DECAY SCHEME OF Ba^{140}

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The gamma-ray spectrum of Ba^{140} was measured with a scintillation gamma spectrometer. The spectrum was treated by the method of Maeder, Müller, and Wintersteiger. The relative intensities of gamma rays with energies of 30, 160, 305, 430, and 537 kev were respectively 0.7, 0.18, 0.12, 0.18, and 1.0. Measurements of $\gamma-\gamma$ and $\beta-\gamma$ coincidences were obtained. A decay scheme for Ba^{140} is proposed on the basis of the results of the present and previous investigations.

BEACH, Peacock and Wilkinson[1] have studied the beta spectrum of Ba^{140}, the two components of which have end-point energies of 1022 and 480 kev and relative intensities of 60 and 40%. Cork and his co-workers[2] have investigated the internal conversion electrons from the gamma rays of Ba^{140} by measuring the conversion electron energies and determining their relative intensities. The conversion electrons were ascribed to gamma rays with energies of 29.6, 118.5, 131.8, 162.1, 304, 421.8, 435.8 and 536.7 kev. Maerker and Birkhoff[3] and Rohr and Birkhoff[4] measured the internal conversion coefficient of 540-kev gamma rays from Ba^{140}, obtaining $\alpha_K = (5.6 \pm 1.9) \times 10^{-3}$ with $K/L + M = 6 \pm 2$ and 5 ± 0.5, respectively.

Kelly and Wiedenbeck[5] using a scintillation spectrometer recorded gamma rays from Ba^{140} with energies of 30, 132, 162, 304, 436 and 537 kev. Through an analysis of the gamma spectrum measured from a source inside the crystal conclusions were reached regarding $\gamma-\gamma$ coincidences. The same article gives the angular correlation of 162 and 304-kev gamma rays.

EXPERIMENTAL PROCEDURE

Radioactive Ba^{140} decays with a half life of 13 days to radioactive La^{140} which, in turn, decays with a half life of 40 hours to the stable isotope Ce^{140}. Thus the source always contains a mixture of the radioactive isotopes of Ba^{140} and La^{140}.

Chemical purification was effected by precipitating La from the Ba in solution. Drops of the filtered solution were deposited on a collodion film and dried. Gamma radiation from the prepared source was measured by means of a scintillation spectometer. $\beta-\gamma$ and $\gamma-\gamma$ coincidences were also recorded. The Ba^{140} spectrum was automatically recorded.[6] Since La^{140} is gradually accumulated in the source measurements were performed as soon as possible after preparation of the specimen and not later than 5 hours afterward.

The amount of La^{140} in the source was estimated from its 800-kev line. The La^{140} spectrum was subtracted from the spectrum of Ba^{140} containing La^{140}; the remaining spectrum is shown in Fig. 1.

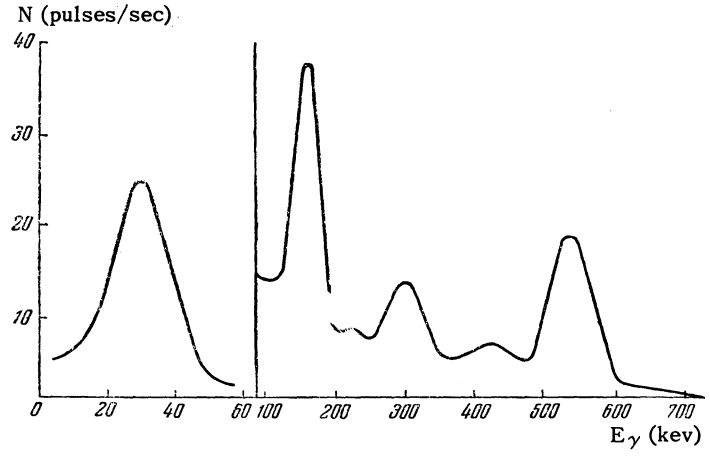

FIG. 1. Gamma-ray spectrum of Ba^{140}: E_γ – gamma-ray energy; N – counting rate (analyzer output).

In analyzing the spectrum the method of Maeder et al.[7] was employed to calculate the form of the line (the form of the photopeak and the form and magnitude of the Compton electron spectrum) from the frequency and height of the gamma-ray photopeak at a given energy. In order to ascertain that 30-kev gamma rays came from the source and did not result from secondary effects in the crystal a copper absorber with a thickness of 1 g/cm^2 was placed between the source and the crystal. This caused the 30-kev gamma peak to disappear completely while the remaining spectrum of harder gamma rays was attenuated only slightly.

TABLE I. Energies and relative intensities of gamma radiation from Ba^{140}

From Cork et al.[2]	From Kelly and Wiedenbeck[5]	Our measurements	
		Energy (kev)	Relative intensity
29.6	30	30	0.7
118.5	—	—	—
131.8	132	—	—
162.1	162	160	0.18
—	—	230	0.02
304	304	305	0.12
421.8	—	—	—
435.8	436	430	0.18
536.7	537	537	1.0

Gamma rays at about 230 kev were observed in addition to previously known gamma radiation. This is probably scattered radiation. Table I shows the measured relative intensities of the gamma rays.

Figure 2 presents three spectra of gamma rays coincident with beta rays of different energies. The counting rate of the beta spectrometer was normalized for all three gamma spectra. The hard beta rays correspond to a transition to the ground level or first excited level of La^{140}; with the same counting rate of the beta spectrometer for different energies the $\beta-\gamma$ coincidence rate was reduced when the beta spectrometer was adjusted for the harder part of the spectrum. The 540-kev gamma rays coincide only with soft beta rays.

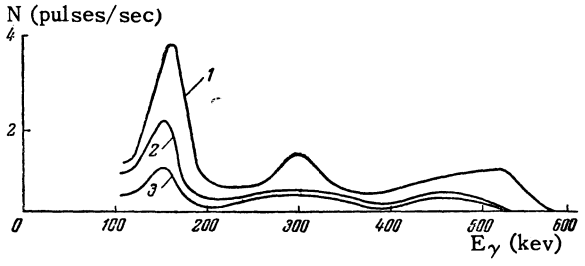

FIG. 2. Spectrum of gamma rays coinciding with: 1 – the soft part of the beta spectrum, 2 – the middle of the beta spectrum, 3 – the hard part of the beta spectrum; N is the counting rate at the output of the coincidence scheme.

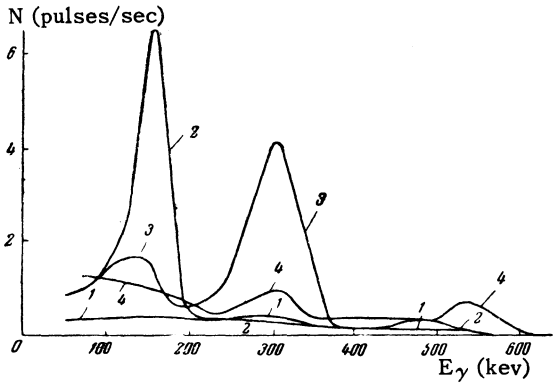

FIG. 3. Spectrum of gamma rays coinciding with other gamma rays of the following energies: 1 – 450 kev, 2 – 304 kev, 3 – 160 kev, 4 – 30 kev; N is the counting rate at the output of the coincidence scheme.

Figure 3 contains the spectra of gamma rays coinciding with other gamma rays of various energies. The following gamma-ray coincidences occur: 300-kev gamma rays coincide with those of 160 kev, while 30-kev gamma rays coincide with those of 540 and 300 kev.

CONCLUSIONS

Since we know the internal conversion coefficient of the 540-kev gamma transition[3,4] we can compare the present results with those of Cork and his co-workers[2] and attempt to estimate the internal conversion coefficients for the remaining transitions Preliminary values of the internal conversion coefficients can be taken from tables in Refs. 8 and 9, using the relative intensities of conversion electrons in Ref. 2. The latter method must be preferred because the relative intensities of conversion electrons can be determined more accurately when their energies are close than when they are separated by a large energy interval. These results are shown in Table II.

It can be seen from Table II that the x-ray contribution to the 30-kev gamma transition may be neglected. Conversion also has little effect on the relative intensities of hard gamma transitions but greatly changes the 30-kev transition. Table III gives the relative intensities of gamma transitions with the internal conversion coefficients taken into account.

In the decay scheme proposed by Kelly and Wiedenbeck[5] the 450-kev gamma transition goes to the ground level. This is contradicted by the facts given below, which permit the conclusion

TABLE II. Preliminary values of internal conversion coefficients.

Energy of gamma transition (kev)	Conversion electron level and energy (kev)	Relative intensity of electron conversion	Conversion coefficients (Ref. 8 and 9) in the ratios L_I: L_{II}: L_{III} or K:L	Conversion coefficients computed from the conversion coefficient for E=540 kev	Conversion coefficients used in the present work	Relative intensity of 39-kev x-rays
29.6	L_I 23.3	20	3.8	$5\cdot10^{-2}$	3.8	
	L_{II} 23.7	2	$3.1\cdot10^{-1}$	$5\cdot10^{-3}$	0.3	
	L_{III} 24.1	1	$6.3\cdot10^{-2}$	$2\cdot10^{-3}$	0.1 6.6	0
	M 28.2	10	—	$2\cdot10^{-2}$	1.6	
	N 29.3	5	—	$1\cdot10^{-2}$	0.8	
118.5	K 79.8	1	—	—	—	—
131.8	K 93.1	4	—	—	—	—
162.1	K 123.3	10	$2.8\cdot10^{-1}$	$1.0\cdot10^{-1}$	$2.8\cdot10^{-1}$	
	L 156.0	5	$7.5\cdot10^{-2}$	$5\cdot10^{-2}$	$0.7\cdot10^{-1}$	$1.6\cdot10^{-2}$
	M 160.8	2	—	$2\cdot10^{-2}$	$0.3\cdot10^{-1}$	
230	—	—	—	—	—	—
304	K 265.5	4	—	$6\cdot10^{-2}$	$6\cdot10^{-2}$	$0.6\cdot10^{-2}$
421.8	K 382.8	1	—	—	—	—
435.8	K 397.1	1	—	$1\cdot10^{-2}$	$1\cdot10^{-2}$	$0.16\cdot10^{-2}$
536.7	K 498.0	4	—	$6\cdot10^{-3}$	$7\cdot10^{-3}$	$0.5\cdot10^{-2}$
	L 530.0	1	—	$1\cdot10^{-3}$		
						0.03

that the transition in question goes to the first excited level at 30 kev. The analysis of $\gamma-\gamma$ coincidences shows that 540-kev and 30-kev gamma rays coincide. To account for the large relative intensity of the 30-kev transition it must be assumed that the 540-kev transition goes to the first excited state rather than to the ground level of La^{140}. The difference between the end-point energies of the two beta components is 542 kev according to Beach et al.[1] rather than the 507 kev of the decay scheme in Ref. 5. All of the other data obtained in the present work agree with the decay scheme in Ref. 5.

Figure 4 shows the decay scheme of Ba^{140} which is in accordance with the results of our present work.

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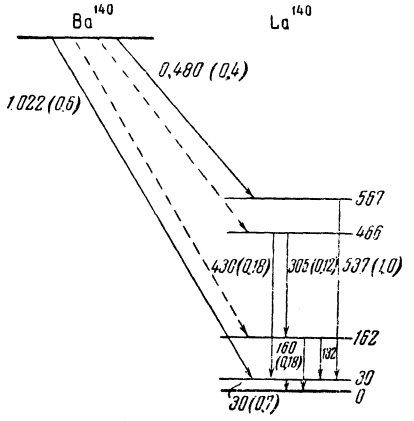

FIG. 4. Decay scheme of Ba^{140}.

TABLE III. Relative intensities of gamma transitions

Energy (kev)	Relative intensities	Energy (kev)	Relative intensities
29.6	5.3*	304	0.13
118.5	—	421.8	—
131.8	0.25	435.8	0.20
162.1		536.7	1.0
230	0.02**		

*The relative intensity of the 30-kev transition is probably too high because of inaccurate knowledge of the internal conversion coefficients.

**The 230-kev line evidently belongs to scattered radiation.

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MEASUREMENT OF FAST NEUTRON ABSORPTION CROSS SECTIONS

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The absorption cross sections for 25, 220 and 830-kev photoneutrons have been found for 20 elements, using neutron transmission in strict spherical geometry.*

1. METHOD OF MEASUREMENT.

FOR the measurement of neutron absorption cross sections, we used the transmission of neutrons in strict spherical geometry (with the neutron source placed inside a sphere of absorbing material). The spherical geometry of the experiment eliminates the direct effect of elastic scattering. The effect of inelastic scattering, which is important for high energy neutrons, was scarcely evident because a long counter was used for detecting the neutrons. Thus, from relative measurements we determined the absolute value of the neutron absorption cross section.

2. EXPERIMENTAL ARRANGEMENT

The experimental arrangement is shown schematically in the figure. Three photoneutron sources, spherical in shape, were used (Sb — Be, Na — D_2O, and Na — Be). They consisted of γ sources of Sb or NaF 25 — 30 mm in diameter, embedded in spherical targets of Be or D_2O, 8 mm in thickness. After assembly, the source had a diameter of 45 — 50 mm. Table I gives the characteristics of the neutron sources used in the present work.

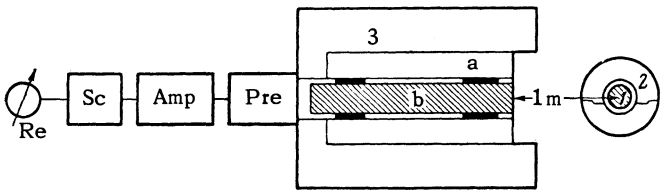

FIG. 1. Arrangement of the experiment. 1 — neutron source, 2 — absorbing sphere of sample material, 3 — long counter: a — paraffin container, b — boron counter; Pre — preamplifier, Amp — amplifier, Sc — scaler, Re — mechanical recorder.

The energy and intensity of the hard neutron group from the (Sb — Be) source was determined from the decay scheme[6] of Sb^{124} and the behavior of the (γ, n) reaction on beryllium.[7]

The samples of materials for study were in the form of spheres with outer diameter 15 — 22 cm, with a cavity 5 — 8 cm in diameter in their interior. They consisted of two hemispheres, so that the neutron source could be inserted into the cavity. The materials to be studied were taken both in cast metal and in powder form. The powders were placed in spherical brass containers having wall thickness 1 — 1.5 mm. The dimensions of the containers were the same as those of the cast spheres. The powders were thoroughly dried before filling the containers.

The neutron detector used was a long counter,[8]

*The measurements were carried out in 1952-1955.