Anomalous conversion of the 113.8 keV transition in ^{175}Lu

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Introduction

The internal conversion coefficient is some times sensitive to details of nuclear structure through the penetration of the electronic wave function. The penetration parameter λ in M1 transitions is the ratio of the penetration matrix element to the gamma ray matrix element. A large penetration effect was remarked in the internal conversion for an M1 transition between first excited state and the ground state of a rotational band when the dominant $\upsilon j|\Omega>$ component of the nuclear wave function is that with the largest orbital momentum for a given shell N, i.e. when $L_{dominant} = N$. The $9/2^+ \rightarrow 7/2^+$, 113.81 keV transition in ^{175}Lu is one of these stated above. In the intrinsic state $7/2^+[404]$, the component with l = 4 has a 0.9 weight even for large deformations. For this transition, the anomalous L-sub-shell ratios of the ICCs reported by Novakov and Hollander [1] and the large value of the penetration matrix element computed using Woods Saxon wave functions for a deformation parameter β = 0.25, prove the existence of the penetration effect.

Penetration effects give information on nuclear structure and their existence shows up as large errors in the ICCs or as discord between the results obtained through various methods. Earlier measurements of α_K of this transition did not allow the accurate determination of the penetration parameter λ. The accuracies of the theoretical ICCs are now very much improved with BRICC data [2] as compared to Hager and Seltzer data [3]. Further, in all the previous ICC measurements, the XPG method has been used and hence the precision has been limited. In the present work, accurate and precise measurement of the ICCs for the 113.8 keV transition by the NPG method was aimed at, where a precision of 2% or lower can be achieved with proper calibrations of the spectrometers involved.

Experiment

The radioisotope ^{175}Yb (half life = 4.185 days) prepared by thermal neutron irradiation of Yb_2O_3 powder at Bhabha Atomic Research Centre, Trombay, Mumbai was obtained as Ytterbium Chloride in three batches. Experiments were performed using a 60 cc HPGe coupled to PC based 8K MCA gamma spectroscopy system for the gamma spectra and a Mini-Orange type electron transporter coupled to LN_2 cooled Si(Li) detector and PC based 8K MCA system for conversion electron spectra. The gamma spectra were acquired at a source to detector distance of 25 cm for counting periods of 6.5 x 10^5 seconds. For the conversion electron spectra, the mini-orange spectrometer was optimized for the energy region from 40 keV to 400 keV and the values of the source-magnet and magnet-detector distances, f = 7.5 cm and g = 4.5 cm, corresponding to best transmission, were used in the set up. GammaVision and FIT software were used for spectral analysis. The NPG method was employed for determining the internal conversion coefficients.

The most intense 396.33 keV transition has been used for normalization of the gamma as well as conversion electron intensities. The K, L and M conversion coefficients of the 113.81 keV transition has been determined using an experimental value of α_K = 0.0445 (13) for the 396.33 keV normalizing transition. The experimental as well as the theoretical data on ICCs are shown in Table I. The data corresponding only to the 113.81 keV transition and the normalizing 396.33 keV transition are shown.

Table I

Gamma Energy E_γ (keV)	Experimental ICC values α_i (i= K, L, M)	Theoretical BRICC values M1	E2
113.81	K 1.86 6	2.12	0.742
	L 0.358 26	0.327	0.998
	M 0.119 2	0.074	0.247
396.33	K 0.0445 13	-	-

Results and Discussion

We present in Table II, the α_K value from the present experiment along with those of many more measurements. Our measurement is in very good agreement with that of Constantinescu et al [5] but with improved precision.

The M1 internal conversion coefficient for any sub-shell depends on the parameter λ through the relation

$$\alpha(\lambda,\delta)=\frac{\beta(M1)(1+B_1\lambda+B_2\lambda^2)+\delta^2\alpha(E2)}{1+\delta^2}$$

where β(M1) and α(E2) are the theoretical conversion coefficients interpolated from the BRICC data [2] and B_1 and B_2 are the penetration functions tabulated by Hager and Seltzer [4]. We have interpolated the values of B_1 and B_2 for Z = 71 and E_γ = 113.81 keV and obtained B_1(M1) = -0.0315 and B_2(M1) = 0.000245. We have used different values for δ from the literature. We give in Table III, the parameter values obtained for different mixing ratios and our experimental value for α_K. From a graph between α_K and λ, corresponding to our α_K the penetration parameter has been determined.

The existing discrepancies in mixing ratios of the 113.81 keV transition can be resolved by assuming that dynamic structure effects exist in its internal conversion process. The range of λ obtained in the present work is very small compared to that of Constantinescu et al [5]. Also we have used the tested, more accurate and precise theoretical internal conversion coefficients from BRICC, while Constantinescu et al have used the Hager and Seltzer theoretical data. The average value of λ, for our present α_K is found to be 1.603 ± 0.144.

Table II

Method	α_K	Reference
XPG- Crystal Spectrometer	1.90 8	Reierson et al [6]
XPG-NaI after Coulomb Excitation	2.07 6	Ashery et al [7]
ICC Ratios & Conversion Probabilities	1.94 20	Nilsson et al [8]
XPG	1.73 21	Emery and Perlman [9]
XPG-Ge(Li)	1.82 15	Constantin-escu et al [5]
NPG- Mini Orange-Si(Li) and HPGe	1.86 6	Present work
BRICC Theory	2.12	Theory

Table III

Mixing ratio δ	Method	Penetration parameter λ
$0.154 \pm {}^{0.017}_{0.015}$	L-sub-shell ratios	3.50 ± 0.40
0.45 ± 0.05	$\gamma(\theta)$ -oriented nuclei	0.503 ± 0.056
0.426 ± 0.004	$\gamma(\theta)$ Coulomb excitation	0.863 ± 0.079
0.57 ± 0.04	Life time and B(E2)	1.546 ± 0.113

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