Degree of Alignment of the Angular Momentum of Nuclei Produced in Inelastic Excitation

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Introduction

In prompt gamma ray spectroscopic measurements, the spin-parity (J^π) of an excited state is generally assigned from the knowledge of the multipolarity (L) and type (E/M) of the gamma transition decaying from that state. The multipolarity of a gamma ray can be deduced from the angular distribution of the gamma ray or from the Directional Correlation of Oriented (DCO) state ratio. However, in either case, the nuclear substates must be aligned in a particular direction, normally perpendicular to the beam direction. For a nucleus with poor alignment, the decay gamma ray may not show a "good" angular distribution pattern. The degree of alignment is given by the spin alignment parameter σ/J, where σ is the width of the substate population distribution. The smaller the value of σ/J, the better is the alignment.

The heavy-ion induced fusion evaporation reaction is one of the common method to populate the high spin states in nuclei. It has been observed that it is one of the better reactions in which "good" alignment is obtained. In these types of reactions, the nominal value of σ/J is taken around 0.3. However, the value of σ/J depends on the reaction. The degree of alignment is expected to be less (larger value of σ/J) for light-ion induced reactions. We have obtained $\sigma/J \sim 0.39$ in case of α-induced fusion evaporation reaction [1].

The gamma ray angular distribution has large dependence on the value of σ/J. The angular distribution calculated for an E2 gamma ray is shown in Fig. 1 for different values of σ/J. This is obtained using the code "ADRAP" that we have developed for the calculations of gamma ray angular distribution and gamma ray angular correlations. It can be seen that as the alignment decreases (the value of σ/J increases), the distribution becomes flatter and it approaches towards an isotropic distribution for larger value of σ/J. Therefore, it is important to know the value of σ/J i.e the degree of orientation if the angular distribution is used to assign the J^π of a nuclear state.

Recently, the excited states of the stable nucleus ^{169}Tm has been studied by populating them in the reaction ^{169}Tm(^{32}S,^{32}S$'$)^{169}Tm* [2]. In this reaction, the prompt gamma rays were detected but the excited states can be populated in various inelastic excitations. Therefore, it is not possible to get a-priori knowledge on the value of σ/J in order to do J^π assignment of the excited states.

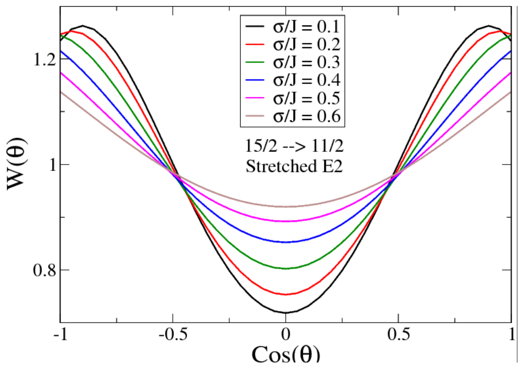

Fig-1 Angular distribution of an E2 gamma transition for different values of σ/J.

We have obtained the value of σ/J in this type of reaction from the knowledge of the transitions with known multipolarity in ^{169}Tm. The angular distribution of two different types of transitions, 323-keV E2 and 337-keV M1+E2, are shown in Fig. 2. It can be seen from these plots that "good" angular distribution is obtained, indicating a reasonably smaller value of σ/J. The angular distributions are fitted by the equation

$$W(\theta) = a_0(1 + a_2P_2(\cos\theta) + a_4P_4(\cos\theta))$$

and the fitted parameters are shown.

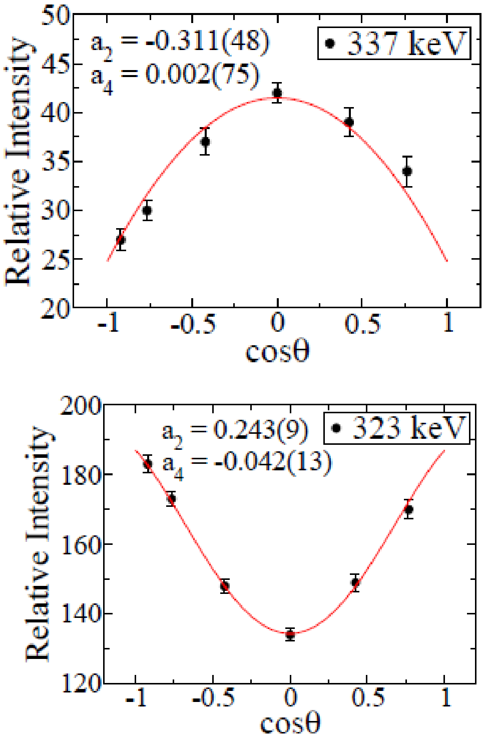

Fig.2: Angular distribution curve for a mixed M1+E2 (top) and a stretched E2 (bottom) transition.

To obtain the σ/J value, we have calculated the angular distribution parameters a_2 and a_4 corresponding to the M1+E2 mixed transition for different values of the mixing ratio δ. The result of the calculations is shown in Fig. 3. In this calculation, the value of σ/J was varied from 0.05 to 1.0. The experimental data point in Fig.3 is the values of the a_2 and a_4 coefficients obtained from the fitting of the experimental angular distribution data. It can be seen that the experimental data point corresponds to σ/J = 0.42 which can be considered as the degree of alignment obtained in this inelastic types of reaction. This value is somewhat larger than the ones in the fusion evaporation reaction but is small enough to perform angular distribution and DCO ratios measurements to get multipolarity and mixing ratios. We have used this value of σ/J to obtain the mixing ratio δ which comes out to be δ = -0.13(4) for the 337 keV transition which is in good agreement with the reported one [3].

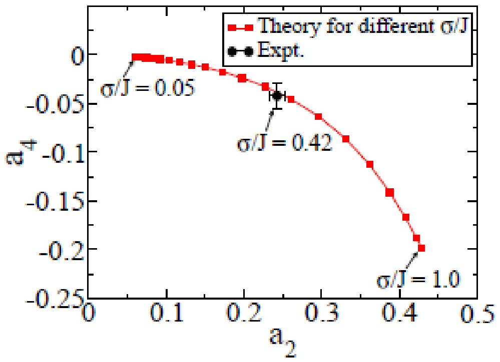

Fig-3 Calculated values of angular distribution coefficients for different values of σ/J. The experimental data is also shown which corresponds to σ/J = 0.42.

In conclusion, we have obtained the σ/J value for a non-conventional inelastic reaction for the study of gamma ray spectroscopy and have shown that the value of σ/J is larger than the conventional fusion evaporation reaction but small enough to get "good" angular distribution to deduce the multipolarity of a gamma ray transition to assign J^π of the states and to deduce mixing ratio.

References:-

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