Spherical to axially symmetric shape transition $SU(5) \rightarrow SU(3)$ in the frame work of interacting boson model IBM

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Introduction

In the interacting boson model-1, one assume that low-lying collective quadrupole states can be generated as states of a system of N bosons able to occupy two levels, one with angular momentum J=0, called s, and other with angular momentum J=2, called d-boson. In the second quantized formalism, the most general Hamiltonian containing only one-body and two-body terms can be written as [1]

$$H = \epsilon n_d + a_0 P^{\dagger}.P + a_1 L.L + a_2 Q.Q + a_3 T_3.T_3 + a_4 T_4.T_4$$

The computer program code PHINT was used for the construction of the IBM Hamiltonian. The input parameters EPS, ELL, QQ, OCT and HEX are related to the coefficients ϵ, a_0, a_1, a_2, a_3, a_4 respectively, where $EPS = \epsilon$, $PAIR = a_0/2$, $ELL = 2a_1$, $QQ = 2a_2$, $OCT = a_3/5$, $HEX = a_4/5$.
Interacting boson model has a very definite group structure, that of the group U(6). Different reductions of U(6) gives three dynamical symmetry limits known as harmonic oscillator, deformed rotor and asymmetric deformed rotor which are labeled by $U(5)$, $SU(3)$ and $O(6)$ respectively.

$$U(6) \supset U(5) \supset O(5) \supset O(3) \supset O(2)$$
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A. The E2 and B(E2) transitions

For the E2 transitions one uses the transition operator T(E2) which is related to the quadrupole operator Q of the Hamiltonian

$$T(E2) = e_b Q = \alpha[d^{\dagger}s + s^{\dagger}\tilde{d}]^{(2)} + \beta[d^{\dagger}\tilde{d}]^{(2)}. \quad (1)$$

Also the charge parameters $\alpha(= e_b)$ and $\beta(= e_b\chi)$ in Eq.(1) are called E2SD and E2DD, respectively. In the consistent Q formalism [2], one uses the same form of the quadrupole operator for the Hamiltonian as well as the T(E2) operator (i.e the same value of χ). For this, one employs the level energy data as well as the B(E2) values to determine the parameters of H and T(E2). In the alternative procedure, one uses the SU(3) value of χ for the Hamiltonian and the variables α and β (or χ) for the T(E2) operator.
The B(E2) branching ratio for two transitions from a particular level in a given band to the two states of other band i.e $(I_i \rightarrow I_f/I_f)$, depends on the Alaga value [3]. In the SU(3) [4] these rules are slightly modified because the $(\gamma \rightarrow g)$ and $(\beta \rightarrow g)$ transitions are prohibited, but in the slightly broken symmetry the $(\gamma \rightarrow g)$ transition should be faster than $(\beta \rightarrow g)$ transition. The observed B(E2) ratios are obtained from the γ-ray spectrum data, using the relation [5]

$$\frac{B(E2; I_i \rightarrow I_f)}{B(E2; I_i \rightarrow I'_f)} = \frac{I_\gamma}{I'_\gamma} \times \frac{(E'_\gamma)^5}{(E_\gamma)^5} \quad (2)$$

where I_γ and I'_γ are the intensities and E_γ and E'_γ are the γ-ray energies for $(I_i \rightarrow I_f)$ and $(I_i \rightarrow I'_f)$ transitions.

Result and discussion

Figure 1 shows the collective quantities including the spacing of β_1 band relative to the

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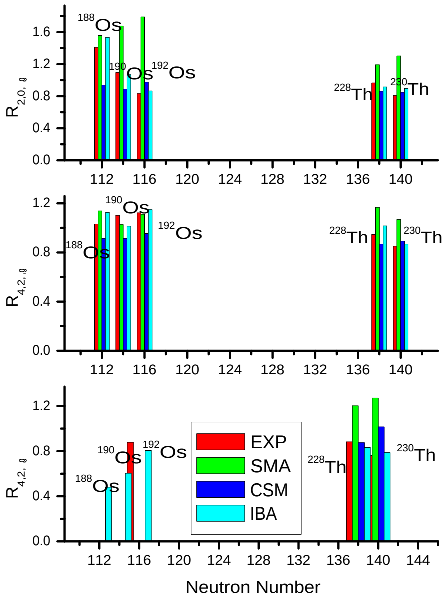

FIG. 1: Experimental and theoretical data for the energy ratios $R_{2,0,\beta,g}$, $R_{4,2,\beta,g}$ and $R_{4,2,\gamma,g}$ for $^{188-192}$Os, $^{228-230}$Th nuclei.

ground state band,

$$R_{2,0,\beta,g} = \frac{E(2^+_\beta) - E(0^+_\beta)}{E(2^+_1)},$$

and

$$R_{4,2,\beta,g} = \frac{E(4^+_\beta) - E(2^+_\beta)}{E(4^+_1) - E(2^+_1)}$$

and spacing of the γ_1 band relative to the ground state band ,

$$R_{4,2,\gamma,g} = \frac{E(4^+_\gamma) - E(2^+_\gamma)}{E(4^+_1) - E(2^+_1)}.$$

Table 1 represent the B(E2) transition values for Os nuclei. We observe that both formalism (IBM and CSM) describe fairly well intra-transition in the ground and γ-bands. Both calculations show small variation in there B(E2) values but are comparable to the experimental data. In many transitions, IBM shows more improvement in results as compared to the CSM calculations.

TABLE I: Some B(E2) values for $^{188-190}$Os obtained with IBM and compared with the corresponding Experimental data and CSM approach.

BE(2)	Exp	IBM	CSM	Exp	IBM	CSM
$2_g \to 0_g$	0.502	0.504	0.456	0.468	0.454	0.360
$4_g \to 2_g$	0.776	0.713	0.744	0.623	0.654	0.579
$6_g \to 4_g$	0.843	0.757	0.918	0.679	0.702	0.708
$8_g \to 6_g$	0.927	0.734	1.062	0.814	0.686	0.814
$2_\gamma \to 0_g$	0.047	0.0078	0.165	0.039	0.0040	0.202
$2_\gamma \to 2_g$	0.150		0.150	0.227	0.289	0.155
$4_\gamma \to 2_g$	0.009	0.0028	0.163	0.005	0.003	0.220
$4_\gamma \to 4_g$	0.036	0.0032	0.001	0.229	0.245	0.229
$6_\gamma \to 4_g$	0.001	0.001	0.194	0.003	0.009	0.269
$6_\gamma \to 6_g$	0.164	0.0029	0.227	0.238	0.259	0.270

Conclusion

The interacting boson model was applied to five nuclei ^{188,190,192}Os, ^{228}Th and ^{230}Th. The calculated B(E2) values agree fairly well with the experimental data. Some E2 transitions which are forbidden in O(6) limit become allowed because of the broken symmetry of the three body potential.

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