PHYSICAL REVIEW VOLUME 102, NUMBER 5 JUNE 1, 1956

Decay of Ce^{144}†

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(Received February 20, 1956)

The decay scheme of 282-day Ce^{144} was investigated using a thin-lens beta spectrometer, proportional counters, and scintillation counters. Intensity measurements and coincidence studies were used to obtain the decay scheme. Two beta rays were found; the main branch is a 76%, 309±5-kev beta ray to the ground state while the 24±5%, 175-kev beta ray goes to a 134-kev level in Pr^{144}. From this level there are three parallel γ-ray branches: In 15.3% of the Ce disintegrations one observes a 134-kev gamma ray, in 7.2% a cascade of 81-kev and 54-kev gamma rays, and in 1.5% a cascade of 100 kev and 34 kev. For the conversion of the 134-kev gamma ray, $\alpha_K=0.71\pm0.20$ and $K/L=7.1\pm0.5$, while for the 81-kev gamma ray, $\alpha_K=1.2\pm0.3$ and $K/L=5.8\pm0.7$. There is insufficient intensity in the 54-kev gamma ray to explain observed coincidences and a strong unobserved 42-kev gamma ray is implied.

I. INTRODUCTION

THIS paper describes a series of measurements on the much studied 282-day[1] Ce^{144}. When we did this work in 1952 and 1953, four different research groups[2–5] had reported detailed studies of the complex conversion electron spectrum but very little work had been done on the photons, on coincidence measurements, or on intensity measurements. Since our results were not conclusive and since we hoped to improve them, we merely reported[6] that our data confirmed the main features of the decay scheme suggested by Porter and Cook.[5] Since our work was done, three other reports have appeared[7–9] which have emphasized the need for data such as we obtained. Since we have been unable to do any more work on this problem, we shall report the results we obtained in the hope that they will help determine the actual decay scheme of Ce^{144}.

II. EXPERIMENTAL TECHNIQUE

The equipments used in this work were (A) a thin-lens beta-ray spectrometer to measure electron intensities, (B) a proportional counter to measure low-energy gamma rays, and (C) both NaI and anthracene scintillation counters to measure gamma-ray intensities and coincidences.

A. Thin-Lens Electron Spectrometer

The beta and conversion electron spectrum was measured in a thin-lens spectrometer which had a momentum resolution of 2.4% and a transmission of 1%. The Ce^{144}, aged and carrier-free, was obtained in the form of an acid solution of $CeCl_3$ from the Isotopes Division of the AEC, Oak Ridge, Tennessee. The sources were made by evaporating this solution onto a thin nylon film which had an acid-resistant layer of LC-600 resin[10] and which was made conducting by an evaporated aluminum backing. The source thickness was estimated to be less than 20 μg/cm^2 while the source backing material had a thickness of about 100 μg/cm^2. The electrons which passed through the spectrometer were detected by a Geiger-Mueller counter having a window thickness of 50 μg/cm^2 and filled with amyl acetate vapor in equilibrium with the liquid at room temperature. Corrections were made for the absorption of very low-energy electrons by the Geiger counter window by using the absorption curves published by Saxon.[11] The correction factor was only 1.14 at 18 kev and became negligible above 114 kev. Although the energy resolution was too poor to reproduce the details of the spectrum found by earlier investigators,[2–9] the intensity measurements could be made relatively accurate by using the higher resolution results as a guide to the interpretation of the thin-lens spectrum.

B. Proportional Counters

Proportional counters filled with either argon or krypton were used to detect low-energy photons with relatively high resolution. The counters had brass walls and were cylindrical in shape, 6 in. in diameter and 20 in. long.[12] Each counter had a one-inch diameter beryllium window, 175 mg/cm^2 thick. One counter had a 90% argon, 10% methane mixture and the other contained 90% krypton and 10% methane; the total pressure in each case was one atmosphere. Both counters had an energy resolution of 15% at 27 kev. The calculated absorption coefficient for 36-kev photons was 5±0.5% for the argon counter and 49±4% for the

† This research was supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

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TABLE I. Conversion electrons assigned to Ce^{144} decay.

Keller and Cork kev	Cork, Brice and Schmid kev	Porter and Cook kev	No. of line	Assumed shell	This work Inferred gamma-ray energy (kev)	Relative intensity 175-kev beta ray = 1000
11.7			[a]	K	53.9±0.3	
27.2	26.6	26.9	1[b]	L_1	33.8±0.3	56 ±22
	28.5	29.2	2[b]	Auger	x-ray 36	27 ±11
32.5	31.7	32.0	[c]	M	33.8	<11
34.5	34.0	34.0	3[b]	L_1	42	70 ±22
			[d]	Auger	x-ray	11 ± 7
38.8	38.1	38.7	4	K	81.0±0.3	142 ±11
40.0	39.3		[c]	M	42	
47.0	46.4	46.6	5	L_1	53.9	2.2± 1
53.0	52.2		[c]	M,N	53.9*e*	
	53.0		6[e]			23 ± 4
58.5	57.6	58.0	7[e]	K	100.3±0.3	11 ± 2
74.1	73.1	74.1	8	L_1	81.0	25 ± 2
	73.9		[c]	L_3		
79.4	78.4	79.2	9	M	81.0	2.3± 0.7
80.6			[c]	N	81.0	
	88.2		[c]	?		
92.4	91.6	92.2	10	K	134.4±0.3	248 ±11
		93.8	[c]	L_1	100.3	
		98.6	?[b]	M_1	100.3	<5
	103.2		?[f]			<1
127.8	126.7	127.3	11[b]	L_1	134.4	34 ± 5
132.0	131.9	133.0	12[b]	M	134.4	9 ± 2
134.1			[c]	N	134.4	
	138.6		[f]			<0.5
	143.7		[f]			<0.5

[a] Not observed, energy too low.
[b] Partially resolved.
[c] Not resolved.
[d] Intensity inferred from expected Auger ratio [E. H. S. Burhop, "The auger effect," Cambridge Monograph, 1952 (unpublished)].
[e] Intensity due partially to 60-kev gamma ray assigned to Nd^{144}.
[f] Assigned in reference 9 to 145-kev gamma ray.

krypton counter. The krypton counter had the disadvantage that krypton x-rays formed in the counter often escaped, thereby causing "escape peaks" of energy E(photon)$-E$(krypton x-ray).

C. Scintillation Counters

Scintillation experiments were performed both at the University of Illinois and at Brookhaven National Laboratory. At Illinois, two cubic NaI crystals were used; one had sides of 1 cm and the other 2 cm. Each crystal when mounted on an RCA 5819 phototube had a resolution of about 16% for the 662-kev gamma ray of Cs^{137}. At Illinois, we also used a cylindrical anthracene crystal, 0.5 cm thick and 2 cm in diameter. The anthracene crystal was covered with a foil of 0.16 mg/cm^2 of aluminum. The anthracene crystal spectrometer was calibrated with internal conversion electrons of known energy. It had a linear energy response at energies above 70 kev and had an energy resolution of 50% at 110 kev. Conventional linear amplifiers, pulse-height selectors,[13] and 2-μsec resolving time coincidence circuits were used.

The equipment of the Brookhaven National Laboratory was used by one of us (P.A.) while he was a summer visitor (1953) in the Electronics Division. The NaI scintillation crystals varied in thickness from 0.5 cm to 3 cm and were mounted on Dumont 6292 phototubes. The energy resolution of the scintillation spectrometers[14] was about 10% (full width at half-maximum) for the Cs^{137} 662-kev gamma ray. In addition to the conventional amplifiers, pulse-height selectors, and power supplies, the spectrometers were equipped with a coincidence gray-wedge pulse-height analyzer,[15] an improved and more versatile version of the gray-wedge pulse-height analyzer.[16] This coincidence pulse-height analyzer could be adjusted to display a spectrum of those gamma rays which were in coincidence with gamma ray pulses in a preselected energy range. The coincidence circuit had a resolving time of about 0.1 μsec.

All photon intensity measurements made with NaI crystals were corrected for absorption in the C or Be electron absorbers, for the efficiency of the crystal, and for the escape of iodine x-rays.[17]

III. RESULTS

A. Beta Rays

A Fermi-Kurie analysis of the beta-ray spectrum showed two beta-ray groups: 76±5% of the transitions

[13] The pulse-height selectors were designed and tested by Dr. Sherman Frankel of the University of Pennsylvania.

[14] The scintillation spectrometers were those operated by A. W. Schardt and by W. Bernstein. The electronic equipment for these spectrometers had been designed by W. A. Higinbotham and R. L. Chase.

[15] R. L. Chase, Brookhaven National Laboratory Report BNL 263 (*T*42) (unpublished) and A. W. Schardt, Brookhaven National Laboratory Report BNL 237 (*T*37) (unpublished).

[16] Bernstein, Chase, and Schardt, Rev. Sci. Instr. **24**, 437 (1953).

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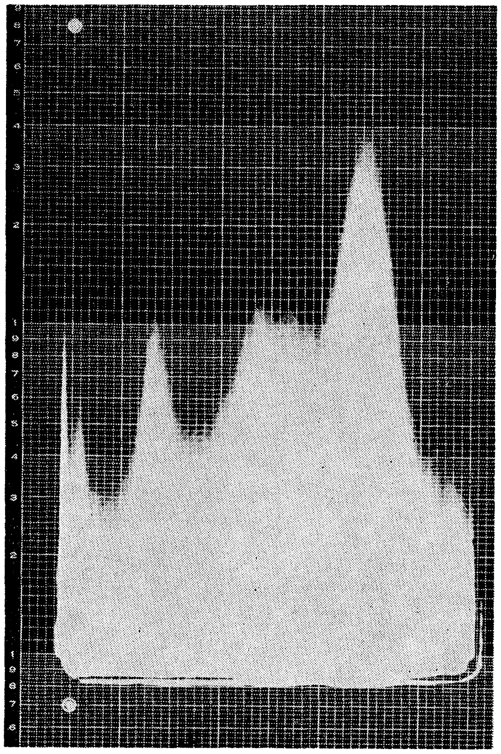


FIG. 1. Gray-wedge spectrum of photons. The peaks from left to right are identified as follows, with position given in graph divisions to right of zero line which is defined by two circular dots: Marker line (−1), noise (1), x-ray (10), 81 kev (22), 100 kev (26), and 134 kev (35.5).

occur via an allowed 309±5 kev beta ray, while 24±5% occur via a 175±5 kev transition. There is a slight excess of electrons below 100 kev which can be explained by scattering but which might be interpreted as a low-intensity low-energy beta ray. There was no evidence for either 228-kev or 255-kev beta-ray branches. Analysis of the energy region between 175 kev and 309 kev puts an upper limit of 5% to the intensity of intermediate energy beta rays. Using allowed f values, the $\log ft$ values of the 175-kev and 309-kev beta rays are 7.0±0.3 and 7.4±0.3, respectively.

B. Beta Ray-Photon Coincidences

The x-ray, the 81-kev gamma ray, and the 134-kev gamma ray are each in coincidence with a beta-ray group which (within the precision obtainable) is identical with the 175-kev beta ray. No evidence for coincidences could be obtained for beta rays above 180 kev. If there are any beta rays with energies above 180 kev which lead to the 81-kev gamma ray their intensity must be too small to explain an appreciable fraction of the 81-kev gamma rays.

C. Conversion Electrons

The spectrometer resolution of 2.4% was too poor to resolve all the lines reported by earlier investigators. However, the intensity measurements and the other experimental results permitted us to make the identifications given in Table I. The table also indicates which lines were partially or completely unresolved in the lens spectrometer.

There are two ambiguous features of the assignments made in Table I. The first involves the energy of the gamma ray assigned by us to 42 kev. The L conversion electrons of this gamma ray are unresolved from the Auger K-L-M electrons and thus may have been misinterpreted by earlier workers to have too low an energy. A consistent interpretation of the coincidence experiments requires that the "42-kev" gamma ray have enough energy to be K-converted in Pr which has a K binding energy of 41.99 kev. Thus, we prefer to assume that the reported electron conversion energy was too low and that the data are actually consistent with a 42-kev rather than a 41.5-kev gamma ray. The second ambiguous feature involves the L conversion electrons of the 100-kev gamma ray which could barely be resolved by Porter and Cook[5] and which we assume could have been missed by the other investigators[3,9] because of its low intensity. If the 145-kev gamma ray[9] actually exists, its intensity must be quite low.

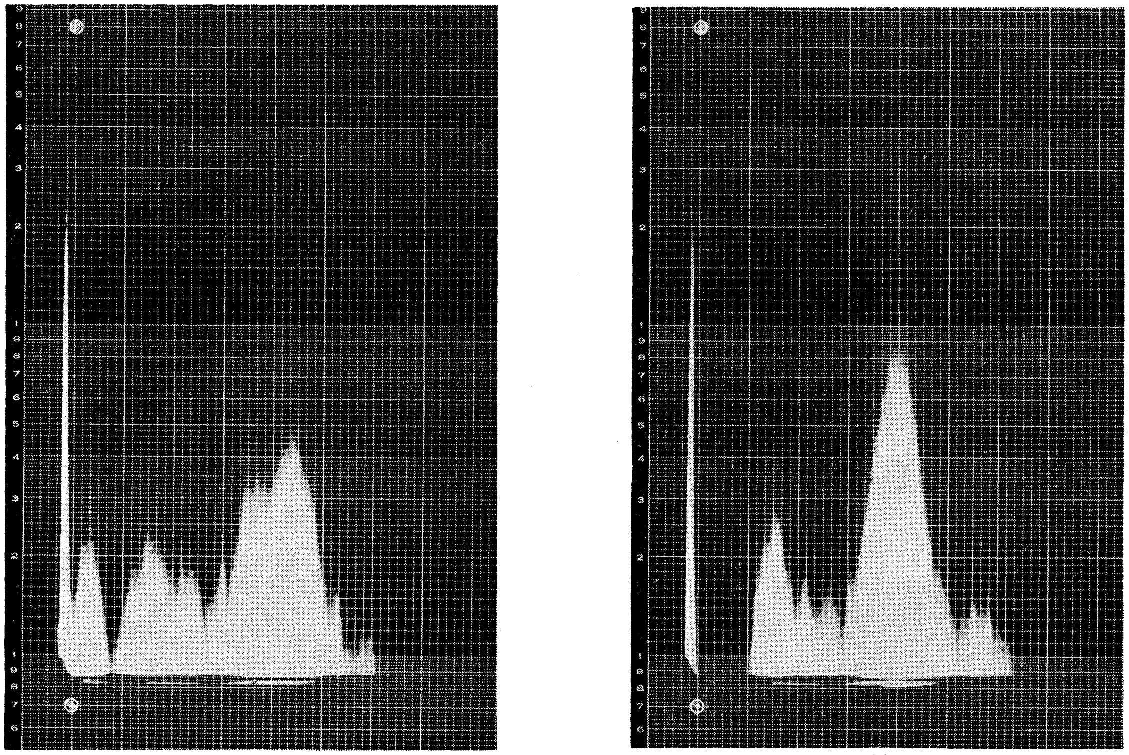
D. Proportional-Counter Photon Spectrum

The proportional counter was used in order to take advantage of its high resolution for low-energy photons. Despite the higher resolution it was impossible to get any measure of the unconverted 34-kev and 42-kev gamma rays since they were masked by the K_α and 41-kev K_β x-rays, respectively. The observed ratio of K_α to K_β was consistent with the value of 4 to be expected[18]; however some 34-kev and 42-kev gamma rays might have been undetected. No unconverted 54-kev gamma ray was observed; the sensitivity was sufficient to detect an intensity 1% that of the observed

TABLE II. Photon−photon coincidences.

	System A		System B			
Run No.	Radiation	Singles 10^3 counts/min	Radiation	Singles 10^3 counts/min	Coincidences counts/min	Coincidences per single in A
1	x-ray	34 ±0.2	x-ray	36.8±0.2	40 ±3	$(1.3\pm0.1)\times10^{-3}$
2	81 kev	8.7±0.1	x-ray	36.8±0.2	10.3±0.6	$(1.2\pm0.1)\times10^{-3}$
3	134 kev	27.4±0.5	x-ray	36.6±0.2	0±2	$(0\pm0.07)\times10^{-3}$
4	81 kev	8.6±0.1	134 kev	38.6±0.2	0±0.5	$(0\pm0.06)\times10^{-3}$

[18] A. H. Compton and S. K. Allison, *X-Rays in Theory and Experiment* (D. Van Nostrand Company, Inc., New York, 1948).



(a) (b)

FIG. 2(a). Gray-wedge spectrum of pulses coincident with the 134-kev gamma ray. The most intense line, 26 divisions to right of zero line (defined by dots), shows the 100-kev gamma ray. The picture was taken for 10 minutes and included about 5550 events. (b) Gray-wedge spectrum of pulses coincident with x-rays. The most intense line is predominantly due to the 81-kev gamma ray. The picture was taken for 10 minutes and included about 5900 events.

x-ray intensity. Some evidence was observed for unconverted 12-kev gamma rays which are postulated in our decay scheme below. However, the data pertaining to the 12-kev gamma ray were erratic and should be considered uncertain because they were not reproducible.

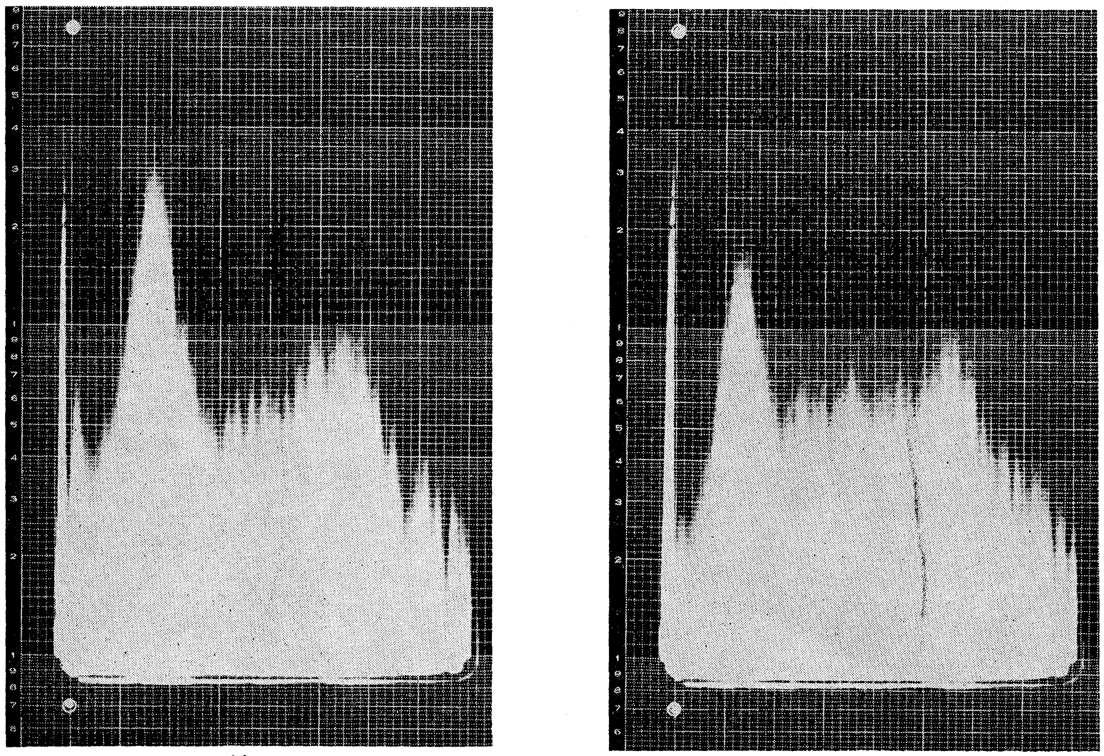
E. Scintillation Photon Spectrum

A typical photon spectrum taken with the gray wedge is shown in Fig. 1; an aluminum absorber used to absorb electrons attenuated the x-rays excessively. For precise intensity measurements, the electrons were absorbed by 1.67 g/cm^2 of beryllium. The observed intensity was corrected for absorption in the Be, for the NaI crystal efficiency, for the iodine escape (a factor of 1.33), and for the x-ray fluorescent yield (a factor of 1.11). The intensity ratio of K holes to the unconverted 134-kev gamma ray was 1.43±0.20; the ratio of unconverted 134-kev gamma ray to the unconverted 81-kev gamma ray was 2.6±0.5. There is unmistakable evidence for a gamma ray whose energy is about 100 kev; we shall attribute these photons to a 100-kev gamma ray although our energy precision for this unresolved photon group would certainly not differentiate between 95-kev and 100-kev gamma rays. The ratio of 134-kev photons to 100-kev photons is about 7.5±2.0. There is a possibility of some photons existing in the energy range between 50 kev and 65 kev but the total intensity of this is less than 10% of the unconverted 134-kev gamma rays.

F. Photon-Photon Coincidences

Photon-photon coincidences using scintillation detectors show that (1) there are coincidences between x-rays, implying that one or more converted gamma ray cascades exist, (2) the 81-kev gamma ray is in coincidence with an internally converted gamma ray, and (3) the 134-kev gamma ray is not in cascade with other gamma rays.

A typical set of quantitative coincidence measurements made at Illinois is shown in Table II. When x-rays were being accepted, about 0.95±0.05 of the x-ray peak was selected; any 34-kev or 42-kev gamma rays would have been counted partially in the same channel. The 81-kev channel accepted 0.5±0.1 of the 81-kev photopeak pulses and a considerably smaller fraction of 100-kev pulses. The 134-kev channel accepted about 0.8±0.1 of the pulses in the 134-kev photopeak. The data of Table II shows that the number of x−x coincidences per x-ray is about the same as the number of 81-kev—x coincidences per 81-kev photon. In contrast, the coincidence rates per single count is



(a) (b)

FIG. 3(a). Gray-wedge spectrum of pulses coincident with the 81-kev gamma ray. The picture was taken for 10 minutes and included 7060 events. The sensitivity is three times that used in Fig. 2. (b) Gray-wedge spectrum of pulses coincident with the 100-kev gamma ray. The picture was taken for 10 minutes and included 5940 events.

smaller by a factor of at least 20 for coincidences involving the 134-kev transition.

The coincidence data obtained at Brookhaven were only semiquantitative and showed coincidences between two pairs of unresolved photons. Figure 2(a) shows a gray-wedge spectrum of pulses in counter B which were in coincidence with those pulses in counter A in the low-energy part of the apparently single x-ray peak. The energy scale of Fig. 2(a) is the same as that of Fig. 1: the zero-energy line is defined by the two dots on the sixth division from the left edge of the graph paper. The position of the 36-kev x-ray, the 81-kev, 100-kev, and 134-kev gamma rays are 10, 22, 26, and 36 divisions to the right of the zero line. For Fig. 2(a), counter A accepted pulses between 7 and 8 divisions from the zero line, and the coincidence spectrum showed a main peak at 26 divisions (due to the 100-kev photons). For Fig. 2(b), counter A was set to accept pulses between 12 and 13 divisions (thereby emphasizing the x-ray and de-emphasizing the 34-kev gamma ray). The resultant coincidence spectrum has an apparently single peak shifted towards the 81-kev x-ray. The existence of 34-kev–100-kev coincidences and of x-ray—81-kev coincidences was confirmed by measurements such as those shown in Fig. 3. Figure 3(a) is a gray-wedge spectrum of pulses in counter B in coincidence with 81-kev gamma rays (counter A set between 22 and 23 divisions from the zero line). The coincidences are mainly in the x-ray region and the peak is at 10 divisions. In Fig. 3(b), counter A was set on the 100-kev gamma ray (between 26 and 27 divisions) and the coincidence peak has shifted slightly, but unmistakably, to 9 divisions. These gray-wedge coincidence measurements could not be analyzed quantitatively because the 34-kev gamma ray could not be separated from the x-ray. Furthermore, if a 42-kev unconverted photon exists, it would not have been differentiated from the x-ray.

The gray-wedge coincidence measurements also showed very strong evidence for the existence of weak-intensity unconverted 54-kev gamma rays in coincidence with both x-rays and 81-kev gamma rays. Absolutely no evidence was obtained for coincidences between 134-kev gamma rays and any other photons.

We do not understand why our coincidence results differ from those of Cork, Brice, and Schmid.[9]

IV. DECAY SCHEME

A. Intensities

Since there were no coincidences observed with the 309-kev beta rays, it seems reasonable to assign these to a transition from the ground state of Ce^{144} to the ground state of Pr^{144}. The energy difference between the beta-ray groups implies that the 24% 175-kev beta-ray group goes to a level at 134±8 kev. It is attractive to attempt to explain three different gamma-ray branches as originating from this level: 134.4±0.3 kev, 100.3+33.8=134.1±0.5 kev, and 81.0+53.9=134.9 ±0.5 kev.

If the intensity of the 175-kev beta ray is taken as 1000 units, the data of Table I show that the total intensity of all observed conversion lines adds up 660 units. Of this total, only 516 correspond to independent branches; these 516 are made up of 291 units of 134 kev (lines 10, 11, and 12), 169 units of 81 kev (lines 4, 8, and 9) and 56 units of 34 kev (line 1). Other electron lines not included in this sum are assignable either to Auger electrons, to electrons of the 60-kev transition in Nd^{144}, or to electrons from transitions in coincidence with the 81-kev gamma ray (lines 3 and 5) or the 34-kev gamma ray (line 7).

If this figure of 516 intensity units is accepted as the electron intensity following the 175-kev beta ray of 1000 units, 484 intensity units must be explained by photons of 34 kev, 81 kev and 134 kev. The intensity of the 34-kev photons can be assumed to be quite small since the total of all 100-kev transitions is small. Thus, from the data on relative photon intensities we can assign about 139 intensity units to the 81-kev photons and the remaining 345 units to the 134-kev photons.

These data imply a decay scheme in which a single beta ray group leads to the observed gamma rays, all of which originate in a 134-kev level as shown in Fig. 4. 64% of the decays from this level are 134-kev gamma rays or conversion electrons. 6% of the decays go through a 100-kev gamma ray followed by a 34-kev gamma ray. The remaining 30% of the decays go through a branch containing the 81-kev gamma ray and a 54-kev gamma ray. This decay scheme is quite similar to others suggested[5,7] but requires an additional branch competing with the 54-kev gamma ray. We suggest a competing cascade of a 42-kev and a 12-kev transition which is considerably more intense than the 54-kev transition.

The fact that the 81-kev gamma ray must be in coincidence with another gamma ray is clear both because there are no higher energy beta rays in coincidence with the 81-kev gamma ray and because there are 81-kev x-ray coincidences. The intensity of the 54-kev transition is much too small to explain the intensity of the 81-kev branch. The intensity of the 54-kev *K*-conversion line was reported[3] to be less than that of the *L*-conversion line which is only 2 intensity units on our scale. Even if the *K*/*L* ratio of the 54-kev transition were 10, the *K*-conversion intensity of the 54-kev gamma ray would not be large enough to explain either the observed coincidences or the intensity of the 81-kev transition. In contrast, the *L* conversion of the 42-kev gamma ray is 70 intensity units. If this line were partially *K*-converted or if some 42-kev unconverted photons existed, the observed intensity and coincidence data would be explicable. Thus, of the 30% of the decays from the 134-kev state which occur through the 81-kev gamma ray, we suggest that 28% occur through a 42-kev–12 kev cascade and only 2% occur through the 54-kev transition. The existence of a 12-kev transition is still in doubt. Another possibility is that a state exists at 122-kev which is fed independently by an unresolvable 187-kev beta ray and that the 42-kev gamma ray decays from this state to an 81-kev state. In this case, the 54-kev gamma ray would decay to the 81-kev state a very small part of the time. The decay scheme suggested by Cork, Brice, and Schmid[9] is quite inconsistent with our intensity and coincidence measurements.

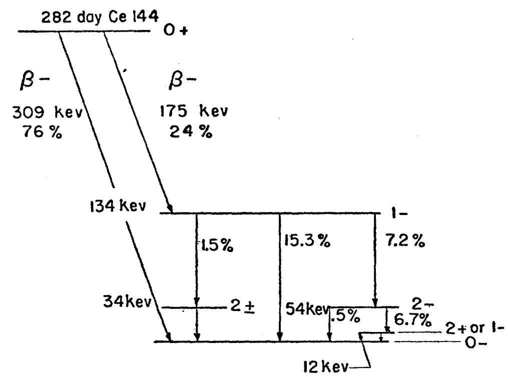


FIG. 4. Proposed decay scheme of Ce^{144}.

V. CONVERSION COEFFICIENTS

One way of determining the conversion coefficients of the most prominent gamma rays is to assume the decay scheme and to compare the intensity of the conversion electrons with that of the 175-kev beta rays, using the measured photon ratio. This determination gave: $\alpha_{K81}=1.02\pm0.4$, $\alpha_{L81}=0.18\pm0.07$, $\alpha_{M81}=0.02\pm0.01$, and $\alpha_{K134}=0.72\pm0.22$, $\alpha_{L134}=0.10\pm0.04$, $\alpha_{M134}=0.025\pm0.01$.

A second method for determining the *K*-conversion coefficients is to use the observed ratio of x-rays to photons and to use the *K*-conversion electrons only as a guide to the fraction of x-rays originating from conversion in particular gamma rays. Assuming the existence of 42-kev *K*-conversion electrons as shown in the decay scheme, this analysis gave $\alpha_{K134}=0.70\pm0.20$ and $\alpha_{K81}=1.3\pm0.3$.

The third method of determining the 81-kev *K*-conversion coefficient was available because of the coincidence data. This method gave a value of $\alpha_{K81}=1.3\pm0.3$.

The best values for the conversion coefficients are $\alpha_{K81}=1.2\pm0.3$ and $\alpha_{K134}=0.71\pm0.25$. The observed ratios of *K* conversion to *L* conversion were 5.8±0.7 for the 81-kev gamma ray and 7.1±0.5 for the 134-kev gamma ray. These data indicate that the 134-kev gamma ray is an *M*1 transition and that the 81-kev gamma ray is probably an *M*1 transition. Confirmation of these $M1$ assignments comes from the fact that the L_{III}/L_I ratio is small[9] in both cases.

VI. SPIN ASSIGNMENTS

The spin parity of the ground state Pr^{144} is probably $0-$ as indicated by log ft values of Ce^{144} and Pr^{144} beta rays which have Pr^{144} in common and otherwise involve similar even-even, $0+$ ground states.[19] The other spins assigned in Fig. 4 are given only to indicate that a set of spins is possible which is consistent with the multipolarities and relative intensities of the gamma rays. Since the available data do not define a unique decay scheme, the spins given in Fig. 4 should be considered merely as illustrative of a possible consistent pattern.

[19] R. W. King, Revs. Modern Phys. **26**, 327 (1954).

ACKNOWLEDGMENTS

One of the authors (I.P.) would like to thank the U. S. Atomic Energy Commission for the grant of a fellowship during the time that this research was being performed. The other author (P.A.) would like to express his appreciation to Brookhaven National Laboratory and particularly to W. A. Higinbotham for the opportunity of doing some of the research at Brookhaven. We wish to thank John D. Fox for his help in preparing this manuscript.

PHYSICAL REVIEW VOLUME 102, NUMBER 5 JUNE 1, 1956

Energy Levels of Np^{237} Populated by Alpha Decay of Am^{241}

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The conversion electron spectrum following alpha decay of Am^{241} has been reinvestigated with 180° focusing beta-ray spectrographs at $\sim$0.1% resolution. Multipolarity assignments for several gamma transitions are made, principally on the basis of relative L-subshell conversion coefficients. Energy-level spacings and relative transition probabilities are compared and discussed in terms of the Bohr-Mottelson model. The excellent agreement of energy-level spacings with the rotational formula and the general pattern of radiative transitions firmly establish the essentially rotational nature of these bands of levels. However, calculations involving $M1$ transition probabilities and magnetic moments lead to discrepancies with the simple theory in the case of the ground rotational band.

INTRODUCTION

THE decay properties of Am^{241} have recently been the subject of an extensive paper by Jaffe, Passell, Browne, and Perlman[1] in which experimental information on the alpha decay,[2] conversion electrons, gamma rays, and L x-rays is presented and correlated into a detailed disintegration scheme. The gamma-ray spectrum has also been examined with high precision by Day.[3] The conversion-electron spectrum has been studied by Milsted, Rosenblum, and Valadares[4] and by Wolfson[5]; more recently, Baranov and Shlyagin have published the results of an extensive beta-spectroscopic study.[6] A discussion of the excited states of Np^{237} in terms of the Bohr-Mottelson model has been given in various publications.[1,6,7]

The ground-state spin of Np^{237} has been measured as 5/2 by Tomkins.[8] Quite recently, Newton[9] has studied the excited states of Np^{237} that appear from Coulomb excitation experiments.

Figure 1 presents the energy-level scheme for Np^{237}, consistent with the above investigations.

Jaffe *et al.*[1] discuss the unusual properties of the 59.6-kev state in Np^{237}, which is populated by more than 99% of the Am^{241} disintegrations. They measured the total conversion coefficient of the 59.6-kev gamma ray to be 0.92, and concluded that the radiation is electric dipole. However, their observed $(L_I+L_{II})/L_{III}$ conversion ratio of 4.4 is more than twice that expected for an $E1$ transition according to the calculations of Rose,[10] and the total L-conversion coefficient is about twice the theoretical value. In addition, Beling, Newton, and Rose[11] have shown that the lifetime of this transition is more than 10^5 times that calculated for a single-proton transition.

Because in the work of Jaffe *et al.*[1] the L_I and L_{II} conversion electrons from this gamma ray were not

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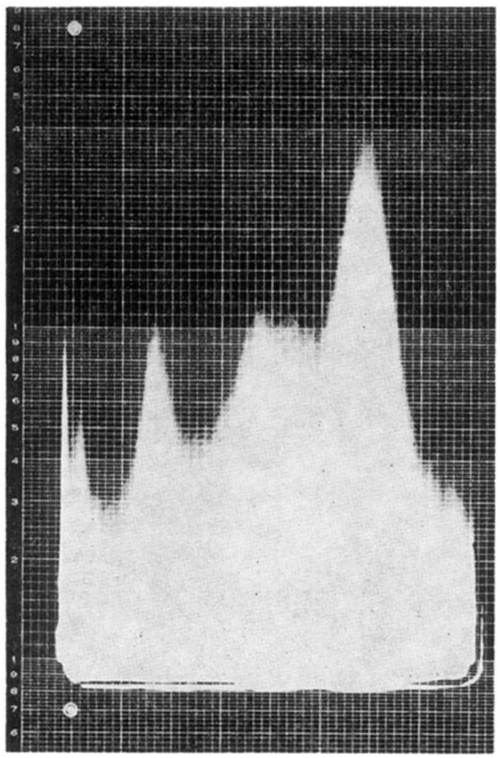
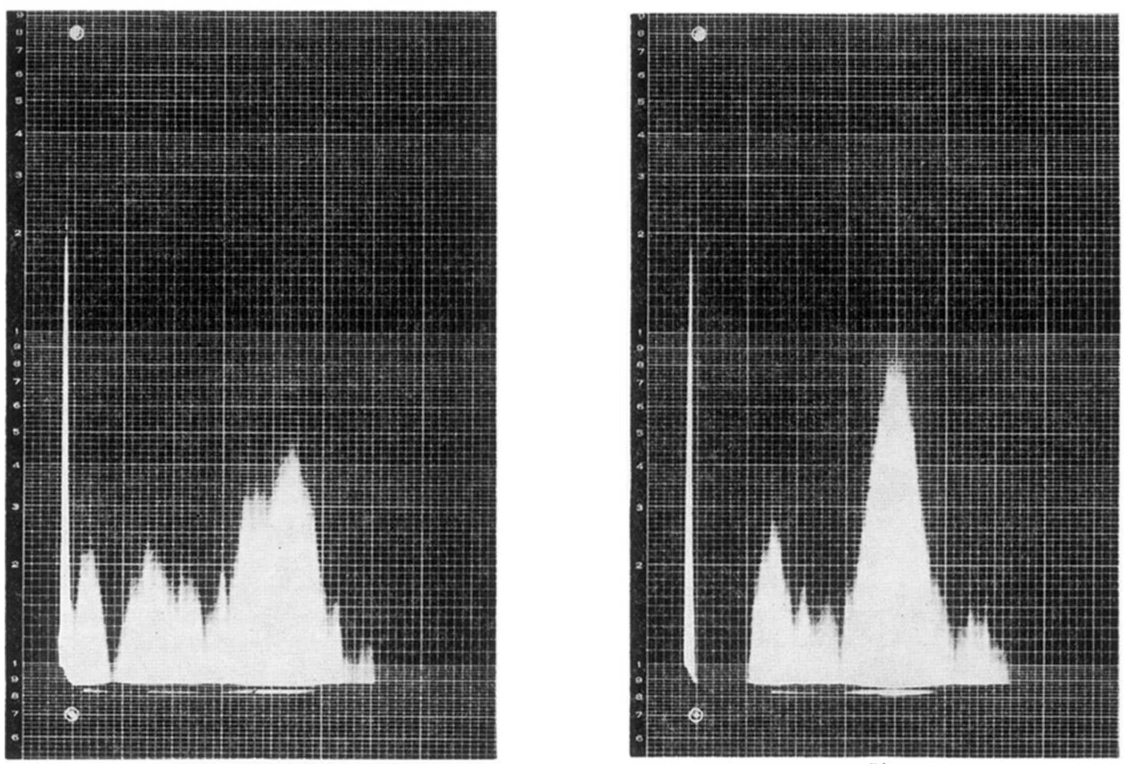


Fig. 1. Gray-wedge spectrum of photons. The peaks from left to right are identified as follows, with position given in graph divisions to right of zero line which is defined by two circular dots: Marker line (−1), noise (1), x-ray (10), 81 kev (22), 100 kev (26), and 134 kev (35.5).



(a) (b)

FIG. 2(a). Gray-wedge spectrum of pulses coincident with the 34-kev gamma ray. The most intense line, 26 divisions to right of zero line (defined by dots), shows the 100-kev gamma ray. The picture was taken for 10 minutes and included about 5550 events. (b) Gray-wedge spectrum of pulses coincident with x-rays. The most intense line is predominantly due to the 81-kev gamma ray. The picture was taken for 10 minutes and included about 5900 events.

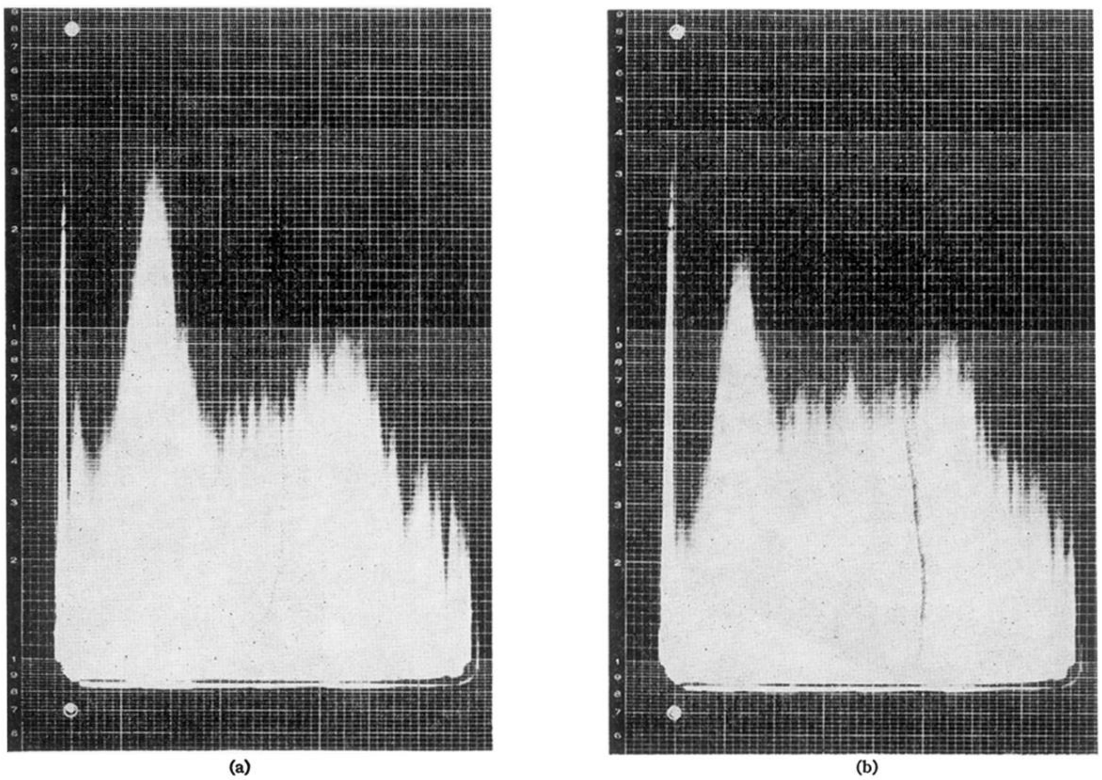


Fig. 3(a). Gray-wedge spectrum of pulses coincident with the 81-kev gamma ray. The picture was taken for 10 minutes and included 7060 events. The sensitivity is three times that used in Fig. 2. (b) Gray-wedge spectrum of pulses coincident with the 100-kev gamma ray. The picture was taken for 10 minutes and included 5940 events.