of the bremsstrahlung from several species. No further attempt was made to identify this activity.

TABLE I. Comparative lifetimes of 81-neutron isomers.

Nuclide	E_γ (Mev)	$T_{\frac{1}{2}}$ (sec)	γ Branch	$1+\alpha$	$T_{\frac{1}{2}\gamma}$	$\log T_{\frac{1}{2}\gamma}A^2E^9$	$\lvert M\rvert$
Sm^{143m}	0.68	137	1.0	1.199	164.2	5.0185	1.021
Nd^{141m}	0.76	63.9	1.0	1.105	70.6	5.0744	0.968
Ce^{139m}	0.74	55	1.0	1.091	60	4.8868	1.188
Ba^{137m}	0.662	156	1.0	1.116	174	4.8994	1.171
Xe^{135m}	0.53	920	1.0	1.249	1149	4.8396	1.254
Te^{133m}	0.334	3180	0.13	2.47	60 400	4.7430	1.407

DISCUSSION

Goldhaber and Sunyar[1] define a comparative lifetime for magnetic transitions of multipole order l, $T_c=T_{\frac{1}{2}\gamma}E^{2l+1}A^{[(2l-2)/3]}$ where $T_{\frac{1}{2}\gamma}$ is the gamma half-life after correcting the observed half-life for internal conversion and any beta branching; E is the energy in Mev. For $M4$ transitions, $T_c=T_{\frac{1}{2}\gamma}E^9A^2$. Table I presents the data relating to the comparative lifetimes of the known even-Z, 81-neutron isomers. M is the Mayer matrix element.[3] The agreement of the values of T_c (and the related values of M) is remarkably good. The existence of the two new isomers is further confirmation of the well-known success of the single particle model in this region.

Figure 2 shows the isomeric transition energies of the even Z, 81-neutron family of isomers and the relation of these to the series having 79 and 77 neutrons.

[2] Ketelle, Thomas, and Brosi, Phys. Rev. **103**, 190 (1956).

[3] M. G. Mayer and J. H. D. Jensen, *Elementary Theory of Nuclear Shell Structure* (John Wiley and Sons, Inc., New York, 1956).