VARIATION OF ROTATINAL CONTENT IN $E(2_1^+)$ WITH VALENCE NUCLEON PAIRS

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Treating the energy of $I^{\pi}=2_1^+$ state in even Z - even N nuclei as a sum of rotational energy (ROTE) $bI(I+1)$ and vibrational energy aI plus R-V interaction energy $cI^2(I+1)$, called shape fluctuation energy (SFE), the evaluation of shape transition with increasing nucleon (or hole) pairs product (N_pN_n) is studied. A correspondence of ROTE and $B(E2, 0^+ - 2^+)$ versus the N_pN_n product is illustrated. The constancy of the $E(2_1^+) \times B(E2)\uparrow$ which is a measure of the partial E2 transition strength (Energy Weighted Sum Rule) EWSR at low excitation energies is thus made more transparent.

In earlier work of Gupta et al.[1], the variation of ROTE and SFE with N_pN_n product was studied. However, with increasing deformation of a nucleus, both ROTE and SFE fall, so that a realistic picture of the rotational content in a collective state (say 2_1^+) is not given. Here we illustrate the variation of ROTE/$E(2_1^+)$ versus the N_pN_n product, which shows an exponential growth in the Z=50-82,N=82-126 region and almost linear rise in the Xe-Gd, N<82 region. As earlier, the energy equation

$$E(I) = bI(I+1) + aI + cI^2(I+1) \qquad (1)$$

was used to determine the coefficient a,b,c by a least square fit to the known energies of $I^{\pi} \leq 12^+$ states for each nucleus. Then ROTE in 2_1^+ was evaluated. The exponential growth ROTE is illustrated by a LS fit to the theoretical curve given by

$$Y = \mathrm{ROTE}/E(2_1^+) = B + A[1 - e^{-C(X - X_o)}] \qquad (2)$$

where $X=N_pN_n$. The LS fit equations here were solved by a special method, wherein one has to input approximate values of A,B,C,X_o obtained by hand fit. Then defining $A = A_o + \alpha$ etc., the values of α, β, γ are determined by using the residuals

$$r_i = Y_i(\text{calc}) - Y_i(\text{expt}) \quad (3)$$

in the equation

$$d_i = r_i + \alpha\left(\frac{\partial Y_i}{\partial A}\right)_o + \beta\left(\frac{\partial Y_i}{\partial B}\right)_o + \gamma\left(\frac{\partial Y_i}{\partial C}\right)_o \quad (4)$$

and solving Eq.4 by the standard LS fit method.

Again, the Z = 50-82, N = 82-126 space was divided into 4 quadrants by the mid Z=66, N=104 values so that the space of particle pairs is distinct from that of hole pairs. For the three regions: Ba-Gd (N<82), Dy-Pt (N<104) and Yb-Hg (N>104), data was fit to exponential growth curve (2) with the values of constants as listed below.

Region	B	A	C	X_o
I	0.195	0.833	0.131	5
II	0.04	1.053	0.114	15
III	0.415	0.67	0.167	10
β_2/β_{sp} 2)	0.605	3.175	0.012	0

The variation in these growth constants reveal the underlying physical differences in the three regions.

In a hydrodynamic description, the rotation and vibration represent the 2 branches of a single surface wave motion on a liquid drop. The smooth N_pN_n dependence exhibits the macroscopic deformation effects and the intimate relation of the two branches. Systematic deviations from smooth curve represent the underlying microscopic effects.

Raman et al. [2] plotted the B(E2)↑ and (β_{def}/β_{sp}) versus the N_pN_n product for the Z=50-82, N=82-126 regions on a single plot and obtained a fit to Eq. 2. Their values of A,B,C are similar to our values. Thus a rise in B(E2)↑ corresponds to the rise of ROTE in 2_1^+ state. The constant $E(2_1^+)$ x B(E2)↑ and EWSR implies a falling vibrational component and the rise in B(E2)↑ comes from the increase in rotational content which represents a coherent motion.

References

1. J.B. Gupta et al., Phys. Scripta 41 (1990) 660
2. S. Raman et al., Phys. Rev. C37 (1988) 805