Chiral Candidate Bands in $^{102}$Rh

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INTRODUCTION

Chirality is a phenomenon which is often found in nature. Examples of systems demonstrating chirality are present in chemistry, biology, high energy physics, etc. A spontaneous breaking of the chiral symmetry can take place for configurations where the angular momenta of the valence protons, valence neutrons, and the core are mutually perpendicular [1]. Under such conditions, the angular momenta of the valence particles are aligned along the short and long axes of the triaxial core, while the angular momentum of the core is aligned along the intermediate axis. The projections of the angular momentum vector on the three principal axes can form either a left- or a right-handed system and therefore, the system expresses chirality. Since the chiral symmetry is dichotomic, its spontaneous breaking by the axial angular momentum vector leads to a pair of degenerate $\Delta I = 1$ rotational bands, called chiral doublet bands. Pairs of bands, presumably due to the breaking of the chiral symmetry in triaxial nuclei, have been recently found in the mass region $A \approx 130$ [2,3], $A \approx 105$ [4-7], $A \approx 195$ [8], and $A \approx 80$ [9]. In many cases the energy degeneracy of the chiral candidate bands was almost observed but the transition probabilities are different, like in the case of $^{134}$Pr [10-12]. The main goal was to check for the existence of chirality in the mass region $A \approx 100$. According to the work of Meng et al. [13], the nucleus $^{102}$Rh is candidate to present such a phenomenon. All these recent results simulated our work to check for the existence of chirality in $^{102}$Rh.

EXPERIMENT

Excited states in $^{102}$Rh were populated using the reaction $^{96}$Zr($^{11}$B, 3n) $^{102}$Rh at a beam energy of 36 MeV. The beam was delivered by the 15-UD Pelletron accelerator at the Inter University Accelerator Center (IUAC) in New Delhi. The target consisted of 0.9 mg/cm$^2$ $^{96}$Zr, enriched to 96.5%, evaporated onto a 8 mg/cm$^2$ gold backing. The recoils were derived the level scheme. Chirality is a phenomenon which is often found in nature. Examples of systems demonstrating chirality are present in chemistry, biology, high energy physics, etc. A spontaneous breaking of the chiral symmetry can take place for configurations where the angular momenta of the valence protons, valence neutrons, and the core are mutually perpendicular [1]. Under such conditions, the angular momenta of the valence particles are aligned along the short and long axes of the triaxial core, while the angular momentum of the core is aligned along the intermediate axis. The projections of the angular momentum vector on the three principal axes can form either a left- or a right-handed system and therefore, the system expresses chirality. Since the chiral symmetry is dichotomic, its spontaneous breaking by the axial angular momentum vector leads to a pair of degenerate $\Delta I = 1$ rotational bands, called chiral doublet bands. Pairs of bands, presumably due to the breaking of the chiral symmetry in triaxial nuclei, have been recently found in the mass region $A \approx 130$ [2,3], $A \approx 105$ [4-7], $A \approx 195$ [8], and $A \approx 80$ [9]. In many cases the energy degeneracy of the chiral candidate bands was almost observed but the transition probabilities are different, like in the case of $^{134}$Pr [10-12]. The main goal was to check for the existence of chirality in the mass region $A \approx 100$. According to the work of Meng et al. [13], the nucleus $^{102}$Rh is candidate to present such a phenomenon. All these recent results simulated our work to check for the existence of chirality in $^{102}$Rh.

DATA ANALYSIS AND RESULTS

For the investigation of the level scheme and electromagnetic properties of the transitions we have performed four different types of data analysis. Such complex approach is employed for the first time in the case of the investigation of chirality in nuclei. The ordering of the transitions was determined according to gamma ray relative intensities, gamma-gamma coincidence relationships and gamma ray energy sums. The electric or magnetic character and multipolarity of the transitions were deduced by linear polarization and angular correlations measurements.

The angular correlation function for two successive transitions from oriented states depends on the spins of initial, intermediate, and final levels. The angular correlations are subject to symmetries which allow us to order the pairs of detectors in unique groups specific for the multidetector spectrometer used (25 correlation groups in our case). Here the angular correlation analysis was carried out with the computer code CORLEONE [15]. The spins of the new band were determined through investigation of different spin hypotheses for the cascades involving transitions the new band and transitions linking the chiral candidate bands. In Fig. 1, the angular correlation pattern involving the 452 and 824 keV transitions is shown.

The four clover detectors from ring at 90° with respect to the beam axis were used as composite Compton polarimeter. The spectrum in Fig. 2 reflects the linear polarization of the transition observed. The negative lines correspond to transitions of predominantly magnetic character while the positive lines correspond to transitions of predominantly electric character. The transitions with energy 824, 913 and 966 keV linking the two bands are with magnetic character ($M1$). The other transitions are with predominantly electric character. In this way was derived the level scheme.
The best fit confirms the spin hypothesis $11^+_1 \rightarrow 10^+_2 \rightarrow 9^+_0$. More details on the analysis have been presented in [16].

**DISCUSSION**

To study the bands structure we have performed two quasiparticles+triaxial rotor (TQPTR) calculations in the framework of the model presented in Ref. [17]. The core is treated as a rigid body with a fixed overall quadrupole deformation $\varepsilon$ and a triaxiality parameter $\gamma$. The theoretically predicted $B(E2)$ reproduce quite well the absolute values and the increasing trend of the experimental data after spin $I=14^+$. At lower spins, the description is worse since the rigid rotor approach cannot explain the small drop of the experimental values between spins 9 and 13.

The comparison between the experimental and calculated $B(M1)$ transition strenghts leads to the conclusion that the TQPTR calculations reproduce roughly the data in band 1 and are consistent with the transition strength in band 2 at spin 11.$h$. The absence of an appreciable staggering of the data in band 1 indicates that the expectation for the observation of a static chirality in $^{102}$Rh is not realized. The TQPTR calculations reveal that the optimum value of the triaxiality parameter $\gamma = 20^\circ$ differs from the value of $30^\circ$ characterizing the static chiral case. The difference in the core contributions to the yrast and yrare negative-parity bands mentioned above point that dynamic effects as coupling of the quasiparticles to fluctuations of the shape of the core may lead to differences in the properties of these two bands.

In summary for the investigation to the level-scheme of $^{102}$Rh we have performed an experiment at the IUAC in New Delhi, India using the INGA spectrometer. To construct the level scheme of $^{102}$Rh we used gamma-gamma coincidence data, relative $\gamma$-rays intensities and energy sums. For the first time we applied angular correlation analysis and polarization measurements for INGA spectrometer data. The results obtained from angular correlation and linear polarization measurements were essential for the spin and parity assignments. As a result from our analysis 4 new exited states in $^{102}$Rh were determined for the first time. 8 new lifetimes have been determined. Our lifetime measurements and the theoretical analysis do not support static chirality in $^{102}$Rh. This means that if the chirality in $^{102}$Rh exists, has a mainly dynamic character.

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