SEARCH FOR THE CHIRAL NUCLEI IN A~80 MASS REGION

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Excited states of $^{80}$Br have been investigated via the $^{76}$Ge($^{11}$B, $\alpha$3n) re-

action and a new $\Delta I = 1$ band has been identified which resides $\sim 400$ keV above the yrast band. Based on the experimental results, a chiral character of the two bands within the $\pi g_{9/2} \otimes \nu g_{9/2}$ configuration is proposed, which provides the first evidence for chirality in the $A \sim 80$ mass region.

Keywords: high spin states; configuration; chiral doublet bands.

1. Introduction

In their pioneering work$^1$ Frauendorf and Meng pointed out that the rotation of triaxial nuclei may give rise to pairs of identical $\Delta I = 1$ bands with the same parity in odd-odd nuclei, the so-called chiral doublet bands. Presently, candidate chiral doublet bands have been observed experimentally in about 25 cases of odd-odd nuclei, odd-$A$ and even-even nuclei (see review$^2$ and references therein). Thus far most studies on nuclear chirality have focused on the mass $A \sim 130$ and 100 regions. However, there is no reason to consider the nuclei in $A \sim 130$ and 100 mass regions as unique in terms of the nuclear chirality, therefore it is necessary to search other candidates in other mass regions. It is also important to show that these chiral symmetry properties are of a general nature and not related only to a specific nuclear mass region. Recently, a pair of negative-parity partner bands in $^{198}$Tl have been suggested as candidate chiral bands.$^3$ Following this motivation we aim to investigate odd-odd nuclei in the $A \sim 80$ mass region, where chiral doublet bands may be formed involving the $\pi g_{9/2} \otimes \nu g_{9/2}$ configuration.

2. Experiment

High-spin states of $^{80}$Br were populated in the $^{76}$Ge($^{11}$B, $\alpha 3n$) fusion-evaporation reaction at beam energies of 54 and 65 MeV. The experiment was performed at iThemba LABS with the AFRODITE array. In total nine CLOVER detectors are applied to accumulate the $\gamma - \gamma$ coincident events. The CLOVER detectors have been arranged in three rings at $45^\circ$, $90^\circ$ and $135^\circ$ with respect to the beam direction, and hence the DCO ratios (Directional Correlation from Oriented nuclei) for $\gamma$ transitions can be subtracted. The CsI particle detectors “Chessboard” were also used with the AFRODITE array to select specific reaction channels. In order to double-check the experimental results, we have also used high-fold coincidence $\gamma$-ray data from a measurement of the reaction $^7$Li + $^{76}$Ge.$^4$
3. Result and Discussion

Partial level scheme of $^{80}\text{Br}$ derived from the present work is shown in Fig. 1, together with the adjacent nuclei, where band 1 is the yrast band and band 2 is the side band. For the yrast band, the odd-spin decay sequence has been extended from $11^+$ to $15^+$ and even-spin decay sequence from $14^+$ to $16^+$. A new side band is observed in the present work and assigned as the $g_9^1 = 2 g_9^1 = 2$ configuration. The configuration-fixed constrained triaxial relativistic mean-field calculation through $\pi g_9^2 \otimes \nu g_9^2$ was carried out to obtain the potential energy surfaces (PES) for each configuration of $^{80}\text{Br}$. The detailed description of this approach with nucleon-nucleon interacting can be found in Ref. 9 and references therein. In Fig. 2, we plot the PES in $^{80}\text{Br}$ as functions of deformation $\beta_2$ in configuration-fixed constrained triaxial RMF calculations. The minima in the PES of each configuration are labeled with A, B, C, and D with quadrupole deformation parameters $(\beta_2, \gamma)$ as $(0.16, 0)$, $(0.26, 6.6)$, $(0.35, 24.6)$, and $(0.39, 18.1)$, respectively. As shown in Fig. 2, the RMF approach predicts that the minimum of $^{80}\text{Br}$ with configuration $\pi g_9^2 \otimes \nu g_9^2$ possesses the triaxial shape with $\beta_2 \approx 0.35$ and $\gamma \approx 24.6^\circ$ (see Fig. 2). This triaxial deformation together with the particle-hole configuration is favorable for forming the chirality in $^{80}\text{Br}$. In addition, as shown in Fig. 1, the bands 1 and 2 maintain a small energy difference ($\sim 400$ keV) within the observed spin interval. By examining the experimental observations against the fingerprints for chirality in Refs., the two bands can be considered as candidates for chiral doublet bands in the $A \sim 80$ mass

Fig. 1. Partial level schemes of $^{74}\text{Br}$, $^{76}\text{Br}$, $^{78}\text{Br}$, and $^{80}\text{Br}$ (present work).
region.

Fig. 2. Potential energy surfaces of $^{80}$Br as functions of deformation $\beta_2$ in configuration-fixed constrained triaxial RMF calculations. The minima in the energy surfaces of each configuration are labeled ACD according to their energies.

4. Summary and Outlook

In summary, excited states of $^{80}$Br were investigated by means of in-beam $\gamma$-ray spectroscopy. The previously known yrast band has been extended up to $I^z=(16)^+$. A new $\Delta I=1$ band has been identified which resides $\sim 400$ keV above the yrast band. The two bands can be considered as candidates for chiral doublet bands in the $A\sim 80$ mass region. For this mass region, total Routhian surfaces (TRS) calculations suggest that $^{78}$Br exhibits a triaxial shape with $\gamma \approx 21.3^\circ$ and $\beta \approx 0.32^\circ$ for a rotational band with configuration $\pi g_{9/2} \otimes \nu g_{9/2}^{-1}$. The deformation parameters together with the particle-hole configuration are suitable for the construction of chiral doublet bands. Hence, it is interesting to populate high-spin states of $^{78}$Br and to search for chiral doublet bands. It is also important to verify whether chirality exists in more than one odd-odd nuclei in the $A\sim 80$ mass region in order to provide systemic survey on the chiral interpretation.
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