Experimental Internal Conversion Coefficients (ICC) of High multipole transitions in some odd-A nuclei

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Introduction

The atomic nucleus is one of the most interesting quantum systems found in nature. It is a unique quantum system of interacting hadrons, may be regarded as an isolated micro-laboratory for spectroscopic studies of fundamental, strong, electromagnetic and weak interactions. The static and dynamic properties of nuclei are studied experimentally by means of various probes. Nuclear electron-gamma spectroscopy which is concerned with the electromagnetic (EM) response of nuclei, has been extensively applied to study both the static and dynamic aspects of nuclear structure. The most important aspects of nuclear structure probed by nuclear electron-gamma spectroscopy are: basic quantum numbers of nuclear states such as energy, angular momentum, parity etc, the transition probabilities and multipole mixing ratios, other quantum numbers like isospin, projection of J etc. Electromagnetic diagonal moments and electromagnetic transition moments lead directly to the nuclear matrix elements relevant to electromagnetic moments. Magnetic dipole (M1) and electric quadrupole (E2) moments give diagonal M1 and E2 matrix elements, respectively. Non diagonal matrix elements are obtained from gamma or conversion electron probabilities. These nuclear matrix elements give directly the required nuclear structure information.

Internal conversion (IC) electrons provide useful data, which are complementary to the γ- ray data in many cases and even provide crucial additional information in some cases. The Internal Conversion Coefficients (ICC) α_i are quite sensitive to the multipolarity E(M)J, but they are rather independent of the nuclear transition matrix elements. These multipolarities can be uniquely assigned by observing absolute values of α_i and their ratios α_i / α_j such as K/L, L_I / L_{II}, L_{II} / L_{III} and so on. ICC can be easily obtained from the ratio of conversion electron yield to the γ- ray yield.

The IC process is used extensively in solving many problems of nuclear physics. Through comparison of experimental ICCs with the corresponding theoretical values, multipolarities and mixing ratios of nuclear transitions are determined. These are used for assignment of spins and parities for nuclear levels, elaboration of level schemes and nuclear decay schemes and checking the balance of transition intensities – that is, in the end to test and refine various nuclear structure models. For an analysis of experiments involving ICC measurements, theoretical ICCs are also required. The more accurate the experimental and theoretical ICC calculations, the more reliable will be the calculations about nuclear properties. Deviation of an experimental ICC value from the theoretical value is expected only in special case that a nuclear transition under consideration is strongly hindered.

Since low energy and/or high multipole transitions have large conversion coefficients, they show up strongly with respect to many other transitions. With an objective to determine precise ICCs of high multipole transitions ($L \geq 3$) in some of the odd-A nuclei, our Nuclear Physics group at SSSIHL, Prasanthi Nilayam has taken up this experimental work [1-3]. The results of this work are presented in the Table 1.

Experiment

The radioisotopes under study are obtained from the Board of Radiation and Isotope Technology, BARC, Mumbai. Sources with an activity of ≈1000 cps were prepared for the γ-spectroscopy. The γ- spectra were acquired with the sources placed at 25 cm from the large volume, coaxial type HPGe detector (GMX–1080, EG&G) of approximately 60 cc with an energy resolution of 1.8 keV at 1.332 MeV coupled to a PC based 8k MCA has been optimised for its best performance conditions. The efficiency curve has been obtained using the standard sources (^{152}Eu, ^{241}Am, ^{55}Fe, ^{60}Co, ^{133}Ba and ^{125}Sb) from IAEA. For electron spectroscopy, a BETA-X Si(Li) detector (SLB-10490, EG&G) has been used. It has an energy resolution (for conversion electrons) of 1 keV at 115 keV and 3.5 keV at 976 keV. The ICCs are determined employing the NPG method using the relative conversion electron and γ- intensities normalised via the ICC of the intense transition in the respective decays. Spectral acquisition and analysis was performed with MCA emulator and spectrum analysis software GammaVision-32 and the interactive computer program FIT [4]. The typical counting periods were about 5 x 10^5 seconds. The spectra were also examined for any impurity activity that may be present in the radioisotope.

Results and discussion

These ICCs can be used for estimating the M1, E2 mixing ratios (δ^2) and reduced transition probabilities, B(E2) and B(M1) with a knowledge on the corresponding theoretical ICCs and the life times of the corresponding levels. As the reported ICCs are of high precision, the deduced results on the (δ^2) and the transition probabilities would involve lesser uncertainties, thus providing experimental data for comparison with the various model predictions. An extensive experimental work on these measurements is underway.

References

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Table 1: Experimental ICC data

Nuclide	E_γ (keV)	E_x (keV)	$I_i^\pi \to I_f^\pi$	E(M) J	α_i (i=K, L, M)	Expt. ICC
$^{75}_{33}As$	38.47 (8)	860	$1/2^+ \to 7/2^-$	E3	α_K	335 (24)
	234.79 (12)	822	$7/2^- \to 1/2^-$	M3	α_K	0.226 (9)
	282.92 (19)	587	$1/2^- \to 9/2^+$	M4	α_K	0.40 (2)
	303.96 (1)	304	$9/2^+ \to 3/2^-$	E3	α_K	0.045 (2)
	555.76 (5)	860	$1/2^+ \to 9/2^+$	E4	α_K	0.014 (5)
$^{131}_{55}Cs$	533.67 (17)	658	$7/2^+ \to 1/2^+$	M3	α_K	0.06 (2)
$^{177m}_{71}Lu$	115.874 (91)	970	$23/2^- \to 17/2^+$	E3	α_K	2.10 (11)
					α_L	19.62 (87)
					α_M	6.65 (54)
$^{197}_{79}Au$	130.2	409	$11/2^- \to 5/2^+$	E3	α_K	1.93 (6)
	409.1	409	$11/2^- \to 3/2^+$	M4	α_K	2.21 (6)
$^{197}_{80}Hg$	164.97	299	$3/2^+ \to 5/2^-$	M4	α_K	69.9 (14)