

BETA SPECTRUM OF ^{175}Yb

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ABSTRACT

The study of ^{175}Yb is interesting from the point of view of Nilsson model, as this nucleus lies in the deformed region $150 \leq A \leq 190$. The shape data on the $7/2^- \rightarrow 9/2^+$ beta transition of ^{175}Yb is scanty and any attempt to measure the same by the usual singles method results in large uncertainties because of the presence of the conversion electron lines in the same energy region besides the weak intensity ($\approx 3\%$) of the transition. The present work aims at a reasonably good estimate of the shape of the beta group in ^{175}Yb employing a coincidence beta ray spectrometer which eliminates the interferences.

1. INTRODUCTION

THE decay scheme of ^{175}Yb has been studied by many investigators¹⁻⁵. The inner beta with an end-point energy of 353 keV, which is of present interest, is a non-unique first-forbidden transition ($7/2^- \rightarrow 9/2^+$) with a high log ft value (7.48). Cork *et al.*¹ measured the beta spectrum of ^{175}Yb with a double focussing magnetic spectrometer and reported that after subtraction of the high energy component ($W_0 = 466$ keV) there was rather a large scatter in the points of the residual Kurie plot. A least-square fit to these points, in regions where no interference from internal conversion lines was expected, gave a beta component with $W_0 = 374 \pm 30$ keV whose intensity was about 253 times that of the high energy component. Mize *et al.*² conducted beta-gamma coincidence experiments in which scintillation spectrometers were employed, (a bare Pilot plastic scintillator- ^{11}B as β -detector and NaI (TI) as γ -detector) and concluded that a beta group of end-point energy 355 ± 5 keV would populate the 113.6 keV level of ^{175}Lu . Bashandy *et al.*⁵, using a medium thick lens spectrometer, measured the relative intensities of the beta groups in the decay of ^{175}Yb and also the coincidence spectrum of 353 keV beta transition. But no detailed shape analysis of the 353 keV beta transition is available from any one of the above measurements. Hence a detailed shape factor measurement of the inner beta of ^{175}Yb is undertaken. The experimental shape factor has also been compared with the theoretical predictions in the light of Nilsson model. The validity of CVC theory and the applicability of ξ -approximation to the beta transition have been discussed in detail.

2. EXPERIMENTAL

Ytterbium-175 was obtained from B.A.R.C. as YbCl_3 in HCl solution. To look for impurities in the source, the singles gamma spectrum of ^{175}Lu was studied with a 30 c.c. Ge (Li) coaxial type of detector. This showed no detectable impurities. All sources were 2 mm in diameter, on thin mylar foils ($\approx 250 \mu\text{g}/$

cm^2) and the thickness was found to be less than $150 \mu\text{g}/\text{cm}^2$. The 353 keV beta was studied in coincidence with the following 114 keV gamma in Lu-175. The intermediate-image beta ray spectrometer was set to focus the beta spectrum above 200 keV, while the gamma channel was adjusted to accept apart of the 114 keV within a narrow channel width so as to exclude the interference of the 137.6 keV gamma ray. The resolving time of the fast coincidence unit was set up at 24 ns as in the case of ^{198}Au experiment⁶. All the spectra were roughly scanned in steps of 10 keV in the energy range 200 to 350 keV. For each run, about 900 counts were taken at the maximum of the beta continuum since the intensity of the present beta was very low ($\approx 3\%$). The data were analysed by the methods described elsewhere^{6,7}. The experimental shape factor was weighted least square fitted to a shape correction factor of the form $C(W) = k(1 + aW + cW^2)$. Figure 1 shows the experimental shape factor curve of the 353 keV beta and the results are summarised in Table I.

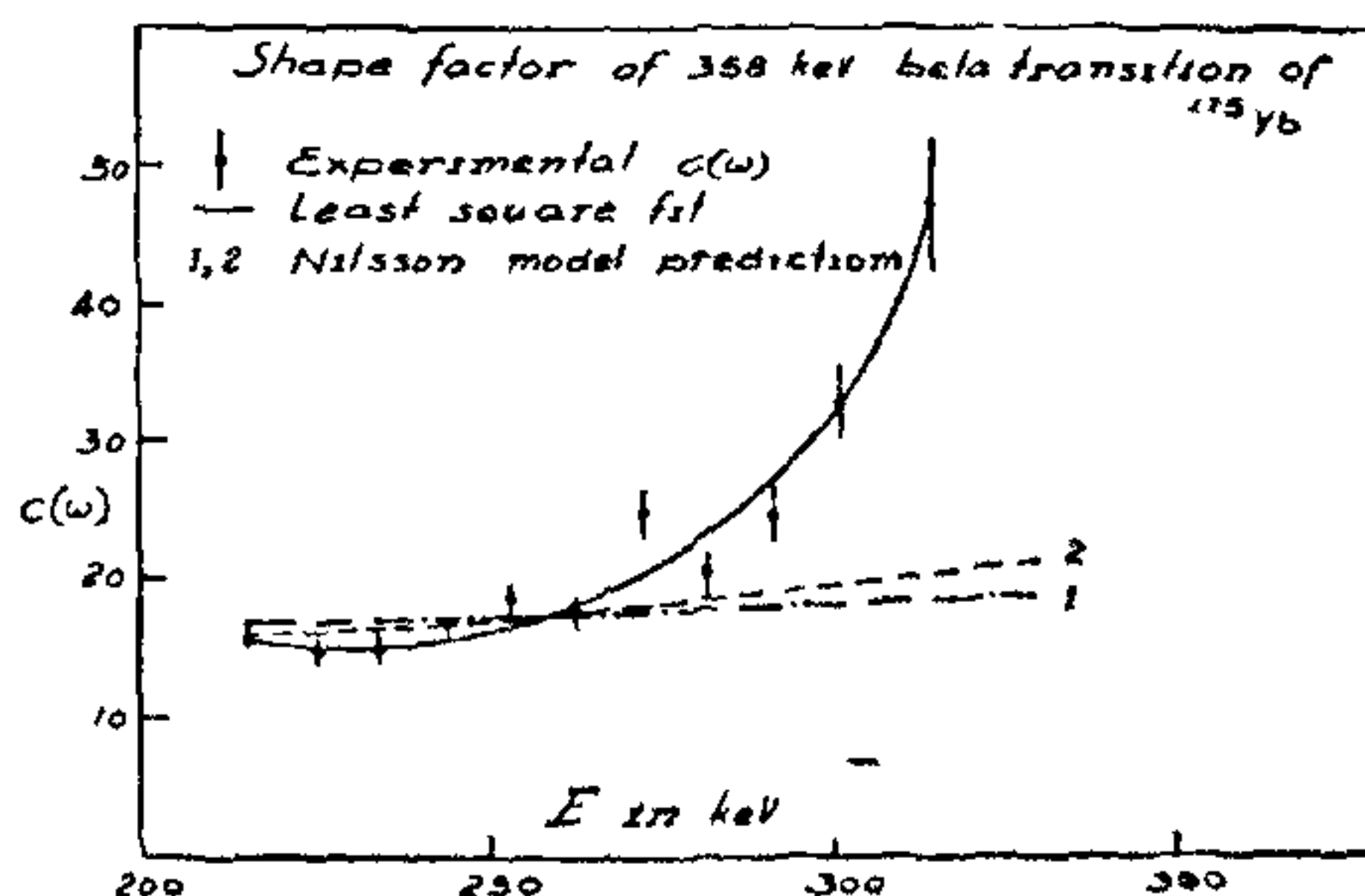


FIG. 1

The value of the end-point energy of the beta transition obtained in the present work is in excellent agreement with those (355 ± 5 keV) reported by Mize *et al.*² and Bashandy *et al.*⁵ while it is in disagreement with the value (374 ± 30 ; 350 keV) reported by Cork *et al.*¹ and De Waard³

TABLE I

Run No.	W_0 (keV)	$C(W) = k(1 + aW + cW^2)$	
		$a(m_0c^2)^{-1}$	$c(m_0c^2)^{-2}$
1	358 ± 2	-1.36 ± 0.34	0.468 ± 0.114
2	358 ± 2	-1.36 ± 0.23	0.467 ± 0.079
3	360 ± 4	-1.37 ± 0.43	0.476 ± 0.201

3. DISCUSSION

The odd-mass nuclide ^{175}Yb with 105 neutrons lies in the deformed region $150 \leq A \leq 190$. Bogdan⁸ developed theoretical expressions for both relativistic and non-relativistic nuclear matrix elements, incorporating superfluid model correction⁹. These improved the theoretical log ft values, for the beta transitions of arbitrary forbiddenness, using Nilsson wavefunctions for one particle configuration in a deformed potential. Using these expressions, Bogdan derived the matrix element parameters for ^{175}Yb beta decay. The ground state of ^{175}Yb was assigned, using the Nilsson diagram character $7/2^-$ (514) while the first excited stage of ^{175}Lu was characterised by $9/2^+$ (404). By taking the deformation parameter δ as 0.28, the values of the matrix element parameters for the $7/2^- \rightarrow 9/2^+$ beta transition ($\Delta J = 1$) are as follows:

$$x = -3.74; \quad u = 0; \quad Z = 1 \\ w = 0; \quad \xi y = -3.464; \quad \xi v = 0.$$

Berthier and Lipnik¹⁰ considered the beta transition of ^{175}Yb by assigning the Nilsson orbitals of the initial neutron and of the final proton as $7/2^-$ (514) and $9/2^+$ (404) respectively. By taking the deformation parameter $\delta = 0.28$, they expressed the wavefunctions of the initial and final states as:

Initial wavefunction:

$$X_{\Omega=7/2} = -0.253 | 553 + \rangle + 0.206 | 533 + \rangle - 0.945 | 554 - \rangle$$

Final wavefunction:

$$X_{\Omega=9/2} = -0.219 | 443 + \rangle + 0.975 | 444 - \rangle.$$

They calculated, the values of the nuclear matrix element starting from the above Nilsson wavefunction as:

$$x = 1, \quad u = -0.511 \quad \text{and} \quad Z = -1.830.$$

In the present analysis, the theoretical shape factor was computed for the above two sets of matrix elements in the exact Simms¹¹ formalism, treating Λ as a free parameter. The experimental shape factor was compared with the theoretical predictions as

shown in Fig. 1. It is evident that the agreement between the experimental shape factor and the theoretical shape factor, following the Nilsson model is somewhat good at low energies, rather than at high energies. It is difficult to comment on the disagreement between the Nilsson model and the experiment in the high energy portion, as the intensity will be very low near the end-point energy due to the poor transition intensity ($\approx 3\%$), resulting in a large statistical spread.

Eventhough the errors of shape factor coefficients 'a' and 'c' of the present measurement (Table I) are large, due to the low intensity ($\approx 3\%$) of the involved beta, the shape of the $7/2^- \rightarrow 9/2^+$ beta transition is consistent with the correction term $C(W) = k(1 + aW + cW^2)$. The shape deviation observed in the present work is also consistent with the log ft value (7.5) and the large anisotropy reported in the recent beta-gamma correlations¹² and nuclear orientation measurements¹³. These observations suggest that ξ -approximation is not valid in the case of 353 keV beta transition of ^{175}Yb eventhough the value of ξ (14.99) is much greater than $W_0 - 1 \approx (0.101)$, which is generally expected for the breakdown of ξ -approximation. The value of Λ (2.36) obtained is in good agreement with Fujita's estimate¹⁴ thus indicating the validity of CVC theory in the present case.

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