Study of ^{152}Sm using interacting boson model-1

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Introduction

The energy ratio R_4 (=$E4_g/E2_g$) = 3.01 and R_β (=$E0_\beta/E2_g$) = 5.62 for ^{152}Sm (N=90) nucleus and these ratios are very close to the X(5) symmetry limiting values (R_4 = 2.9 and R_β = 5.65). Therefore, ^{152}Sm is the best example of X(5) symmetry of IBM-1 [1]. The large experimental data [2, 3, 4] is now available for ^{152}Sm from decay and reaction work. The interacting boson model-1 (IBM-1) [1] is used to study the energy spectra, B(E2) values/ ratios for inter-band and intra-band transitions. The theoretical results of present IBM calculation are compared with the predictions of DPPQ, BEM and RVM models [5-9] and the experimental data [2, 3, 4, 10, 11].

Result and Discussion

In ^{152}Sm the members of g-band and β_1-band are available up to 14^+, for β_2 up to 2^+ and γ_1 up to 5^+ [2]. In the present calculation the band-head of the g-, β- and γ–bands are very close to the experiment and the spacing of different members in the different bands is also like in the experiment [2-3]. For $K^\pi = 0^+_3$ band the calculated 0^+ state lies at 1.496 MeV compared to the 1.0829 MeV in experiment. The variation of E_I with spin (I) for different bands is presented in Fig. 1. The slopes of E_I vs. I for different bands in experiment [2-3] are similar to the theoretical slopes.

The variation of B(E2;Ig→Ig-2)

The variation of B(E2;Ig→Ig-2) vs. spin (Ig) is shown in Fig. 2. The experimental [3,4] B(E2) values increases rapidly on increasing Ig from 2^+ to 10^+ indicating the sharp change in the nuclear shape. In the previous IBM calculation [5], the B(E2) first increases when Ig increases from 2^+ to 4^+ and it decreases while Ig increased from 4^+ to 8^+ *unlike* the observed trend. But in the present IBM work, the B(E2) values follow the observed trend and values the more closer than other theoretical data. The BEM6 [6] data points are much below the observed data points. However, the BEM4 [6] values are close to present calculation. Only two data points are available for DPPQ [7], RVM1 and RVM2 [8, 9] to find any definite conclusion.

The theoretical results of vibrational model (VM), SU(5), O(6) and SU(3) limiting values, present calculation and IBM calculation of [5] along with the experimental data for B(E2) values[3,4] are shown in Fig. 2. It is clear that the observed data is quite below from the VM limiting values and is lying between SU(5) and SU(3) limiting values. The B(E2) values from present IBM calculation and BEM4 [6] are very close to the experimental data points and also present IBM calculation produces the observed slop of this ratio with I_g.

B(E2) ratios for β– band

In the β-decay of ^{152}Eu, 13 new transitions and 5 new levels were reported [10], which are included here for useful discussion.

In Table of Isotopes [11], the B(E2) ratio for ($2_\beta \rightarrow 0_g/2_g$) transition is 0.84 which is more than the SU(3) limiting value 0.7. This ratio may be large due to 0.2% M1 and 4% E0 mixing in the ($2_\beta \rightarrow 2_g$) 0.6886 MeV γ–ray. In a recent compilation work [3] this ratio is 0.17(1) compared to the theoretical value 0.12 & DPPQ value 0.076 [7].

The ($2_\beta \rightarrow 4_g$) 0.444 MeV γ–ray was overlapping with ($2^- \rightarrow 3_\gamma$) transition and gives B(E2; $2_\beta \rightarrow 2_g/4_g$) = 0.35 (the intensity of ($2^- \rightarrow 3\gamma$) γ–ray was 12 which gives this ratio 0.56) [11]. But in the recent compilation [3], this ratio is 0.30(3) compared to 0.030(1) in decay of ^{152}Eu [10].

In Table of Isotopes [11]; the ($4_\beta \rightarrow 4_g$) 0.6565 MeV γ–ray was not pure E2 but has 16% M1 and 5% E0 mixing, which gave the B(E2;$4_\beta \rightarrow 2_g/4_g$) = 0.11 and B(E2;$4_\beta \rightarrow 4_g/6_g$) = 0.76, but Peker [3] deduced these ratios equal to 0.21(2) and 3.6(22); Stewart et al. [10] deduced 0.11(2) and 0.08(2); and in the present IBM calculation these ratios are 9.3 and 231, respectively.

For ($6_\beta \rightarrow 4_g/6_g$), ($8_\beta \rightarrow 6_g/8_g$) and ($10_\beta \rightarrow 8_g/10_g$) transitions; the observed B(E2) ratios lie away from the respective Alaga values and theoretical values are close to the observed values. It is also evident that (β→β) transitions are stronger than (β→g) which is supported by present IBM calculation values (Results will be presented).

B(E2) ratios for γ–band

The experimental data was available for 21 ratios, for transition from γ–band. It is evident from the observed data that the (γ→β) transitions are stronger than (γ→g); and (γ→ γ) transitions are stronger are than (γ→β). Theory supports these aspects. Most of the B(E2) ratios lie on the transition from SU(5) to SU(3).

The theoretical B(E2) ratios for the transition from 5_γ, 6_γ, 7_γ and 9_γ states were not available from any previous work [6,7,8,9]. The present study is extended for these four states along with three other lower states i.e. 2_γ, 3_γ and 4_γ states for calculating the B(E2) ratios. The B(E2) ratios for the transition from 2_γ, 3_γ, 4_γ 5_γ, 6_γ, 7_γ and 9_γ states are compared with the present work and found that most of the theoretical values are close to the observed values (Results will be presented).

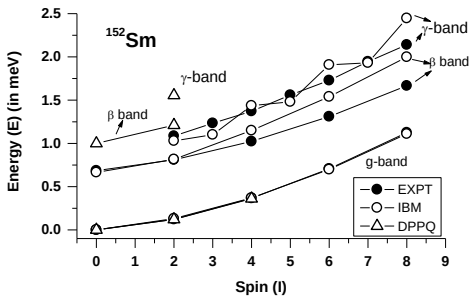

Fig 1: The variation of E_I with spin (I).

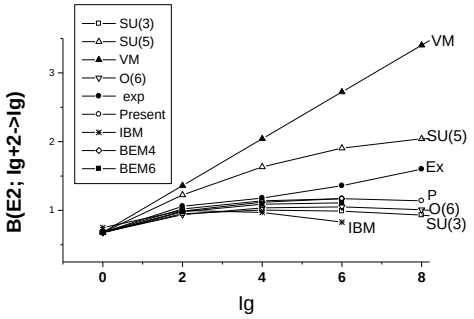

Fig 2: The variation of B(E2;Ig→Ig-2) with Ig for ground band. The experimental data of [3,4] are shown by solid circles (●), present IBM calculation by hollow circles (○), BEM4 [6] by hollow diamond (◊), BEM6 [6] by solid square (■), IBM [5] by star (*). The vibrational model (VM) is shown by (▲), SU(5) limiting values by (Δ), O(6) limiting values by (∇) and SU(3) limiting values by (□).

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