Theoretical calculation of angular distribution, RDCO and Polarization for the geometry of I.N.G.A. (T.I.F.R.)

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Abstract

Theoretical calculations were carried for angular distribution R_{DCO} and polarization sensitivity for INGA set-up at TIFR. Angular distribution for ΔJ=0, ΔJ=1 and angular distribution coefficient has been calculated for different multi-pole transitions. The theoretical results are compared with the experimental data of ^{135}La.Variation of R_{DCO} with mixing ratio at (157° vs. 90°) and (140 vs.90°) have been calculated for the transition (11/2- → 9/2+). Polarization asymmetry were also investigated for Eγ=202 keV (11/2- →9/2+) for different value of mixing ratios.

Introduction

Finding the spin-parity of nuclear levels is one of the major tasks in nuclear physics. One of the ways to find the spin-parity of nuclear levels is the measurement of correlation between the directions of emission of two gamma rays that were emitted consecutively from the same nucleus. The table of angular distribution coefficient published by T. Yamazaki in Nuclear Data [1] is useful for getting angular distribution of gamma rays which were emitted due to the nuclear transition ($J_i \rightarrow J_f$). Spin parity of the nuclear states can be identified from this angular distribution of gamma rays. The electric and magnetic characters of the gamma rays with same multiple orders can not be distinguish from angular distribution. In such case, linear polarization, RDCO and polarization asymmetry are the tools to find spin parity of nuclear levels.

Definition and Formulas

The angular distribution function for the transition ($J_i \rightarrow J_f$) is,

$$W(\theta) = 1 + a_2 P_2(\cos\theta) + a_4 P_4(\cos\theta) \qquad (1)$$

Where, a_2 & a_4 are angular distribution coefficients.

$$a_2 = \alpha_2 A_2^{max} \ \ \& \ \ a_4 = \alpha_4 A_4^{max} \qquad (2)$$

The values of α_2 ,α_4 (attenuation coefficients) & A_2^{max}, A_4^{max} for the pure multi-pole transitions ($J_i \rightarrow J_f$) are tabulated in table of attenuation coefficients published by E. Der Mateosian and A.W. Sunyar in Nuclear Data[2]. In the case of mix multi-pole transition,

$$A_2^{max} = \frac{1}{1+\delta 2}[F2(L1L1) + 2\delta F2(L1L2) + \delta^2 F2(L2L2)]$$

$$A_4^{max} = \frac{1}{1+\delta 2}[F4(L1L1) + 2\delta F4(L1L2) + \delta^2 F4(L2L2)]$$

Where, mixing ratio, $\delta = I_\gamma(L_2) / I_\gamma(L_1)$ and $F(L_m L_n)$ are the angular distribution functions[3].

The degree of polarization of gamma rays at 90° is defined as,

$$P_{cal}(90^o) = \pm[3a_2H_2 - 7.5a_4H_4]/[2 - a_2 + 0.75\, a_4] \qquad (3)$$

Where, +(-) sign applies for a transition without(with) parity change. For pure E1 or M1 case (δ=0) H_2=1and H_4=-1/6. For mixed dipole-quadrapole transition,

$$H_2(1,2) = \frac{[F2(11) - 0.667\delta F2(12) + \delta^2 F2(22)]}{[F2(11) + 2\delta F2(12) + \delta^2 F2(22)]} \ \ \& \ \ H_4=-1/6$$

Polarization asymmetry[3] is $\Delta = P(\theta)Q$

Where $Q(E) = (CE\gamma + D)Qo(E\gamma)$

$Qo(E\gamma)=[\alpha+1]/[\alpha^2 + \alpha + 1]$; C=-0.0001 ke$V^{-1}$ & D=0.446 keV^{-1}

The multipole nature of transitions can be investigated by Directional Correlations from Oriented states (DCO) which is a function of intensities of gamma rays at different angles [(157° vs. 90°) and (140 vs.90°)]

$$R_{DCO} = \frac{W(\gamma 2,\theta 2)\, W(\gamma 1,\theta 1)}{W(\gamma 2,\theta 1)\, W(\gamma 1,\theta 2)} \qquad (4)$$

Calculations and results

Angular distribution of gamma rays for pure and mixed multi-polarity transition is as follows,

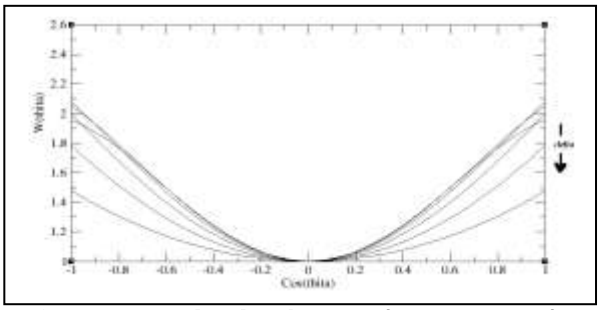

Figure I. Angular distribution of gamma rays for ΔJ=0 (2+→2+), for different δ values (step of 0.2)

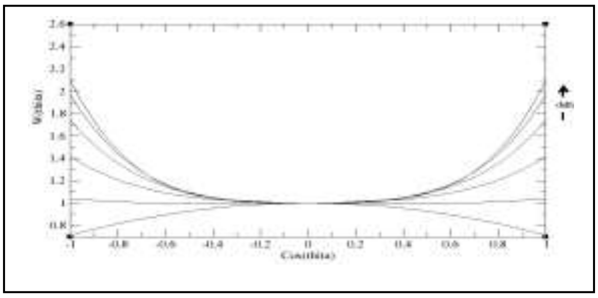

Figure II. Angular distribution of gamma rays for ΔJ=1 (3+ →2+), for different δ values (step of 0.2)

Table I. Angular distribution coefficient and degree of Polarization for dipole (D), Quadrapole (Q) and mixed transition at different ΔJ values, the transitions are (2→0), (3→2) and (2→2).

ΔJ	Mult.	a_2	a_4	P(E)	P(M)
2	Q	0.247	- 0.044	0.399	-0.399
1	D	-0.197	0.0	0.269	-0.269
1	Q	-0.319	0.0	+0.412	-0.412
1	D+Q	+0.77 to - 0.32	0.0 to 0.18	+0.41 to +0.69	-0.41 to -0.69
0	D	0.412	0.0	-0.778	0.778
0	Q	-0.377	-0.13	-0.26	0.26
0	D+Q	0.39 to -0.37	0 to - 0.13	-0.77 to -0.26	0.77 to 0.26

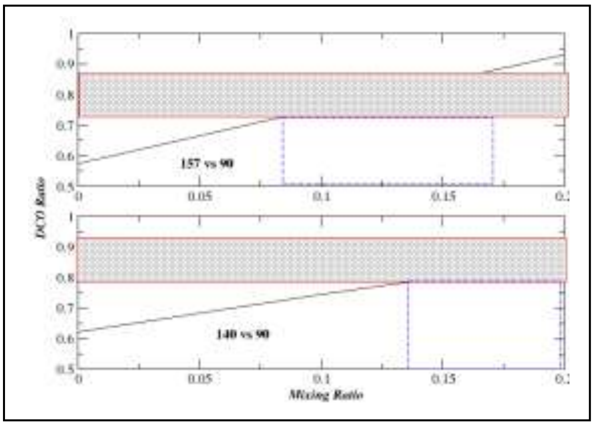

Figure III. RDCO (157°vs. 90°) and RDCO (140°vs. 90°) at quadrapole gating for different values of mixing ratio for transition (11/2- → 9/2+)

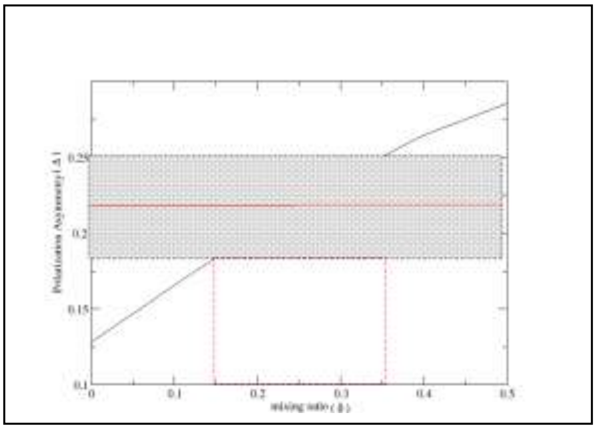

Figure IV. Polarization asymmetry (Δ) vs different values of mixing ratio (δ) for transition (11/2- → 9/2+) at Eγ=202.2 keV.

R_{DCO} for transition ΔJ=1 (11/2- → 9/2+) at (157°vs. 90°) and (140°vs. 90°) is calculated (at the gating of quadrapole transition (9/2+ → 5/2+)) at different values of mixing ratio (δ). From the result of the value of R_{DCO} at two different angles the mixing ratio for 202 keV. lies between 0.1 to 0.2. On the other hand from polarization value the mixing ratio lies between 0.15 to 0.35., but all the solution are merging at 0.15 to 0.18, therefore the combined analysis of polarization and R_{DCO} value can confined the range of mixing value and can be helpful to measure the precise of mixing ratio.

Conclusions

Angular distributions for different ΔJ transition are different, so transitions can be distinguish form angular distributions. Transition not distinguished by angular distribution can be identified by R_{DCO} and Polarization asymmetries at particular value of Eγ. For the transition (11/2- → 9/2+) for Eγ=202.2 keV, for the comparison between experimental values (R_{DCO} and polarization asymmetry) and theoretical values results, mixing ratio lies between 0.15 to 0.18. However in future one need to find a conversing solution for mixing ratio using polarization asymmetry and R_{DCO} value.

References

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