ASYMMETRIC ROTOR MODEL FOR DECOUPLED BANDS IN TRANSITIONAL ODD MASS NUCLEI

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Abstract

The high-spin states in transitional odd-mass nuclei are studied in terms of an odd quasi-particle coupled to an asymmetric rotor with a variable moment of inertia. The results show that these nuclei have stable γ deformations.

The odd nucleon motion in the field of the phenomenologically described even mass nucleus had been treated in terms of the strong and week coupling limits. Since 1972 a third way of particle core coupling has been successfully introduced for the description of odd mass transitional nuclei as well as that of high spin states in odd mass deformed nuclei. This description of the odd nucleon motion is called "decoupling"[1]. The decoupling model has recently been employed by Meyer-ter-Vehn and coworkers[2] for the study of nuclei in Au and La regions in terms of an odd particle coupled to an asymmetric rotor. The results of these calculations, though satisfactory in reproducing the general trend of the experimental spectra, fail to provide quantitative agreement for the excitation energies of especially the high spin states. In this context the present authors have for the first time demonstrated the importance of the softness of the asymmetric core[3]. This softness of the core has been introduced by a generalization of the VMI model[4]. It has been shown by extensive calculations, particularly in Au, La and As regions that such a treatment provides a much satisfactory explanation of the data. We intend here to report the results in brief of our detailed investigations for the nuclei in the transitional regions mentioned above.

In our model the Hamiltonian for the statically deformed odd mass system is given by

$$H = H_{Rot} + H_{Shell} + H_{P-C} + H_{Pair} \ . \qquad (1)$$

The four terms represent, respectively, the rotational motion of the triaxial core, the spherical single particle motion, the single particle interaction with the triaxial deformed core and the pairing interaction. The Nilsson Hamiltonian constructed by the second and third terms is diagonalized in spherical shell model states. The pairing term H_{Pair} is treated by the BCS procedure. The total wave functions of the odd mass nucleus is expanded into the properly symmetrized strong coupling wave functions

$$|IMKi\rangle = \left[\frac{2I+1}{16\pi^2}\right]^{1/2} (D^I_{MK}\chi_i + (-)^{I-K} D^I_{M-K}\chi_{\bar{i}}) \ , \qquad (2)$$

where I,M.K and i denote the total angular momentum of the odd mass system, its Z-components in the laboratory and the body-fixed systems and the intrinsic single particle quantum number, respectively. D^I_{MK} is the usual D-function and χ_i and $\chi_{\bar{i}}$ denote the intrinsic quasi-particle wave function and its time reversed state. To be able to treat the variable moment of inertia of the triaxial rotor H_{Rot}, the basis states are expanded in terms of the core eigenfunctions.

The model described briefly above is applied to the odd mass nuclei in the transitional regions, i.e. A∿190, A∿130, A∿80 nuclei. The numerical details to calculate the decoupled bands proceeds as follows:

(i) The extended VMI model[4] and the asymmetric rotor model are used to adjust the stiffness parameter C and the moment of inertia parameter Θ_{00} for the first 2^+ and 4^+ states of the adjacent even mass nuclei. The deformation β is fixed by the empirical relation: $\Theta_{02} = 3/1225 \cdot A^{7/3}\beta^2$ [MeV].

(ii) In the odd mass nucleus the asymmetric deformation γ and the fermi surface λ are adjusted by minimizing the χ^2 value. The strength of pairing is given by the empirical gap parameter $\Delta = 12/\sqrt{A}$ [MeV], where A is the atomic number.

In figs. 1 and 2 the measured decoupled bands built on $1i_{13/2}$ neutron states of Hg isotopes and $1h_{11/2}$ proton states of Au isotopes are compared with our model calculations.

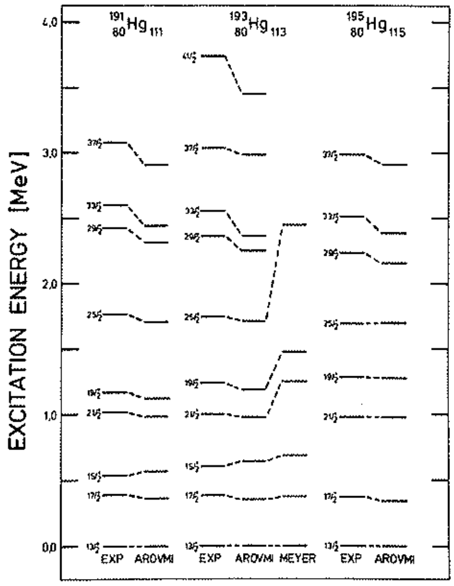

Fig. 1: Experimental and theoretical excitation energies of decoupled bands built on an $i_{13/2}$ neutron of Hg isotopes. AROVMI denotes the results of our calculations. A comparison of our results for ^{193}Hg with the rigid moment of inertia (MEYER) is also shown.

The results of the rigid asymmetric rotor model are also shown. Our results are in nice agreement with experiments. A comparison of our results with those of the rigid asymmetric rotor model reveals the importance of the inclusion of the softness of the core. The γ deformation obtained from the minimization calculations is $\gamma \sim 40^o$ (Hg isotopes) and $\sim 35^o$ (Au isotopes). It should be noted that these γ deformations are very close to those which are obtained from the core excitation energies.

The decoupled bands in the different mass region, i.e. one built on $1h_{11/2}$ proton states of ^{133}La and ^{135}Pr, are shown in fig. 3. As shown above our model provides a better description of the data as compared to the rigid rotor model. Especially, the discrepancy at the higher spin states in the rigid asymmetric rotor model is removed by taking into account the softness of the core. However, the low spin states show systematic discrepancies between theory and experiment; vz. the excitation energies of the low spin states calculated are always higher than the experiments.

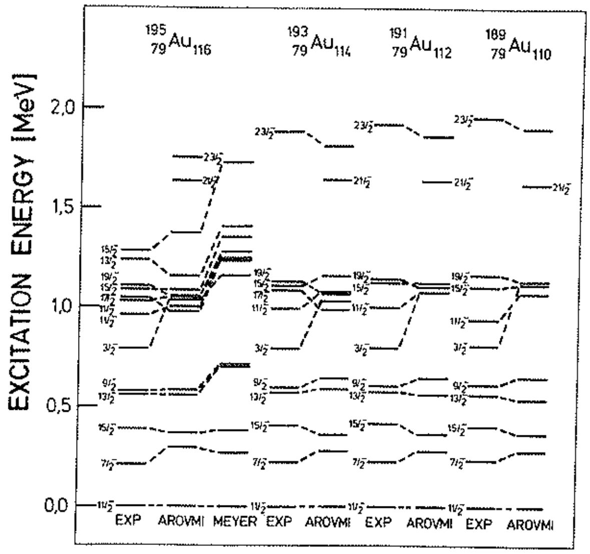

Fig. 2: Experimental and theoretical excitation energies of decoupled bands built on a $h_{11/2}$ proton of Au isotopes.

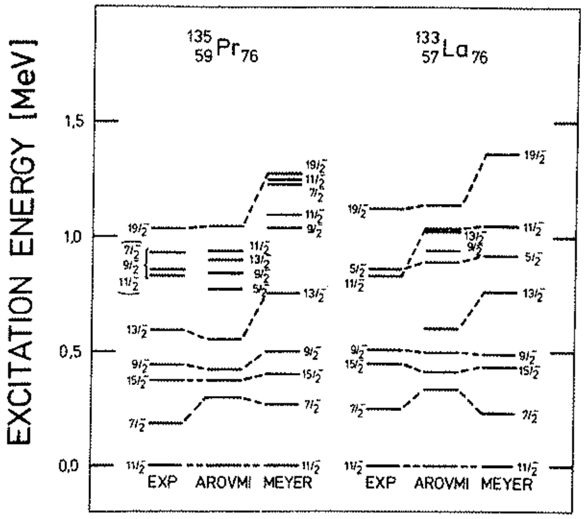

Fig. 3: Experimental and theoretical excitation energies of decoupled bands built on a $h_{11/2}$ proton of ^{133}La and ^{135}Pr.

This is attributed to the break down of the decoupling in such a low spin state, since here the Coriolis interaction ($\propto$I) becomes relatively small compared to the particle core coupling interaction[5]. This strong coupling effect in the decoupling scheme is taken into account by adding one more spherical single particle state for the description of the particle in the deformed field. The test calculation shows that an appreciable mixing comes from (j-2) single particle state. Here j is the total single particle angular momentum which contributes maximum to the decoupling scheme. The contribution from other states is reduced due to the spin flip. The case of the decoupled band built on a $h_{9/2}$ proton state in ^{187}Ir is demonstrated in fig. 4. The state originating from j = $f_{5/2}$ state has second biggest amplitude in I = 1/2 and 3/2 states.

The $4g_{9/2}$ shell region (A $\cong$ 70$\sim$90) has been also investigated using the asymmetric rotor model. As an example, the results for the decoupled band built on a $1g_{9/2}$ proton state in ^{73}As is shown in fig. 5[6].

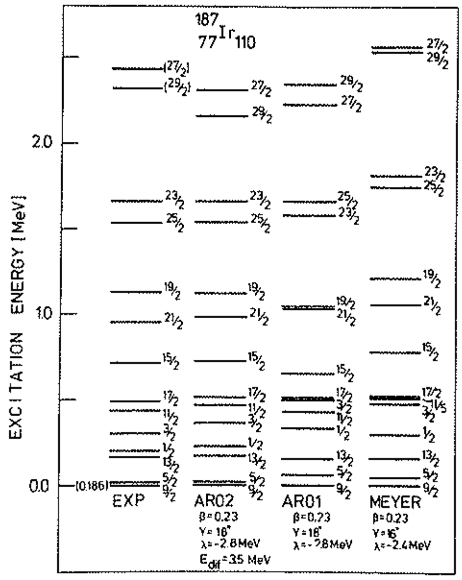

Fig. 4: Experimental and theoretical excitation energies relative to the $9/2^-$ state at 186 keV in ^{187}Ir. AR02 and AR01 indicate the calculations using two ($1h_{9/2}$ and $2f_{5/2}$) and one ($1h_{9/2}$) spherical single particle levels. Also, the results of Meyer-ter-Vehn (MEYER) have been displayed for the purpose of comparison.

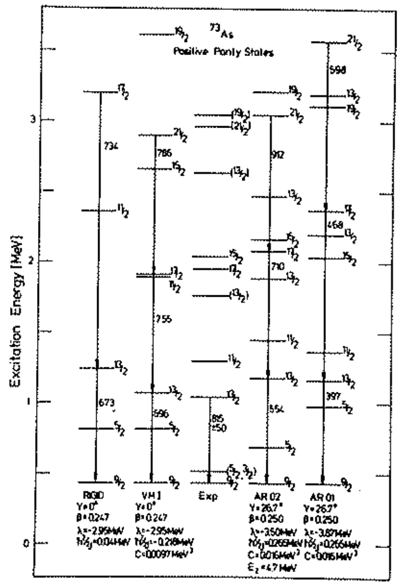

Fig. 5: Experimental and theoretical excitation energies relative to the $9/2^+$ state at 428 keV in ^{73}As. The parameters used for the calculations are also shown for each spectrum.

The relatively large β deformation ($\beta \sim 0.25$) and small total single particle angular momentum requires the inclusion of $2d_{5/2}$ state. Too large energy gaps between 13/2 and 11/2 states and 17/2 and 15/2 states in the axially symmetric model (denoted by RIGID and VMI in fig. 5) are reduced by the γ deformation (γ = 26.7°).

The present theoretical analyses suggests that the transitional odd mass nuclei have appreciable β and γ deformations. Moreover, the successful analysis of the negative parity states in Pt isotopes which could not be explained by the symmetric rotor model also supports the γ deformation.

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