On the conversion of the high multipole transition between the $23/2^-$ 3qp state and the $17/2^+$ rotational state in ^{177}Lu

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Introduction

Gerl et al [1] through a compilation of Internal Conversion Coefficients (ICCs) of high multipole transitions and a comparison with various theoretical calculations and experimental data concluded that the theoretical values of BRICC [2] are close to experimental values within 1-2% when compared to Hager and Seltzer [3] and Rosel et al [4] values. In a programme supported through a DAE BRNS project, we have been trying to experimentally determine the ICCs of high multipole transitions with high precision to garner support and evidence for the findings of Gerl et al [1]. The present measurement is a part of such an effort.

The prolate deformed nucleus ^{177}Lu lies in the rare earth region with Z = 71 and N = 106 between closed shells. Several three-quasi-particle states as well as states originating from the coupling of a quasi-particle to the γ-vibration of the core were established in ^{177}Lu at energies above 1200 keV by different groups. Due to the identification and interpretation of some of these metastable states as beta decaying three quasi particle or five quasi particle states, a number of studies on the levels of ^{177}Lu were undertaken in decay spectroscopy. Following the report of Jorgensen et al [5] of the $23/2^-$ three quasi particle state (160.9 d) at 970 keV, a number of studies have contributed to the elucidation of its decay scheme.

The 970 keV $23/2^-$ isomeric state decays by two branches, a 78% branch to the 3 qp $23/2^+$ isomeric state in ^{177}Hf and a hindered 22% isomeric transition to the $17/2^+$ level of the ground state rotational band $7/2^+$[404]. Five rotational levels of this band are exposed in the isomeric transition up to spin $17/2^+$ with the observation of five cascade and four crossover transitions connecting the levels in this band. The triggering 115.9 keV transition from the 3qp state to the $17/2^+$ rotational level provides the missing link to complete the series leading to the ground state of ^{177}Lu. Owing to the high multipolarity of this transition, it is expected to be heavily converted. But, there had been no absolute conversion coefficient measurements on this interesting high multipole transition. In the present work an attempt has been made to determine the K, L and if possible M conversion coefficients of the 115.9 keV E3 transition with high precision so as to compare them with the existing three theoretical predictions.

Experiment

The carrier free samples of the radioisotope ^{177}Lu, produced by neutron irradiation of enriched ^{176}Lu were obtained in the form of Lutetium chloride ($LuCl_3$) in HCl from Board of Radiation and Isotope Technology (BRIT), Mumbai. The activity of the source was 10 mCi. In the ^{177}Lu radioisotope, the activity of the 160.9 d ^{177m}Lu was also noticed. The initial activity was predominantly that of the 6.647 d ground state decay of ^{177}Lu. Therefore, the actual measurements on the long lived isomer were started after 6 months (25 half lives) of irradiation, when all the short lived activities had disappeared. For electron spectroscopy, it is imperative to make the source extremely thin in order to avoid back scattering and self absorption of electrons in the source. Accordingly, thin uncovered sources with count rates between 500 and 1000 counts were prepared by drying the source solution on aluminized Mylar backing, supported on an aluminum ring of diameter 1.0 cm. The Mini Orange electron spectrometer [6] was used for the conversion electron intensity measurements. The gamma singles spectra were acquired at a source to detector distance of 25 cm for counting periods of 9 x 10^5 s using the gamma spectroscopy system [6] consisting of a 60 cc HPGe coupled to a PC based 8K MCA. The intensities were obtained from the counts in the full energy peaks and the relative efficiencies of the detector by making use of the computer codes Gamma Vision and FIT. The conversion coefficients were determined by the Normalized Peak to Gamma method, by normalizing the measured conversion electron intensities and gamma intensities with that of the 228 keV transition (E2 multipolarity). The theoretical value [2] of the K- conversion coefficient of the said transition was used for normalization.

The K, L and M-shell conversion coefficients of the 115.9 keV isomeric transition to the $17/2^+$ level in ^{177}Lu were determined in our study. Due to the high multipolarity (E3), this transition is heavily converted. The theoretical value of the total conversion coefficient for a 115.9 keV transition in ^{177}Lu of E3 multipolarity from the BRICC tables [2] is 30.7. From the transition intensity balance at the 970 keV level, Hnatowicz [7] had deduced its total conversion coefficient to be 32.9(20). The present K, L, M conversion coefficients of this transition are given in the Tables 1 and 2, where relative gamma and conversion electron intensities and the corresponding conversion coefficients are given along with BRICC [2] values. The present ICC values are found to be close to the E3 multipolarity values from the BRICC tables [2].

A comparison of the experimental ICCs with the three theoretical calculations has been made by calculating the percentage deviation using the formula:

$$\%\Delta = \frac{\alpha_{experiment} - \alpha_{theory}}{\alpha_{theory}} \times 100$$

Table 3 shows that the deviations of experimental ICCs from theoretical values for the high multipole 115.9 keV transition in ^{177}Lu are the lowest in the case of BRICC, thus supporting the recommendations of Gerl et al [1].

Table 1

E_γ keV	Rel. Iγ	Rel. I_{CE}	ICC (Exp)
115.9	10.96(50)	K 31.6(16) L 323(11) M 91(7)	2.00(14) 20.5(12) 5.8(5)
228.5	601.82(17)	K 100(5) L 45.9(47) M 10.8(8)	0.1156(59) 0.053(5) 0.0125(8)

Table 2

E_γ (keV)	ICC(Exp)	BRICC [2]	Multi-polarity
115.9	K 2.00(14) L 20.5(12) M 5.8(5) T 29.3(13)	2.09 21.54 5.64 30.7	E3 E3 E3 E3
228.5	K 0.1156(59) L 0.053(5) M 0.0125(8)	0.1156 0.0533 0.0130	E2 E2 E2

Table 3

BRICC [2]	%Δ	Hager [3]	%Δ	Rosel [4]	%Δ
α_K 2.09	-4.3	2.13	-6.1	2.08	-3.8
α_L 21.54	-4.8	21.84	-6.1	22.08	-7.2
α_M 5.64	+2.8	5.65	+2.7	5.81	-0.2
α_T 30.7	-4.6	31.3	-6.4	31.5	-7.0

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