# Coupling matrix approach for rotation particle coupling

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## Introduction

The particle rotor model (PRM) is widely used and quite successful for a long time, in explaining the observed rotational spectra of several nuclei [1, 2]. Microscopic theories for proton emission utilizing this approach is regarded as one among the most robust and successful approaches [3, 4]. Variations of PRM intended to explain observed rotational bands could utilize several experimental inputs. For the models aimed at identifying the ground and low-lying states, especially at the drip lines, the experimental data are scarce and hence the theory has to be more consistent. We have proposed a formalism named as the *coupling matrix approach* with which the deviation from the rotational behaviour of the core can be taken in to account properly. The key idea of this formalism is based on the coupled channels approach for odd-even nuclei suggested in Refs. [1, 5] which is also outlined here.

## Formalism

The ground state band of the core can be of the form $E_R = (\hbar^2/2\Im)R(R+1)$, where $R = 0, 2, 4, \ldots$. The total wave function for a given spin $(I, M)$ of an odd-even nucleus can be written in terms of $R$ ($R-$representation) as

$$\Psi_{IM} = \sum_{ljR} \frac{\phi^I_{ljR}(r)}{r} |l(jR), IM\rangle, \qquad (1)$$

where

$$|l(jR), IM\rangle = \sum_{mM_R} \langle jmRM_R|IM\rangle |RM_R\rangle |ljm\rangle \qquad (2)$$

represents the coupling between the single-particle, spin-angular wave functions $|ljm\rangle$ to the wave function $|RM_R\rangle$ of the rotor and $\phi^I_{ljR}(r)$ represents the radial wave function of the relative motion of the valence nucleon (particle) with respect to the core. With the definition of

$$A^{IK}_{jR} = \sqrt{\frac{2R+1}{2I+1}} \langle jKR0|IK\rangle \sqrt{1+(-1)^R}, \qquad (3)$$

it is possible to transform the wave functions in the $K$ representation to the $R$ representation through the relation

$$|ljK, IM\rangle = \sum_R A^{IK}_{jR} |l(jR), IM\rangle. \qquad (4)$$

The eigenvalues of the rotational Hamiltonian ($H_R$ ) are $E_R$ and hence in the $K$ representation we can write

$$\langle ljK', IM|H_R|ljK, IM\rangle = \sum_R A^{IK'}_{jR} E_R \, A^{IK}_{jR} = W^{jI}_{KK'}. \qquad (5)$$

For the total hamiltonian $H = H_{av} + H_{pair} + H_R$, we can easily write down the matrix elements as

$$\langle K', IM|H|K, IM\rangle = \epsilon_K \, \delta_{KK'} + \sum_{lj} W^{jI}_{KK'} \times \int dr \, \phi^{IK'*}_{lj}(r) \, \phi^{IK}_{lj}(r), (6)$$

where $\epsilon_K$ are the quasi particle energies.

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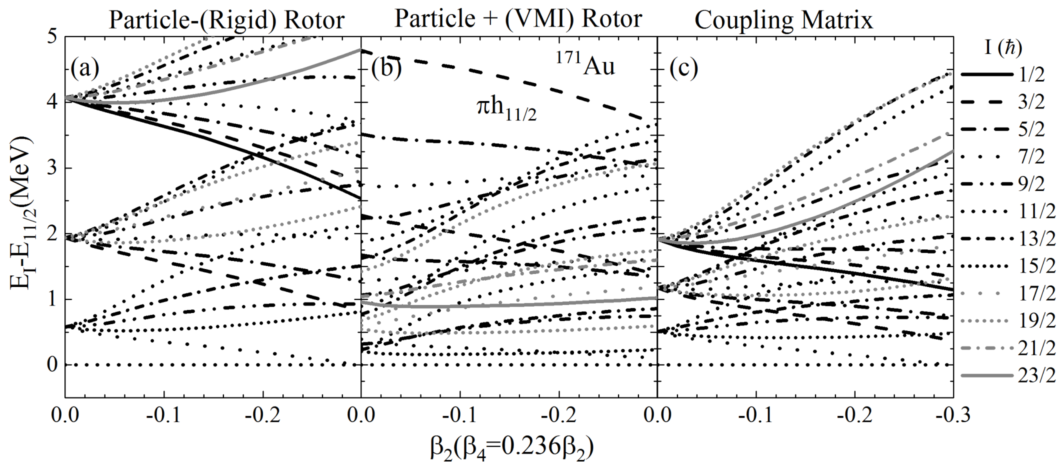


FIG. 1: Trend of rotational levels with the deformation in a quasiparticle plus rotor system $^{171}$Au for the unique parity h11/2 shell. (a) Conventional approach with the core considered as a pure rotor (b) Conventional approach with the core considered as a rotor with variable moment of inertia $\Im(I) = \Im_0\sqrt{1 + b\ I(I + 1)}$ with $b = 0.48$ required to reproduce the observed $4^+$ energy and (c) coupling matrix approach with the energies of the core taken from the experimental data.

## Result and discussions

We consider the case of quasiparticle plus rotor system $^{171}$Au, where the measured spectrum of the core ($^{170}$Pt) deviates considerably from a pure rotor pattern. In Fig. 1 we show the results obtained from the conventional approaches and the coupling matrix approach. In Fig. 1(a), we can see that several rotational states have degeneracy at zero deformation intact and equal to the core energies which are of a rigid rotor with constant moment of inertia. The deviation from the pure rotational behaviour of the core could be treated with a variable moment of inertia and the results from such an approach are shown in Fig. 1(b). Here we can see that the degeneracy at zero deformation is lifted and some of the high angular momentum states are drastically lowered in energy. This leads to an unrealistic situation and hence determining the lowest lying state could be erroneous. In the coupling matrix approach, (Fig. 1(c)) we get back the core energies even when the core is not a pure rigid rotor. Extension of this method to odd-odd nuclei and application to proton emitters will be discussed in the conference in another paper.

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