GENERALIZATION OF GALLAGHER- MOSZKOWSKI RULES TO THREE-QUASIPARTICLE STATES

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Introduction

In a deformed nucleus, coupling of three-quasiparticles in Nilsson states having K values, say, K_1, K_2 and K_3, leads to a quadruplet with resultant $K=|K_1 \pm K_2 \pm K_3|$. These four intrinsic states split up due to the residual interaction among three nucleons; the residual neutron-proton (*n-p*) interaction plays major role in this splitting [1, 2]. In this paper we present some conclusions based on the calculations for band-head energies of three-quasiparticle (3qp) rotational bands by using empirical residual interactions [1-3]. We have also pointed out some special issues involved in these calculations.

The principal motivation behind these calculations is the resolution of problem of ordering of 3qp band-heads in a given quadruplet but not to reproduce the exact values of the band-head energies. The exact estimation of the band-head energies by using this model [1] is not possible because of non-availability of experimental data for the Gallagher Moszkowaski (GM) splitting as well as the Newby Shift energies of all the two-quasiparticle (2qp) doublets comprising the 3qp configurations. In order to handle this situation, we have used the estimated values (if experimental data for GM splitting do not exit for any 2qp doublet) [4]. The second main issue, that we have already pointed out in our compilation [5], is the non-observation of all the members of a given 3qp quadruplet. Thus it is not possible to test the validity of all the rules for a given 3qp quadruplet.

Rules for Ordering of *pnn* and *npp* Configurations

Jain and Jain [1] proposed for the first time two strong rules for *ppn* and *nnp* systems, according to which the state having all the spins in same direction cannot be lowest in energy and the state having spins of like particles parallel while that of unlike antiparallel will be highest in energy. The GM rules provide that the parallel spin (triplet) state lies lower in energy than the antiparallel spin (singlet) state in case of odd-odd nuclei [6], and parallel spin (triplet) state lies higher in energy than the antiparallel spin (singlet) state in case of even-even nuclei [7]. Jain and Jain [1] considered the GM rules and generalized them for the 3qp states. We further refine these rules for fixing the order of all the four members of a given 3qp quadruplet. We note an additional empirical observation that the splitting energy in the doubly odd two quasiparticle (2qp) doublet is of the order of 100 keV while it is of the order of 400-500 keV in doubly even 2qp doublet. On the basis of this empirical fact and the GM rules, we propose the following rules for the ordering of a 3qp quadruplet in case of *npp* and *nnp* systems.

(a) State having spins of like particles parallel and that of unlike particle anti parallel will be highest in energy.
(b) State having all the spins in same direction will be next to the highest state.
(c) State having antiparallel coupling of the like particles and anti-parallel coupling of the unlike particles having larger of the two GM splitting energies, will be at the 2nd position.
(d) State having antiparallel coupling of the like particles and parallel coupling of the unlike particles having larger of the

two GM splitting energies, will be lowest in energy.

It may be pointed out that the rule (a) is a strong rule while deviations from the rule (b) may sometimes be observed due to Coriolis mixing. The rules (c) and (d) are, however, dependent on the information of the GM splitting energies. It should be noted that if input data of GM splitting energies is in accordance with the empirical observation (splitting energies in even-even nuclei are 4 to 5 times greater than that of odd-odd nuclei) then various contributions such as rotational, Newby shift, core particle and particle-particle interactions cannot disturb this ordering [8].

Rules for Ordering of *nnn* and *ppp* Configurations

Jain and Jain [1] also proposed one strong rule for *ppp* and *nnn* configurations. According to this rule, the state having all the spins in the same direction will be highest in energy. But if we consider the GM rules along with the magnitude of GM splitting energies for all the three 2qp doublets taking part in a given 3qp configuration, the ordering of all the four members of given 3qp quadruplet may be fixed as follows:

(a) State having all the spins in same direction will be highest in energy.

(b) State having parallel coupling of 2qp doublet with the highest GM splitting energy will be at the 3rd position.

(c) State having anti-parallel coupling of 2qp pair with highest GM splitting energy and anti-parallel coupling of 2qp pair with lowest GM splitting energy will be at the 2nd position.

(d) State having anti-parallel coupling of 2qp pair with highest GM splitting energy and parallel coupling of 2qp pair with lowest GM splitting energy, will be lowest in energy.

Results and Discussion

The input to band-head energy calculations are the data from the neighboring odd-A, odd-odd, and even-even nuclei. The validity of the above rules has been tested for 15 configurations of the type *nnp/ppn* in 8 nuclei.

The rule (b) given for *nnp/ppn* type configurations appears to be violated in only two cases. This violation is due to low values of GM splitting energy for like particle coupling and Coriolis mixing. Similarly we have tested the validity of rules for 8 *nnn/ppp* type configurations in 7 nuclei. In these cases only one member of given 3qp quadruplet is observed experimentally. So comparison with experimental data is not possible.

It should be noted that due to the empirical fact, (the splitting energy in the doubly odd 2qp doublet is of the order of 100 keV while it is of the order of 400 keV in doubly even 2qp doublet) which is applicable in the case of configurations of the type *nnp/ppn* only, we have considerable splitting among 3qp quadruplet so that rotational energy will not play any major role. That is, it is not necessary that the state having highest K value (and hence maximum rotational energy contribution) will be at the 2nd highest position. But opposite is the situation in the case of configurations of the type *nnn/ppp* where rotational energy is playing an important role for pushing the state having the highest K value (and hence maximum rotational energy) at 2nd highest position.

References

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