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Energy Spectrum and B(E2) transitions of ND-144 Using IBM Results

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Abstract:

The excited energy state of three bands (ground, beta and gama bands) and E2 transitions probability are calculated using the collective models IBM-1 and IBM-2, these calculated results compared with the experimental results. These calculations were made for the even-even nucleus ND-144.

Introduction:

The study of nuclear structure was started by using the low lying spectra for the heavy nuclei because of the collective quadruple motion of the nucleus. In the last few years a new description for the collective quadruple states was observed using the boson variables which divided into two parts: scalar (J=0) called s-boson and quadruple (J=2) called d-boson [1]. This new description is performed by two nuclear models (Interacting Boson Model) IBM-1 and IBM-2, which put by (Otusuka and Arima, Iachell and Talima-1978). The total number of boson calculated from nearest closed shell [2]. The two models of Arima and Iachell have been applied to the calculation of excited energy states and B(E2) transitions. The IBM-2 model is more detailed than IBM-1 because of a distinction is made between proton and neutron boson and IBM-2 include all states of IBM-1 as well as the mixed symmetry states which exists outside the IBM-1 space [3].

Theoretical Model

The IBM-1 Hamiltonian used for calculating the energy spectra for Nd-144 is as following [4]:

$$H = \epsilon_d \; n_d \; + \; a_0\, p.p \; + \; a_1 \, L.L \; + \; a_2 \, Q.Q \; + a_3 \, T_3.T_3 + a_4 T_4.T_4 \quad \ldots\ldots\ldots.(1)$$

Where:

$$n_d = (d^{+}.d)$$

$$p = \frac{1}{2}(d.d) - \frac{1}{2}(s.s)$$

$$L = 10(d^{+} \times d)^{(1)}$$

$$Q = (d^{+} \times s + s^{+} \times d)^{(2)} - \frac{7}{2}(d^{+} \times d)^{(2)}$$

$$T_3 = (d \times d)^3\,, \qquad T_4 = (d \times d)^4$$

And $(s^{+}, d^{+}), (s, d)$ means creation and inhalation operators respectively.

In the same model and to calculate the E2 transition we used the following equation:

$$T(E2) = \alpha\,(d^1 s + s^1 d)^2 + \beta (d^1 d)^2 \ldots\ldots\ldots\ldots.(2)$$

Where α and β are two parameters used for fitting the experimental results.

The IBM-2 Hamiltonian used for calculating the energy spectra has the following form [5]:

$$H = E_p\, n_p \; + E_n n_n + K Q_p.Q_n + V_{pp} + V_{nn} + M_{pn} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Which includes besides a neutron-proton part , a neutron-neutron and proton-proton interaction.

In this model the E2 transition operator is [6]:

$$T(E2) = e_p Q_p + e_n\, Q_n$$

Where $e_p\ and\ e_n$ means the effective charge of proton and neutron respectively and Q means the quadruple operator.

Results and discussion:

To study the nuclei shape and structure , it is more important to study the levels scheme and the quadruple transitions. The study of the level structure includes the calculation of energy levels of these bands: (ground, beta and gamma)using the Hamiltonian given in equation (1) for IBM-1 and equation (3) for IBM-2, in these calculations was found that better results were achieved using the following values of parameters appeared in equation (1): $a_0 = 0.035, a_1 = 0.022, a_2 = -0.0002, a_3 = 0.025 \ \ and \ \ a_4 = 0.015$

Figure show a comparison between the experimental energy levels of the three bands and the two models results, our results are in good agreement accord with the experimental one especially for the ground state band since IBM-1 deals with low laying spectra, on the other hand it not possible to achieve good fitting between IBM-2 and experimental because of the many parameters appeared in the former. The reason for the disagreement between the experimental and theoretical results of o_2 state is : this level is not collective since the used value of the Hamiltonian parameters is unable to fit the experimental values of the level.

Also we calculate the $E4_1/E2_1$ ratio which take the values: 1.88 (exp.), 2.06(IBM-1) and 2.3 (IBM-2) , these values indicate that the nucleus closed to the SU(5) limit of IBM [7].

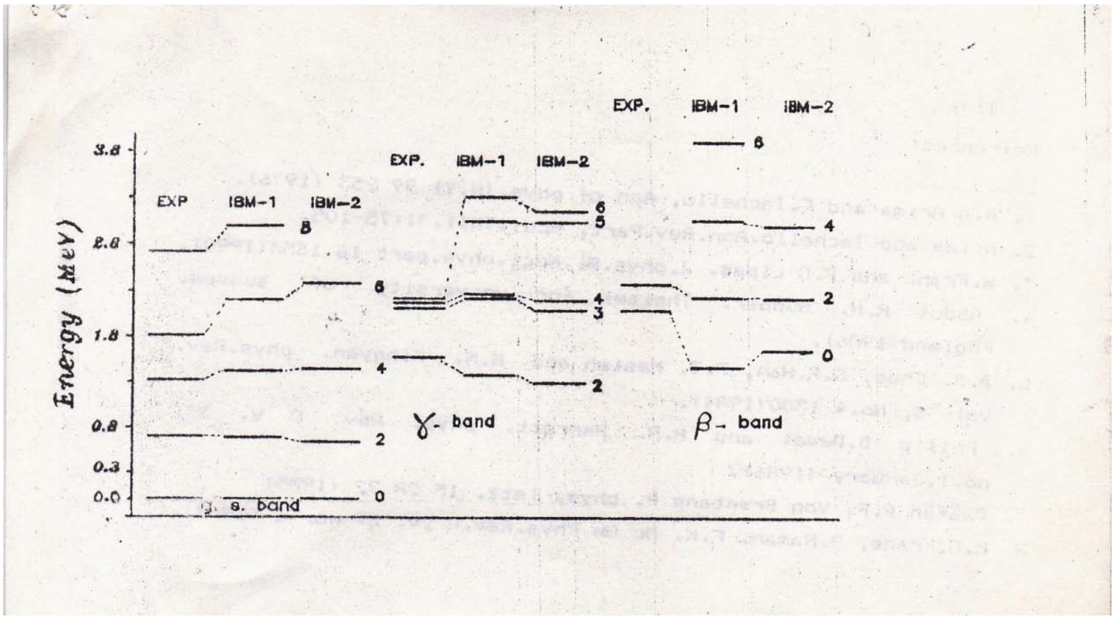
The reduced transition probability B(E2) was also calculated using equation (2) of IBM-1, where the parameters used: α=0.125 e.b and β=0.076 e.b, the values were varied smoothly to give good agreement between the theoretical and experimental for the transition $2_1 \rightarrow 0_1$. Table (1) shows the B(E2) values for different transitions. There is no valiable experimental data to fit the calculated results, we find only two experimental results $[B(E2; 2_1 \rightarrow 0_1), \ B(E2; 4_1 \rightarrow 2_1)]$.

Conclusion:

Two models are used in this study to obtained good agreement with experimental energy levels and B(E2) transitions. The models requires a careful choice of many parameters to make the fitting. The two models results show that the Nd-144 within SU(5) limit.

Table (1) Probability of electric quadruple transition for Nd-144 in e.b unit

I_i	I_f	Exp.	IBM-1
2_1	0_1	0.1020(32)	0.1057
4_1	2_1	0.08(1)	0.1707
6_1	4_1		0.1995
2_2	2_1		0.1706
2_2	0_1		0.0001
3_1	2_1		0.0001
3_1	2_2		0.1424
4_2	4_1		0.0949
4_1	3_1		0.0061
5_1	3_1		0.1023
5_1	4_2		0.0465
6_2	5_1		0.0066



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