PROPERTIES OF THE LOWEST STATES
IN THE ODD-ODD $^{160}\text{Tm}$ AND $^{162}\text{Tm}$ NUCLEI

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Detailed study of the lowest states in the odd-odd $^{160}\text{Tm}$ and $^{162}\text{Tm}$ deformed nuclei and of corresponding electromagnetic transitions has been performed. In the theoretical analysis, performed within the framework of the “two-quasiparticle + rotor” model, the nondiagonal matrix elements of the residual p-n interaction have been included. Comparison of calculated energies and reduced transition probabilities $B(\gamma\gamma)$ with experimental ones have proved importance of these matrix elements in the model calculations. More complex interpretation of the lowest states in both Tm nuclei has been achieved although some ambiguity has not been removed.

1. INTRODUCTION

Large amount of experimental data on odd-odd nuclei accumulated in recent years makes possible to investigate the structure of these nuclei in more detail. The existence of odd neutron and proton above even-even core causes that odd-odd nuclei are a good tool for studying residual p-n interaction.

Inclusion of the effective residual p-n interaction into the model calculations is rather difficult and tedious problem which has not been solved in full extent until now. In all papers published to date the p-n interaction has been involved in the first order of the perturbation theory and corresponding nondiagonal matrix elements have been neglected (e.g. [1–5]). However, experimental data indicate possible role of these elements in the description of electromagnetic transitions in some odd-odd nuclei (see e.g. [6–13]).

Other problem connected with generally complex structure of the odd-odd nuclei is the ascription of quantum characteristics to definite states. Very useful step in this direction is the method suggested by Singh and Sood [14–19]. This method consists in estimating the position of the lowest states in odd-odd nuclei spectrum on the base of the known levels in neighbouring odd nuclei. The simple zero-range effective p-n interaction is used for this aim. Though Singh-Sood method is only approximative, it makes possible to select two-particle configurations most important for further analysis in odd-odd nuclei.

In this paper the influence of inclusion of nondiagonal matrix elements of p-n interaction on electromagnetic transitions is studied in the case of $^{160}\text{Tm}$ and $^{162}\text{Tm}$ nuclei. The most accurate experimental studies of the states in these nuclei were performed by Adam et al. [6] and Hons [7]. In these papers the interpretation of the lowest states in $^{160}\text{Tm}$ [6] and $^{160,162}\text{Tm}$ nuclei was also suggested, however, the interpretations for $^{160}\text{Tm}$ differ. Moreover, some interpretations of the ground state given by Hons [7] and Hons and Kvasil [20] assume the violation of the well-
known Gallagher-Moszkowski rule [21]. Other partly different interpretations of the states in $^{160,162}$Tm nuclei were also suggested in earlier works [8, 9, 13, 22, 23].

Rather specific problem, common for all odd-odd deformed nuclei, are the E1 transitions [9]. Though many E1 transitions were observed in both Tm nuclei, the agreement between the calculated and experimental $B(E1)$ values is rather bad [20].

To elucidate these discrepancies and to demonstrate the importance of non-diagonal matrix elements of the p-n interaction we have done a detailed analysis of energy spectra and E1, M1 and E2 electromagnetic transitions in both nuclei. The starting point of our analysis were all interpretations published until now and the estimates deduced from the systematics of the levels in the odd-odd nuclei following the Singh-Sood method. We have discussed different interpretations and the best of them have been used for calculation and comparison with experimental data of reduced transition probabilities for electromagnetic E1, M1 and E2 transitions.

2. THEORETICAL CONSIDERATIONS

2.1. Model description

The analysis of the odd-odd nuclear states performed in this paper starts from the "two-quasiparticle + rotor" model (TQR model) including Coriolis interaction which represents the coupling between intrinsic and rotational degrees of freedom in nucleus. Within the framework of this model the Hamiltonian of odd-odd deformed nuclei can be written in the form [3, 20]

$$H = H_{in} + H_{rot} + V_{pn},$$

where the intrinsic part $H_{in}$ describes the average nuclear field, in which the pairing interaction is also included. $V_{pn}$ is the potential of the effective residual interaction between odd proton and odd neutron. The part $H_{rot}$ of the Hamiltonian (1) characterizes rotational motion of the nucleus as a whole including the Coriolis interaction (CI). For a nucleus with rotational symmetry this part can be expressed as composed of three terms [3, 5]

$$H_{rot} = H_R + H_{CI} + H_{jj},$$

where

$$H_R = \frac{\hbar^2}{2\mathcal{Q}} (I_2 - I_3^2),$$

$$H_{CI} = -\frac{\hbar^2}{2\mathcal{Q}} (I_+ j_+ + I_- j_-),$$

$$H_{jj} = \frac{\hbar^2}{2\mathcal{Q}} (j_+ j_- + j_- j_+).$$