Display of variation of MoI of rare earths with varying N, Z

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In the Bohr-Mottelson collective model [1], the nucleus is treated as a rotating vibrating nuclear core. For the axially symmetric deformed core, the rotation takes place about the short axes. Then the nucleus has a moment of inertia J, which is displayed in the level energy equation.

$$E(I)=\hbar^2 I(I+1))/2J. \qquad (1)$$

The moment of inertia J is a function of the nuclear mass and the quadrupole deformation β. A good deal of information on the level spectra of the atomic nuclei can be derived from the study of the MoI J. The variation of the MoI with atomic mass number 'A' was displayed in [1] (p.57). In the earlier study [2] of the SU(3) symmetry in the Interacting Boson model [3], the linear dependence of the ground state MoI on the N_pN_n product of valence nucleon pairs was demonstrated.

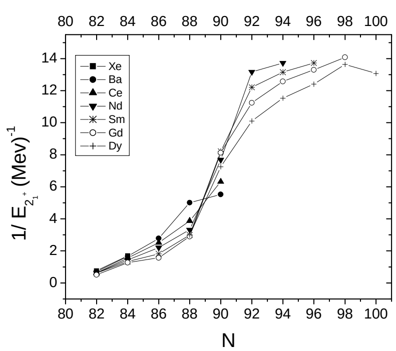

Fig. 1. The plot of $1/E_2$ for quadrant-I.

In the present work, we study the variation of MoI with N, Z in a different way. We limit this study to the 50<Z<82, 82<N<126 region of even-Z even-N nuclei. The major shell space of Z=50-82, N=82-126 can be divided into four quadrants. The β-stability line on the N-Z nuclear chart passes across the quadrants I, II and III diagonally. The Q-IV is vacant. Gupta et al. [4] illustrated that the nuclei in Q-II (Z=66-78, N=82-104), may be grouped into F-spin multiplets [5], in Q-I (Z-50-66, N=82-104) into isotonic multiplets and in Q-III (N>104) into isotopic multiplets, having nearly identical energy level structure.

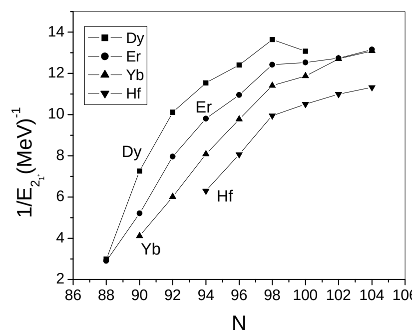

Fig. 2. The plot of $1/E_2$ vs. N for quadrant-II.

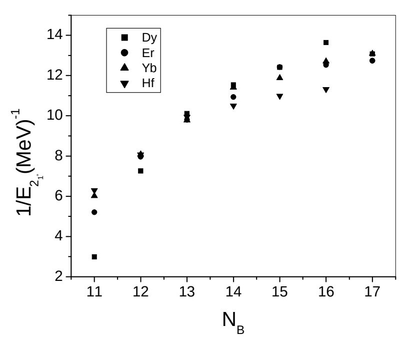

Fig. 3. The plot of $1/E_2$ vs. N_B for quadrant-II.

Here we illustrate these systematics by plotting the inverse of the energy of $I=2_1$ state, i.e. $X=1/E(2_1)$ which is related to the moment of inertia J of the nucleus J=3X. At N=82 closed shell, J (=3X) is almost zero.

As the neutron pairs are added, J increases slowly, and at N=88-90 there is a sharp increase which continues up to N=92 (Fig. 1). There after, there is almost saturation in the values. Here we have linked the J (or X) values of same Z. It is also evident here that the data at each N just lie almost together over each other (see Fig. 1). That is for differing Z, the values of J for each N are nearly the same. Thus the J versus N curves vividly illustrate the occurrences of the isotonic multiplets in quadrant-I as noted earlier in [4]. Also the shape phase transition at N=88-90 for Nd, Sm, Gd, Dy is transparently exhibited. The shape transition in Ce is less sharp and in Ba is the minimum

In fig. 2, the J (or $X=1/E_2$) values for the Dy-Hf nuclei are depicted. Again, the data of same Z are linked. Here the pattern of the J values is very different. The MoI value J ($X=1/E_2$) is decreasing with increasing Z (Dy to Hf).

The total boson number N_B also determines the nuclear structure, as observed in Ref. [5]. The F-spin quantum number is related to N_B by $F=N_B/2$. A plot of J versus N_B (Fig. 3) shows that for each $N_{B,}$ the value of J is almost constant in quadrant II. The data for each N_B almost overlap each other. This illustrates the formation of F-spin multiplets here in Q-II [2, 5].

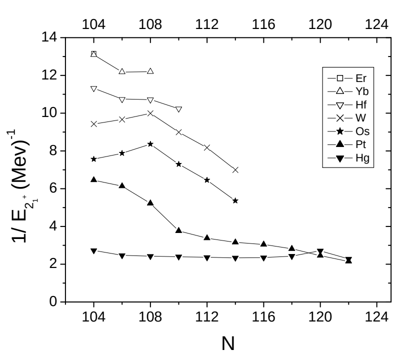

Fig. 4. The plot of $1/E_2$ vs. N for quadrant III.

Next we consider the values of J (or $X=1/E_2$) in Dy-Pt (and Hg) with N>104 in Q-III (Fig. 4). Here the $J=(3/E_2)$ pattern is different. In Yb, Hf there is fair constancy, i.e isotopic multiplets are formed. In W, Os, first there is some rise up to N=108, then slow fall. So, the constancy is somewhat weaker. As is well known, the Os nuclei here tend to be γ-soft. In Pt the same MoI value persists for N=104-108. There after there is continuous fall. In Hg the value of J is constant. Over all in Q-III, the MoI is decreasing with increasing Z.

In conclusion, we find that the quadrant wise presentation of MoI, vividly displays the formation of isotonic multiplets in Q-I, F-spin multiplets in Q-II and the isotopic multiplets in Q-III. Also in each case the role of N. Z is well evident. This agrees with known variation of nuclear deformation in the rare earths in this region of nuclear chart. In quadrant II, the line of beta stability runs almost diagonally, i.e. parallel to the constant total boson number N_B (proton hole bosons, and neutron particle bosons) lines running diagonally in this quadrant.

References

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