Angular distribution and polarization for transitions in ^{200}Tl

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Introduction

Determination of spin-parity of the excited states of a nucleus is an important aspect of the gamma spectroscopic measurements. Along with angular distribution or angular correlation measurements, which gives information about the multipolarity of the transition, determination of linear polarization is very important to know about the electric or magnetic character of the transitions of same multipolarity[1]. To determine the multipolarity of transitions using ratio of Directional Correlation from Oriented (DCO) states it is assumed that the gating transition is of stretched (dipole or quadrupole) character. In case of nuclei near magic shell closures, the level structures are mainly developed from single particle excitations and gives rise to both yrast and non-yrast states. In such cases, it is sometimes difficult to determine the multipolarity using the method of DCO ratio because there are very few stretched pure transitions. In such cases singles measurement of angular distribution is useful. The measured linear polarization can be compared with the calculated one and the multipole mixing ratio δ can also be determined. Moreover, it is to be noted that the measured polarization asymmetry of a non-stretched E1 transition is very similar to a stretched M2 transition. In such cases, the spin-parity of the state can be decided by comparing the experimental polarization with calculated one along with DCO ratio and angular distribution coefficients. In the present paper, the spin-parity determination of excited states in ^{200}Tl, obtained by extracting the DCO ratios, angular distribution and linear polarization of transitions, is reported.

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Experiment and Analysis

The high spin states in ^{200}Tl have been populated in ^{198}Pt(^{7}Li,5n)^{200}Tl reaction using 45 MeV of ^{7}Li beam from the BARC-TIFR Pelletron-LINAC facility at Mumbai and Indian National Gamma Array (INGA) setup with 15 clover HPGe detector was used.. The DCO ratios and polarization asymmetry have been used to determine the spin-parity of the excited levels. The angular distributions of some of the transitions have also been obtained from singles spectrum of detectors at different angles. The details of the analysis can be found in Ref [2].

Experimental Results

The angular distribution of some of the transitions in ^{200}Tl is shown Fig.1, along with fitted curve using the function,

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

The quadrupole and dipole nature of the transitions have also been checked from extracted DCO ratios and the electric and magnetic character of the transitions have been found from the polarization asymmetry measurements. Fig.2 shows a plot of DCO ratios and polarization asymmetry of various transitions in ^{200}Tl. The 659 keV and 311 keV are the known E2 and M1 transitions from previous work [3] and are respectively showing the quadruple and dipole nature from angular distribution (Fig.1), as expected. These transitions are used as gating transitions for determination of DCO ratios for other unknown transitions. The 789 keV is one of the new transitions, decaying from higher spin state of the main yrast band and assigned as E2 from angular distribution, DCO ratio and polarization

measurements, as can be seen both from Fig.1 and Fig.2. The 490 keV, assigned as $7^- \rightarrow 7^+$ transition from previous work [3] is found to be of M2 type in the present measurements.

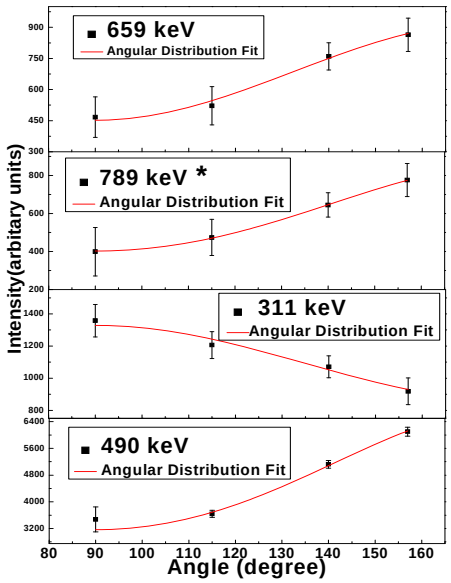

Fig 1: Angular distribution and W(θ) fit of some of the transitions in ^{200}Tl. The transitions marked as '*' are new.

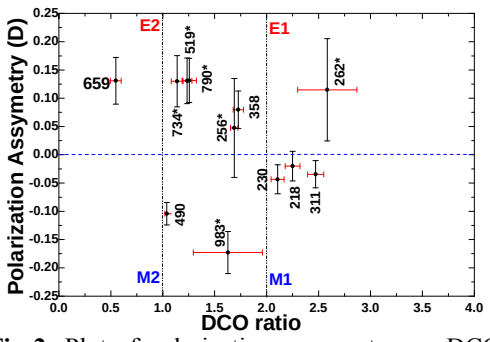

Fig 2: Plot of polarization asymmetry vs. DCO ratio(quadrupole gated) for various transitions in ^{200}Tl. The vertical dotted lines are the values correspond to a quadrupole and dipole transitions in a quadrupole gate. The horizontal line is drawn to indicate the positive and negative value of polarization asymmetry, corresponding to electric and magnetic type respectively.

Calculation of linear polarization

The degree of polarization of gamma rays at 90º is defined as [4],

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

+(-) sign is for without (with) parity change.
The coefficients a2 and a4 are defined as $a_2=\alpha_2 A_2^{max}$, $a_4=\alpha_4 A_4^{max}$, where, α_2 and α_4 are attenuation coefficients and

$$A_k^{max}= \frac{[BkFk(L1L1)+2\delta BkFk(L1L2)+\delta^2 BkFk(L2L2)]}{(1+\delta^2)},$$

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

The mixing ratio δ is defined by $\langle Jf(L_2)Ji\rangle$ / $\langle Jf(L_1)Ji\rangle$ and B_kF_k, $F_k(L_mL_n)$ are the angular distribution functions, which have been obtained using the tabulated values from Ref [5].

The linear polarization can be calculated from the values of H_2, H_4 and a_2, a_4 for different δ [4]. Comparison of theoretical DCO ratio for 490 keV with the experimental one suggests a large δ (E1/M2) for $7^- \rightarrow 7^+$ case, which is ruled out from angular distribution plot. P_{cal} and a_2, a_4 coefficients for the two possible cases have been calculated using the above equations and tabulated in Table-I. Using sensitivity (Q) from Ref [4] the corresponding experimental value of Polarization has been obtained as -0.39±0.07, which is close to the $9^- \rightarrow 7^+$ case. Thus the spin-parity of 1844 keV state in ^{200}Tl, has been assigned as 9^-, instead of 7^-. This assignment is crucial for determination of the spin-parity of the band head of the main yrast band in ^{200}Tl and for the higher lying states.

Table-I: Linear polarization P_{cal} for 490 keV

$J_i \rightarrow J_f$	ΔJ	λ	a2	a4	P(E)	P(M)
$7^- \rightarrow 7^+$	0	D	0.38	0.0	-0.71	+0.71
$9^- \rightarrow 7^+$	2	Q	0.32	-0.08	+0.53	-0.53

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