Low-Lying Collective States in Odd-Mass I, Cs, La and Pr $N=80$ Isotones

Ryoji OKAMOTO

Department of Physics, Kyushu University
Fukuoka 812
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There are systematically low-lying collective states in odd-mass I, Cs, La and Pr $N=80$ isotones which have the same trend of excitation energy as that of one phonon $2_1^+$ states of adjacent even-even nuclei. The level order of low-lying collective $5/2^+$ and $3/2^+$ states coincides with that of one-quasi-particle (1QP) $7/2^+$ ($1g_{7/2}$) and $5/2^+$ ($2d_{5/2}$) states. (Fig. 1(a)) It is of interest to investigate the change in the structure of these collective states corresponding to that of proton number.

The excitation energy spectra remind us of the similar structure of these states to

Fig. 1. The excitation energies of the $5/2^+$ and $3/2^+$ states. (a) Experiment, E. Achterberg et al., Phys. Rev. C5 (1972), 1759, and references therein. However, the values of Ref. 31) in it are cited incorrectly. (b) Calculation.
the anomalous coupling (AC) states with spin \( I=j-1 \). Namely, the largest components of these states are \( \langle \pi d_{5/2} \rangle^3 \) and \( \langle \pi d_{3/2} \rangle^3 \), respectively. Then the trends of excitation energies of the \( 5/2^+ \) and \( 3/2^+ \) states are expected to coincide with those of the 1QP \( g_{5/2} \) and \( d_{3/2} \) states, respectively.

In fact, the structure of the \( 5/2^+ \) state is similar to that of the AC state.\(^1\) For the \( 3/2^+ \) state, however, the earlier study\(^1\) suggests that its structure changes considerably, depending on the relative position of the 1QP \( g_{5/2} \) and \( d_{3/2} \) states.

The aim of this short note is to clarify the relation between the level order change of the \( 5/2^+ \) and \( 3/2^+ \) states and the microscopic structure of the \( 3/2^+ \) state. On the basis of the earlier investigation, we consider the \( 5/2^+ \) and \( 3/2^+ \) states in

\[
\Psi_{\pi N} = (\sqrt{3}! \sum_{\alpha \beta \gamma} \psi_{\pi N} (\alpha \beta \gamma) P(\alpha \beta \gamma) a_\alpha^\dagger a_{\beta}^\dagger a_{\gamma}^\dagger + \sum_{\{\alpha \beta \gamma\}} (1 + \delta_{\alpha \beta})^{-1/2} \psi_{\alpha \beta} (\rho \sigma ; \gamma) \\
\times P(\rho \sigma) a_\sigma^\dagger a_\rho^\dagger a_\alpha^\dagger + (1/\sqrt{3}!) \\
\times \sum_{\alpha \beta \gamma} \varphi_{\alpha \beta \gamma} (\alpha_1 \alpha_2 \alpha_3) P(\alpha_1 \alpha_2 \alpha_3) \\
\times T_{\alpha \beta \gamma \rightarrow \alpha_1 \alpha_2 \alpha_3} (\alpha_1 \alpha_2 \alpha_3) + (1/\sqrt{2}) \\
\times \sum_{\alpha \beta \gamma} \varphi_{\alpha \beta \gamma} (\alpha_1 \alpha_2 \alpha_3) P(\alpha_1 \alpha_2 \alpha_3) \\
\times T_{\alpha_1 \alpha_2 \alpha_3 \rightarrow \alpha_1 \alpha_2 \alpha_3} (\alpha_1 \alpha_2 \alpha_3) + \sum_{\{\alpha \beta \gamma\}} (1 + \delta_{\alpha \beta})^{-1/2}
\]

Fig. 2. The main forward-going amplitudes of the collective dressed 3QP modes. (a) \( 5/2^+ \) states, (b) \( 3/2^+ \) states. Abbreviations such as

\( \langle (5)_{\pi 7} \rangle = \langle d_{5/2} d_{3/2} (J=2) g_{1/2} \rangle \)

and

\( \langle (5)_{\pi 7} \rangle = \langle d_{5/2} d_{3/2} (J=4) g_{1/2} \rangle \)

are used.
Then, we obtain the eigenvalue equation which the correlation amplitudes should satisfy:

\[ \times \varphi_{nl}^{(n)}(\alpha\beta; \tau) \mathbf{P}(\alpha\beta) a_{\lambda\lambda} a_{\lambda\lambda} \]
\[ + \sum_{l=1}^{\lambda} \{1 + \delta_{nl}\}^{1/2} \varphi_{nl}^{(n)}(\rho\sigma; \tau) \times \mathbf{P}(\rho\sigma) a_{\lambda\lambda} a_{\lambda\lambda} \] 

The notations, force strength and single particle energies used in this calculation are the same as those in Ref. 1). The calculated excitation energies and main forward-going amplitudes of the dressed 3QP \( 5/2_1^+ \) and \( 3/2_1^- \) states are shown in Figs. 1(b) and 2, respectively. The trends of excitation energies of these states are well reproduced. The structure of the dressed 3QP mode for the \( 5/2_1^+ \) and \( 3/2_1^- \) states changes. The difference between the structure of the dressed 3QP modes for the \( 5/2_1^+ \) and \( 3/2_1^- \) states are also displayed clearly in the \( B(E_2) \) to the 1QP \( g_{7/2} \) and \( d_{5/2} \) states. (Table I) Thus, the change of relative position of the 1QP \( g_{7/2} \) and \( d_{5/2} \) states causes the drastic change in the structure of the \( 3/2_1^- \) state.

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