Gamma-gamma angular correlation studies for ^{142}Ce

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Gamma-gamma angular correlations for several cascades in ^{142}Ce were measured using a four-detector system. In a recent publication the level at 1219 keV was assigned 2_2^+ in contradiction to a previous assignment of 4_1^+. This makes ^{142}Ce completely different from any known nucleus in the same region. It is shown, however, that this level is, in fact, completely consistent with 4^+ and is in agreement with systematics.

[RADIOACTIVITY ^{142}La [from ^{235}U(n,f)]; measured γ-$\gamma(\theta)$; deduced J^π, δ; mass-separated ^{142}La activity; Ge detectors.]

A striking discrepancy in the systematics of 4^+ levels in Ce isotopes was recently reported[1] for ^{142}Ce, where the 1219 keV level, previously thought[2] to have $J^\pi=4^+$, was assigned 2^+ using the γ-γ angular correlation technique. This is in contradiction to a previous measurement of Basinger *et al.*[2] who assigned 4^+ to this level, and also in contradiction to the systematics of 4^+ levels in Ce isotopes. Moreover, if this assignment is correct, the two lowest excited states of ^{142}Ce both have spins of $^{2+}$, and no conclusive evidence could be presented[1] as to the existence of a 4^+ state, thus making ^{142}Ce completely different than any other nucleus in this region.

In view of the importance of this assignment, a γ-γ angular correlation experiment was undertaken at the TRISTAN fission product separator, at Brookhaven National Laboratory, to study the decay of ^{142}La$\rightarrow$^{142}Ce. ^{142}La is produced by β decay of ^{142}Ba, which is produced directly from thermal neutron induced fission of ^{235}U in a high temperature surface ionization target-ion source assembly. The fission products are deposited on an aluminized Mylar tape. The source thus obtained, containing $A=142$ activity, was retained for 30 min to allow for decay of ^{142}Ba, and then transported to the counting station. There, a four-detector system for γ-γ angular correlations[3] was installed. It consisted of four large ($\approx$17% efficiency) coaxial Ge detectors at fixed angles, so that six angles were measured at the same time: 90°, 105°, 120°, 135°, 150°, and 165°. Counting proceeded for 90 min, while a fresh source was being accumulated, and so on. The detectors were placed at 8 cm from the source. A detailed description of the electronics system is given elsewhere.[3] A mixing unit was used to route the separate timing pulses from the four detectors to a single time to amplitude converter unit, which provided time measurements for all six pairs. Coincident events between any of the pairs were recorded in an

TABLE I. Values of A_i and S_i [Eq. (1)] for the detectors and geometry used in this work.

Detector	A_i	S_i
1	11.41±0.06	1.001±0.009
2	11.46±0.06	1.009±0.009
3	11.64±0.07	1.024±0.010
4	11.40±0.07	0.984±0.011

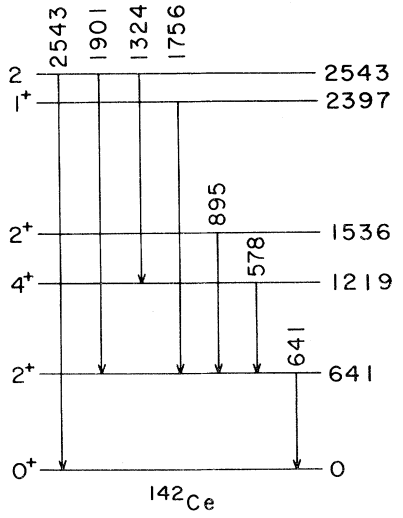

FIG. 1. Partial level scheme of ^{142}Ce. Only the levels and transitions relevant to the paper are included.

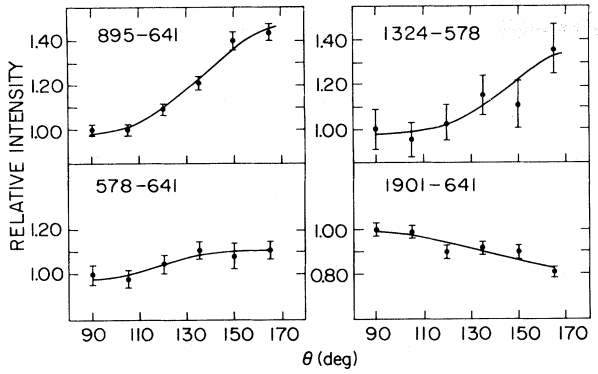

FIG. 2. Several of the angular correlations measured in this work.

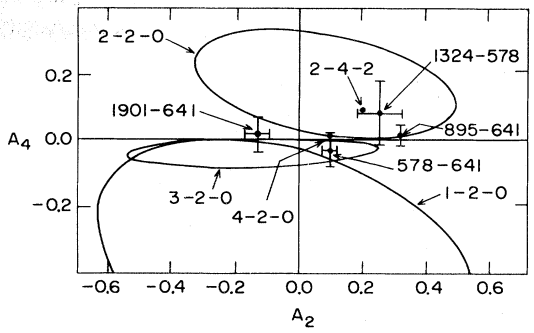

FIG. 3. Experimental coefficients A_2 and A_4 and theoretical ellipses for the various γ-γ cascades.

event mode on a magnetic tape. A total of 5×10^7 events were collected. Singles spectra, gated by the output of the appropriate constant fraction discriminator, were recorded simultaneously for normalization. From these spectra, and using the known[4] relative intensities of the strongest lines in the ^{142}La$\rightarrow$^{142}Ce decay, the relative efficiencies of the detectors were calculated. The results were then fitted to a function of the form

$$\eta_j(E)=A_iE^{-S_i},\quad i=1.4\ , \tag{1}$$

where E is the gamma-ray energy and $\eta_i(E)$ the relative efficiency of detector i. The values of A_i and S_i are given in Table I. It is seen that they are almost identical for all four detectors. Moreover, the values of S_i are in good agreement with the expected values[5] for detectors of the size and shape used in this work. Here we should mention that we found[3] that A_i and S_i do not necessarily have to be identical in order to obtain good results for the angular correlations. Products of the type $\eta_i(E_1)\eta_j(E_2)$ were used for normalization for detector pair ij and cascade $\gamma_1(E_1)\gamma_2(E_2)$.

The system was tested with a ^{152}Eu source, and also on-line by measuring γ-γ correlations for cascades in ^{146}Ce, following the decay of ^{146}La.[3] We found that systematic errors, if at all present, are smaller than the statistical errors of the angular correlation coefficients in a typical experiment such as the one described here.

In Fig. 1 we present a partial level scheme of ^{142}Ce, in which only the levels and transitions relevant to this work were included. The angular correlations for several cascades are given in Fig. 2. The results were fitted to an expression of the form

$$W(\theta)=A_0[1+A_2P_2(\cos\theta)+A_4P_4(\cos\theta)]\ . \tag{2}$$

The coefficients A_2 and A_4, corrected for solid angle attenuation following Camp and Van Lehn,[6] are given in Table II together with those obtained in previous work.[1,2] They are also plotted in Fig. 3 on the theoretical ellipses calculated for the various possible spin sequences. The results for the 895-641 and 1756-641 keV cascades, although not related to the assignment for the 1219 keV level, were included for comparison purposes. We support the results of Basinger *et al.*,[2] and our data for the 578-641 cascade are in disagreement with the experiment of Michelakakis *et al.*[1]

From Table II and Fig. 3 we see that the result for the

TABLE II. A_2 and A_4 coefficients for angular correlations measured in this work, compared with previous results.

From	Transition via	To	Cascade	Proposed spin sequence	Typical counts/angle	Deduced angular correlation coefficients A_2	A_4
1219	641	0	578-641	4-2-0	2400	0.101(21)	−0.04(3)
						−0.055(24)[a]	0.070(43)[a]
						0.094(55)[b]	−0.003(60)[b]
1536	641	0	895-641	2-2-0	10000	0.32(2)	0.01(3)
						0.325(16)[a]	−0.020(36)[a]
						0.417(34)[b]	0.089(36)[b]
2397	641	0	1756-641	1-2-0	1800	0.57(7)	−0.44(11)
						0.528(56)[a]	−0.355(97)[a]
						0.52(4)[b]	−0.40(5)[b]
2543	641	0	1901-641	2-2-0	5000	−0.13(4)	0.01(5)
						−0.223(19)[a]	−0.031(34)[a]
						−0.133(24)[b]	−0.055(26)[b]
2543	1219	641	1324-578	2-4-2	250	0.24(6)	0.085(70)

[a]Reference 1.
[b]Reference 2.

578-641 keV cascade is consistent with a $J=4$ assignment for the 1219 keV level. However, it is seen that a $J=2$ value cannot entirely be ruled out by the angular correlation result for this cascade. (Nor do our data rule out the possibility of a 1-2-2 or 2-2-2 spin sequence for the 1324-578 cascade.) Moreover, if we assign $J=4$ to the 1219 keV level, then we face another problem. Namely, the existence of a weak 1324 keV transition from the 2543 keV level (previously[1,2] assigned $J=1$) to the 1219 keV level.

In order to clarify this point we look at the correlations of the 1324-578 keV and 1901-641 keV cascades. From Fig. 3 it is seen that the first one is consistent with a $2^+ \rightarrow 4^+ \rightarrow 2^+$ sequence, providing further evidence that the 1219 keV level has $J=4$, and indicating a spin of 2 for the 2543 keV level. Such an assignment was already proposed by Larsen *et al.*[4] Our result for the 1901-641 keV cascade is certainly consistent with this assumption, and indicates a mixing $\delta = +0.55^{+0.40}_{-0.54}$ for the 1901 keV transition. Data from the (t,p) reaction for the 2543 keV level do not definitely establish a spin for the 2543 keV level.[7]

In conclusion, our data for the 578-641 keV and 1324-578 keV angular correlations are completely consistent with a $J=4$ assignment for the 1219 keV level. Contrary to Michelakakis *et al.*,[1] we find that a 2^+ assignment, although possible, is *not* unambiguously established by the angular correlation data. Such a 4^+ assignment is consistent with the weak β feeding that would be associated with a 2^- to 4^+ first-forbidden, unique β transition. The 4^+ assignment is consistent with both the $N=84$ level systematics and the $Z=58$ Ce level systematics and avoids the difficulties of accounting for an even-even nucleus whose only excited levels below 1600 keV are three 2^+ levels.

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