The study of nuclear structure of $^{76-78}$Kr and ^{24}Mg nuclei in the frame work of interacting boson model

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Introduction

The phenomenological Interacting Boson Model (IBM) initially introduced by Arima and Iachello[1] has been rather successful in describing the properties of several medium and heavy mass nuclei. There are several equivalent ways of writing Hamiltonian H [1]. The most general Hamiltonian that has been used to calculate the level energies is

$$H = \epsilon n_d + a_0 P^\dagger.P + a_1 L.L + a_2 Q.Q + a_3 T_3.T_3 + a_4 T_4.T_4 \quad (1)$$

where

$$n_d = (d^\dagger.\tilde{d}), \quad P = \frac{1}{2}(\tilde{d}.\tilde{d}) - \frac{1}{2}(\tilde{s}.\tilde{s})$$
$$L = \sqrt{10}\left[d^\dagger \times \tilde{d}\right]^{(1)}$$
$$Q = \left[d^\dagger \times \tilde{s} + s^\dagger \times \tilde{d}\right]^{(2)} - \frac{1}{2}\sqrt{7}\left[d^\dagger \times \tilde{d}\right]^{(2)}$$
$$T_3 = \left[d^\dagger \times \tilde{d}\right]^{(3)}, \quad T_4 = \left[d^\dagger \times \tilde{d}\right]^{(4)}.$$

Here n_d is the number of operator of d bosons, $s^\dagger$, $d^\dagger$ and s, d represent the s- and d- boson creation and annihilation operators. Also P, L, Q, T_3 and T_4 in eq.(1) are the pairing, angular momentum, quadrupole, octopole and hexadecapole operators, respectively.

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

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

Also the charge parameters $\alpha(= e_b)$ and $\beta(= e_b\chi)$ in eq.(2) 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) [1], 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 the $(\beta \rightarrow g)$ transition. The observed B(E2) ratios are obtained from the γ-ray spectrum data, using the relation [4]

$$\frac{B(E2; I_i \rightarrow I_f)}{B(E2; I_i \rightarrow I'_f)} = \frac{I_\gamma}{I'_\gamma} \times \frac{(E'_\gamma)^5}{(E_\gamma)^5} \quad (3)$$

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. For O(6) nuclei the first necessary condition is to test the validity of the expression for the B(E2) ratio similar to

$$\frac{B(E2; 4_1^+ \longrightarrow 2_1^+)}{B(E; 2_1^+ \longrightarrow 0_1^+)} = \frac{10}{7}\frac{(N-1)(N-5)}{N(N+4)} = 0 \quad (4)$$

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Results and Discussion

We present the $(BE2; J \to J-2)$ reduced transition strength which is normalized to the respective $(BE2; 2_1 \to 0_1)$ values and compared them with anharmonic vibrator, an axially deformed rotor and X(5) predictions. It is clear from the Figure 1, that the $^{76-78}$Kr, ^{24}Mg nuclei closely follow the deformed rotor nuclei. For ^{76}Kr the transition values lies between the X(5) symmetry value and rotor values and in case of ^{78}Kr the transition values lies near the rotor values. For ^{24}Mg the transition values lies beyond the rotor values.

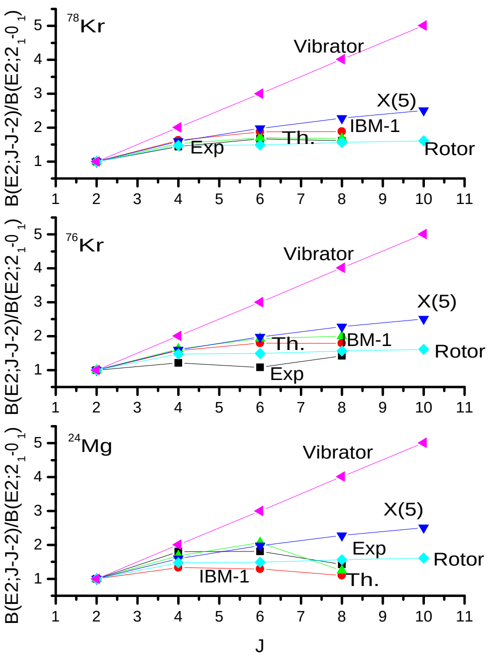

FIG. 1: Variation of $B(E2; J \to J-2)/B(E2; 2_1 \to 0_1)$ with angular momentum (J)

Some important reduced E2 transition probabilities are given in Table 1. In the most cases the deviations from the experimental values are smaller than 10%. These calculated values are compared with experimental values and calculated IBM-1 and IBM-2 values.

B(E2)$e^2 fm^4$	Exp.	IBM-1	IBM-2
^{76}**Kr**			
$B(E2; 2_1^+ \to 0_1^+)$	0.1640(57)	0.1623	0.1092
$B(E2; 2_2^+ \to 0_1^+)$	0.0090	0.0046	0.0016
$B(E2; 2_2^+ \to 2_1^+)$	0.0038	0.1035	0.0653
$B(E2; 3_1^+ \to 2_1^+)$	0.0019	0.0078	0.0025
$B(E2; 4_1^+ \to 2_1^+)$	0.1982(140)	0.2561	0.1945
$B(E2; 4_2^+ \to 2_1^+)$	0.0011(4)		0.0010
$B(E2; 4_2^+ \to 2_2^+)$	0.0858(286)	0.1211	0.1174
$B(E2; 4_2^+ \to 4_1^+)$	0.0209(76)	0.0613	0.760
$B(E2; 5_1^+ \to 3_1^+)$	0.1907(760)	0.1462	0.1448
^{78}**Kr**			
$B(E2; 2_1^+ \to 0_1^+)$	0.1206(79)	01213	0.1278
$B(E2; 2_2^+ \to 0_1^+)$	0.0030(4)	0.0038	0.0047
$B(E2; 2_2^+ \to 2_1^+)$	0.0118(39)	0.0943	0.0958
$B(E2; 4_1^+ \to 2_1^+)$	0.1749(138)	0.1974	0.2250
$B(E2; 4_2^+ \to 2_2^+)$	0.1147(118)	0.1010	0.1283
$B(E2; 4_2^+ \to 4_1^+)$	0.0474 (118)	0.0508	0.0514
$B(E2; 5_1^+ \to 3_1^+)$	0.1523(223)	0.1145	0.1266

Conclusion

The results of this work show that the IBM-1 provides a good description of even-even $^{76-78}$Kr and ^{24}Mg isotopes of the nuclei. The interacting boson model can reproduce a considerable quantity of experimental data and gives useful indications where data are lacking. One observe the transitions between three limit symmetries of the model, corresponding to different nuclear shapes.

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