Assignment of multipolarity for ΔI = 0 γ transitions from Polarization measurements

Sajad Ali[1], S. Rajbanshi[1,2], Abhijit Bisoi[3], Somnath Nag[4], S. Saha[5], J. Sethi[5], T. Trivedi[5], T. Bhattacharjee[6], S. Bhattacharyya[6], S. Chattopadhyay[1], G. Gangopadhyay[7], G. Mukherjee[6], R. Palit[5], R. Raut[8], M. Saha Sarkar[1], A. K. Singh[4], and A. Goswami[1]*
[1]*Saha Institute of Nuclear Physics, HBNI, Kolkata 700064, India*
[2]*Dum Dum Motijheel College, Kolkata 700074, India*
[3]*Indian Institute of Engineering Science and Technology, Howrah 711103, India*
[4]*Indian Institute of Technology, Kharagpur 721302, India*
[5]*Tata Institute of Fundamental Research, Mumbai 400005, India*
[6]*Variable Energy Cyclotron Center, Kolkata 700064, India*
[7]*Department of Physics, University of Calcutta, Kolkata 700009, India and*
[8]*UGC-DAE-Consortium for Scientific Research, Kolkata 700098, India*

It is well known that the determination of the polarization for the γ transition will lead to the unique spin-parity assignments of the nuclear states. The electric and magnetic nature of the γ-rays are distinguishes by the direction of the electric vector of electromagnetic radiation with respect to the beam-detector plane. The difference between the perpendicular and parallely scattered events due to the Compton scattering depends on the direction of electric vector of the emitted γ radiation. The difference is positive for electric type transition and negative for magnetic type transitions while for a mixed transitions it is almost zero. However, for the ΔI =0 γ transitions it can be shown theoretically that the difference is positive for magnetic type of transitions and negative for electric type of transitions. This opposite results of the polarization asymmetry for the ΔI =0 γ transitions may sometimes resulted in different assignments of the nuclear states.

As a consequence of unequal population of magnetic sub-levels and the orientation of the nuclei about a preferred direction in space the angular distribution of γ-ray depends on the type of radiation along with the spin difference of the involved states. If the emitting radiation from an axially oriented ensemble of nuclei is linearly polarized, the angular distribution depends also on the direction (ϕ) of the electric vector **E** of γ-radiation with respect to the reaction plane along with the detector angle (θ). The linear polarization of γ-rays is suitable to express in terms of the angular distribution functions when their electric vector **E** is in the reaction plane, $[W(\theta, \epsilon = 0°)]$, and when it is perpendicular to the reaction plane, $[W(\theta, \epsilon = 90°)]$ and it is expressed as the normalized difference of this two polarization state [1]. In accordance with ref. [1] a distribution of polarization (P) with mixing ratio δ have been evaluated for the transition with spin sequence of $8 \rightarrow 7$ [Fig. 1 (a)]. It shows the value of polarization is positive for parity changing (E1 + M2) transition and negative for transition (M1 + E2) without any change in parity for a large range of mixing ratio. The same is also plotted for $8 \rightarrow 8$ and $7 \rightarrow 7$ transitions which shows that the polarization value is positive for transition without any change of parity (ΔI = 0, M1 + E2) and vice versa over a large range of mixing [Fig. 1 (b) & (c)].

The characteristics of ΔI = 0 transitions are studied in ^{142}Eu, ^{142}Sm and ^{143}Eu nuclei which were populated through the fusion evaporation reaction ^{31}P + ^{116}Cd at a beam energy of 148 MeV obtained from the Pelletron Linac facility at TIFR, Mumbai. The de-exciting γ transitions were detected by

*Electronic address: sajad.ali@saha.ac.in

TABLE I: Energy (E_γ),linear polarization (P) and assignment of the gamma transitions in ^{142}Eu.

Nucleus	Energy ($E_\gamma{}^a$)	$J_i{}^\pi$	$J_f{}^\pi$	Polarization (P)	Mixing Ratio (δ)	Assignment
^{142}Sm	540	7^-	7^-	$+0.29(0.11)$	$+0.06^{+0.01}_{-0.01}$	ΔI = 0, M1
^{142}Eu	283	8^+	8^-	$-0.19(0.08)$	$+0.28^{+0.02}_{-0.03}$	ΔI = 0, E1
^{143}Eu	847	$\frac{35}{2}^-$	$\frac{35}{2}^-$	$+0.37(0.20)$		ΔI = 0, M1

$^a\gamma$-ray energy is rounded of to nearest keV.

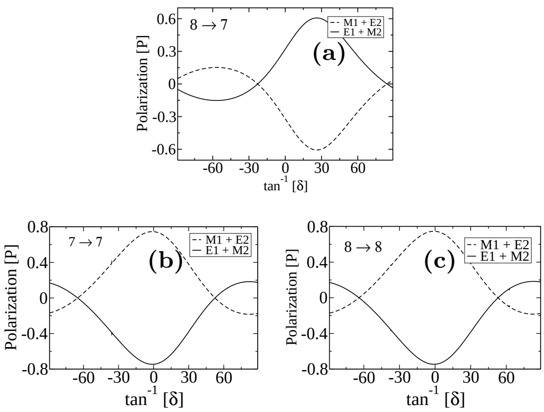

FIG. 1: Variation of polarization with δ for (a) ΔI = 1 ($8 \rightarrow 7$), (b) ΔI = 0 ($7 \rightarrow 7$) and (c) ΔI = 0 ($8 \rightarrow 8$) transitions.

the Indian National Gamma Array (INGA) which was consisted of nineteen Compton-suppressed clover detectors at the time of experiment. Clover detectors can be used as Compton polarimeter. Linear polarization of the γ-ray is defined as $P = \frac{A}{Q}$, where Q is the polarization sensitivity of the clover detector and A is the experimental asymmetry (details in ref. [2]). The previous measurement of ^{142}Sm [2] clearly establishes 540-keV ($7^- \rightarrow 7^-$) γ transition as a ΔI = 0, M1 without measuring the linear polarization. In the present experiment linear polarization measurements of 540-keV ΔI = 0, have been carried out. The polarization value +0.29(0.11) is large positive for a ΔI = 0, M1 transition.

Also a 283-keV transition that depopulates from the 8^+ to the ground state 8^- in ^{142}Eu. The 8^+ state is confirmed by g-factor measurements [4]. The 283-keV is a ΔI = 0, E1 transition which is also confirmed by the present measurement of the linear polarizarion (Table I). Similarly in ^{143}Eu 847-keV ($35/2^+ \rightarrow 35/2^+$) transition was assigned as a ΔI = 0, magnetic transition [5]. The linear polarization value in the present measurement +0.37(0.20). Angular distribution for the 540-keV and 283-keV transitions are carried out using the expression as in Ref. [3]. Mixing ratio are calculated by χ^2 minimization of the measured angular distribution coefficients as in Ref. [6] and tabulated in Table I. Thus the polarization value for ΔI = 0 transition is positive (negative) for M1 + E2 (E1 + M2) type over a large range of mixing of higher multipolarity transition.

The present measurements show that for ΔI = 0 transitions, the value of the polarization for electric and magnetic type are opposite to that of ΔI = 1, 2 transitions respectively.

Acknowledgments

The authors acknowledge the help from all INGA collaborators and the Pelletron staff for giving us steady and uniterrupted ^{31}P beam.

References

[1] L. W. Fagg *et al.*, Rev. Mod. Phys. **31**, 711 (1959).
[2] S. Rajbanshi *et al.*, Phys. Rev. C **89**, 014315 (2014).
[3] T. Yamazaki, Nucl. Data, Sect. A **3**, 1 (1967).
[4] M. Piiparinen *et al.*, Nucl. Phys. **A 605**, 191 - 268 (1996).
[5] S. Rajbanshi *et al.*, Phys. Rev. C **90**, 024318 (2014).
[6] D. M. Van Patter *et al.*, Nuclear Physics **A178** (1972) 355-364.