Precise energy, intensity and ICC determinations in the IT decay of ^{177m}Lu

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Introduction

One of the longest lived K isomers in the deformed region near A=180, can be found in ^{177}Lu, with $K^{\pi} = 23/2^-$ and half life of 160d. This isomer at 970keV has a three quasi-particle Nilsson configuration $\nu\{7/2^-[514] \otimes 9/2^+[624]\} \otimes \pi 7/2^+[404]$. As expected with isomers, transitions from this state are hindered due to low transition energies and the difficulty of making large changes in intrinsic configuration to reach lower lying states. Consequently, this isomeric state decays by a 78% β decay branch to the $K^{\pi} = 23/2^+$ isomeric state in ^{177}Hf and a 22% E3 γ ray branch to the $17/2^+$ member of the $7/2^+[404]$ band within ^{177}Lu.

The 115.8keV E3 transition exciting the $K= 7/2^+[404]$ ground state band effects a series of intraband transitions leading to the ground state of ^{177}Lu. Owing to its high multipolarity, this transition is heavily converted; the theoretical value of the total conversion coefficient is 30.5[1]. Hnatowicz [2] deduced the total conversion coefficient of this transition to be 32.9(20) from the gamma ray transition intensity balance at the 970 keV level. Some experimental values of L subshell ICCs are found in the literature, but there has been no measurement of the conversion coefficient of the K, L, M shells. Although, many investigations [3-7] have determined the gamma intensities of this isomeric transition of ^{177m}Lu, there is a lack of complete and precise electron and gamma spectroscopic measurements dedicated to the determination of the internal conversion coefficients of all the isomeric transitions in ^{177m}Lu. In the absence of precise conversion coefficients and directional correlation data, the multipolarities and the mixing ratios of the transitions have been assigned using theoretical considerations alone. In the present experiment undertaken at SSSU, an attempt has been made bridge this gap by conducting exhaustive electron gamma spectroscopic measurements on this isomeric decay.

Experiment

The radioisotope ^{177}Lu (10mCi) in the form of Lutetium Chloride ($LuCl_3$) in HCl solution, produced by neutron irradiation of enriched ^{176}Lu was obtained from the Board of Radiation and Isotope Technology, BARC, Mumbai, India. A large volume 60cc HPGe detector [FWHM = 665 eV at 5.9 keV (^{55}Fe) and 1.80 keV at 1.33 MeV (^{60}Co)] coupled to a PC based 8K Multi-Channel Analyzer (MCA) was used for gamma energy and intensity measurements after optimization of its relative photo peak efficiency and linearity with IAEA standard sources. Gamma singles spectra were acquired at a source–detector distance of 25 cm for counting periods lasting for 4.5×10^5 s per spectrum on an average. The gamma spectra were analyzed using computer codes FIT [8] and GAMMAVISION [9].

Conversion electron measurements were carried out using a Mini-Orange spectrometer comprising of a windowless Si(Li) detector (surface area = 78 mm^3, sensitive depth =5.3 mm, FWHM = 2.0 keV at 624 keV) and a mini-orange filter of nine thin wedge shaped permanent magnets fixed in a circular array in a brass frame of diameter 16.2 cm with a central absorber made of lead that prevents the direct exposure of the detector to the gamma rays from the source. The entire non-magnetic stainless steel (304L) casing to hold the filter and the source was maintained with a clean vacuum of about 10^{-7} torr using a turbo-molecular pump. After a study of the spectrometer's transmission characteristics using standard sources, the transmission curve obtained for a source to detector distance of 7.5 cm and magnets to

Table 1: Gamma energies, intensities and ICCs in the isomeric transition of ^{177m}Lu

Eγ (present) keV	Iγ (NDS)	Iγ (present)	ICC (present)	Multipolarity
115.874(91)	10.8(5)	7.00(6)	K 2.10(11) L 19.62(87) M 6.65(54)	E3
121.645(2)	98.4(26)	109.24(60)	K 0.797(50) L 0.412(32) M 0.111(11)	M1+E2
147.148(28)	58.4(23)	61.0(29)	K 1.027(95) L 0.122(17)	M1+E2
171.869(5)	80.1(21)	79.1(11)	K 0.321(24) L 0.153(14) M 0.024(2)	M1+E2
195.509(9)	14.1(6)	12.0(3)	K 0.291(58)	M1+E2
218.093(5)	54.6(19)	55.22(80)	K 0.321(23) L 0.0416(47)	M1+E2
268.790(15)	56.9(18)	56.5(14)	K 0.0721(69) L 0.0180(25)	E2
318.984(5)	174(5)	179.0(18)	K 0.036(3) L 0.0110(15)	E2
367.400(5)	52.5(14)	56.39(75)	K 0.0267(35) L 0.0067(9)	E2
413.674(2)	289(6)	310.4(13)	K 0.0222(8) L 0.0054(5) M 0.0013(2)	E2

detector distance of 4.5 cm was used to determine the relative conversion electron intensities.

Results

The gamma intensity and the ICCs for the 115.8 keV high multipole E3 transition have been measured precisely. Apart from this, the energies and intensities of the strong M1+E2 cascade gammas and the intense E2 crossover decay gammas have also been determined with their corresponding conversion coefficients. These results are summarized in table 1. The K conversion coefficients have been reported for all the 10 transitions in ^{177}Lu, the L for 9 and M conversion coefficient for some of the stronger transitions. A total of 23 conversion coefficients (10 K, 9 L and 4 M) were determined precisely. Most of the conversion coefficients are being measured and reported for the first time.

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