High spin structure of ^{161,163}Re by DHF Model

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Introduction

The study of high spin phenomena of highly unstable nucleus is always interesting. To study the interesting structural phenomena, one has to populate the excited states in nuclei at high spin. The collective model emphasizes the coherent behaviour of all of the nucleons. For odd mass nuclei the coupling of single particle and collective rotational degree of freedom gives a variety of bands structure. In many cases rotational states are known upto very high spins. Among the odd mass nuclei, a number of one and multi-quasiparticle bands have been experimentally observed [1, 2]. With proper energetic ion beams and large detector arrays nuclei can be populated to considerably high spins as well as excitation energies. It is thus necessary to have microscopic theoretical results for such nuclei, which will encourage experimental studies of highly unstable nuclei.

In the present work, we have theoretically investigated the rotational bands of highly neutron deficient odd A Rhenium nuclei with deformed Hartree-Fock and Angular Momentum Projection (DHF) model [3]. Nuclei under study are ^{161,163}Re. Experimentally 29 gammas have been observed which have been placed with four different bands for ^{161}Re [4]. Out of four bands, two in one quasiparticle and two is three quasiparticle bands. Similarly in the case of ^{163}Re, 10 gammas have been observed which have been place in one band [5]. We have tried to explain the experimentally observed one and three quasiparticle bands and assigned configuration to all the bands whose configuration have not been assigned yet. At the same time we have predicted a few more bands for future experimental verification.

Theoretical Framework

In deformed odd-N nuclei at high spin states, the coupling of odd neutron to the deformed core and the role of large j orbits give rise to many bands. Deformed single-particle orbits are obtained by self-consistently solving the Hartree-Fock equations. Here we assume these nuclei to have axial symmetry. For axially symmetry, 'm' is a good quantum number (m is projection of j along the symmetry axis). Each orbit αm is superposition of various orbitals j with the same 'm' value

$$|\Omega> = |\propto m> = \sum_{j} C_{jm}^{\propto} \; |jm> \qquad (1)$$

Because of the axially symmetry density distribution, each intrinsic state is a superposition of various J states . $|\Phi_{\mathrm{k}}>$ can be written as

$$|\Phi_{\mathrm{k}}> = \sum_j \; C_j^k \; |\psi_k^j> \qquad (2)$$

The Angular Momentum Projection Operator is needed to project out states of good angular momentum from the intrinsic state Φ_{k} ,which is given by [6]

$$P_K^{JM} = \frac{2J+1}{8\,\pi^2}\int d\,\Omega\, \mathrm{D}_{\mathrm{MK}}^{\mathrm{J}\;*}(\Omega)\mathrm{R}(\Omega) \qquad (3)$$

Here $\mathrm{R}(\Omega)$ is the rotation operator and Ω represents the Euler angles $\propto$, β and γ.

In general two states $|\Psi_{K_1}^{JM}>$ and $|\Psi_{K_2}^{JM}>$ projected from two intrinsic configurations are not orthogonal to each other even if $|\Phi_{K_1}>$and $|\Phi_{K_2}>$ are orthogonal. Thus, whenever necessary, we do band-mixing using the following equation:

$$\sum_{K'}(H_{KK'}^{J} - E_J N_{KK'}^{J}) = 0 \qquad (4)$$

Results and Discussion

The deformed HF orbits are calculated with non interacting spherical core of ^{132}Sn. Here $2s_{1/2}$, $1d_{3/2}$, $1d_{5/2}$, $0g_{7/2}$, $0h_{9/2}$, $0h_{11/2}$ orbital are taken with spherical single particle energy 3.654, 3.288, 0.731, 0.0, 5.630, 1.955 MeV for protons and $2p_{1/2}$, $2p_{3/2}$, $1f_{5/2}$, $1f_{7/2}$, $0h_{9/2}$, $0i_{3/2}$ orbital are taken with energy 4.462, 2.974, 3.432, 0.0, 1.667, 2.963 MeV for neutrons respectively. We use surface-δ interaction among the active nucleons with nucleon-nucleon interaction strength $V_{pp}=V_{np}=V_{nn}=0.3$MeV [7]. We have performed self-consistent deformed HF calculation for both prolate and oblate deformations. The prolate HF orbits are considered for angular momentum projection studies because prolate solution is energetically lower than oblate solution. We have constructed one, three and five qusiparticle intrinsic configuration by appropriate quasiparticle excitation across proton and neutron Fermi surfaces.

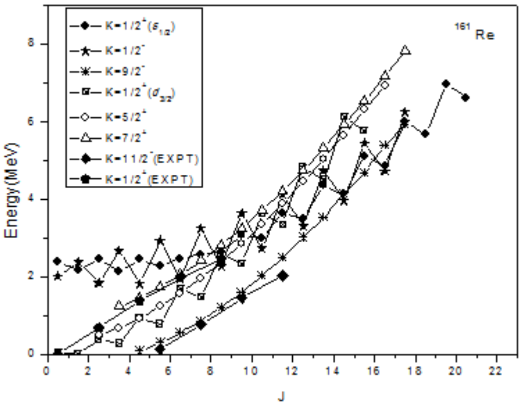

Fig. 1:Comparison of theoretical and experimental spectra of one quasiparticle bands of ^{161}Re. Experimetal results are taken from Ref.[4].

To study the one quasiparticle bands we have kept the unpaired proton in $1/2^+$, $1/2^-$, $9/2^-$ $1/2^+$, $5/2^+$, $7/2^+$ orbits, these are mainly originated from $d_{3/2}$, $h_{9/2}$, $h_{11/2}$, $s_{1/2}$, $d_{5/2}$, $g_{7/2}$ respectively. For three and five quasiparticle bands we have considered $3/2^-$, $5/2^-$ neutron orbits along with above proton orbits. We get high K with K=$35/2^+$, $35/2^-$ and $33/2^+$ for 5-qp and K=$27/2^-$, $27/2^+$ and $25/2^+$ for 3-qp configuration. In our calculation we get high spin upto J=47/2 with excitation energy around 11MeV for these high K bands. Our calculation gives magnetic moment (μ) around $15\mu_N$ for 5-qp high K bands.

The theoretical and experimental one-quasiparticle bands are compared in the Fig.1. Upto bandcrossing our results are agreeing well, for higher states it needs more bandmixing calculation.

Conclusion

The DHF calculation is performed to understand the microscopic structure of ^{161,163}Re. The ground bands as well as excited high spin states are well understood with this model. B(M1), B(E2), Qs, Qo and g-factor and Magnetic moments are calculated for all the cases. A few more one, three and five quasi particle bands with details spectroscopic property are predicted for future experimental study. The systematic of Ground State (GS) of neutron deficient Re isotopes are studied to explain the GS of these nuclei.

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