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# THE IBM-1 STUDY FOR SOME Ce ISOTOPES

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**Abstract-**The structure of even-even Ce isotopes with neutron number $72 \leq N \leq 76$ are studied within the framework of the Interacting Boson Model (IBM-1). The excitation energies and the B(E2) values of the above nuclei are calculated. It is found that the agreements between the calculated and observed data are much better in the model of the effective boson consideration.

## 1. INTRODUCTION

The nuclei $^{130-134}$Ce have 8 valance protons outside the closed shell Z=50 and 10, 8 and 6 neutron holes according to N=82, respectively. Their structure is therefore determined by the interplay of collective and quasi-particle degrees of freedom. As such these nuclei have been commonly considered to exhibit γ-unstable-like properties

The even-mass Ce isotopes have been extensively investigated both theoretically and experimentally in the last years with special emphasis on interpreting experimental data via collective models [1-8].

In the present work the energy levels with positive parity and B(E2) transition probabilities of Ce isotopes with neutron number $72 \leq N \leq 76$ were study in the framework of IBM-1, and compare the experimental data to the calculated results.

## 2. THE MODEL

The interacting boson model of Arima and Iachello [9] has become widely accepted as a tractable theoretical scheme of correlating, describing and predicting low-energy collective properties of complex nuclei. In this model it was assumed that low-lying collective states of even-even nuclei could be described as states of a given (fixed) number N of bosons. Each boson could occupy two levels one with angular momentum L=0 (s) and L=2 (d). In the original form of the model, known as IBM-1, proton- and neutron-boson degrees of freedom are not distinguished. The most general two-body hamiltonian the boson space is written in terms of the generators of the groups SU(6). It has been shown, that in three special cases this hamiltonian can be expressed in terms of generators of a subgroups of U(6), namely the SU(5) group [10], SU(3) group [11] and O(6) group [11-13]. The extreme cases, which permit the construction of analytic solutions of energy spectra and transitions rates, correspond to the spherical vibrator, the symmetric rotor, and the γ-unstable rotor, respectively of the geometrical shape.

The most general IBM-1 two-body collective Hamiltonian between bosons can be expressed as [12]

$$H=\varepsilon_s s^{\dagger} s+\varepsilon_d(d^{\dagger} \cdot d) + \sum C_L[(d^{\dagger} d^{\dagger})^{(L)} \cdot (dd)^{(L)}]+\tfrac{1}{2} v_0[(d^{\dagger} d^{\dagger})_0^{(L)} s^2+(s^{\dagger})^2 (dd)_0^{(0)}]$$
$$+(\tfrac{1}{2})^{1/2} v_2 [[(d^{\dagger} d^{\dagger})^{(2)} ds]_0^{(0)}+[s^{\dagger} d^{\dagger} (dd)^{(2)}]_0^{(0)}]+\tfrac{1}{2}u_0(s^{\dagger})^2 s^2+1/(5)^{1/2} u_2 s^{\dagger} s(d^{\dagger} \cdot d) \qquad (1)$$

Where $\varepsilon_s$ and $\varepsilon_d$ are the single-boson energies, and $C_L$, $v_L$ and $u_L$ describe the two-boson interaction.

### 2.1. Electromagnetic Transitions

The E2 transition operator must be a hermitian tensor of rank two and conserve the number of bosons. Since, with these constraints, there are two operators possible in lowest order, the general E2 operator can be written as [14]

$$T_m(E2) = \alpha_2 [(s^{\dagger} d+ds)]_m^{(2)} + \beta_2[d^{\dagger} d]_m^{(2)} \qquad (2)$$

where $\alpha_2$ plays the role of the effective boson charge and $\beta_2=-(7)^{1/2}/2\alpha_2$. The B(E2) strength for the E2 transitions is given by

$$B(E2;L_i \rightarrow L_f) = 1/(2L_i+1)^{1/2} \, |\langle L_f || T_m (E2) || L_f \rangle|^2 \qquad (3)$$

## 3. RESULTS

In order to calculate the B(E2) values, we first searched for the suitable values of $\alpha_2$ which can best reproduce the experimental B(E2) values within the ground band. Different $\alpha_2$ values for each Ce isotopes have been calculated by using the method, which was proposed by Wolf *et. al.* [15]. The experimental and calculated energy levels of Ce isotopes were given table 1. In table 2 the calculated and observed B(E2) values for above nuclei were given. As can be seen from table 1 and 2 the calculated values are in agreement with the experiment.

**Table1.** Energy levels for $^{130-134}Ce$ isotopes in keV
Experimental values are taken from ref. 16.

| Nucleus | Energy Level | Experiment | This Work (IBM-1) |
|---|---|---|---|
| $^{130}Ce$ | $0_1^+$ | 0 | 0 |
| | $2_1^+$ | 253.9 | 237 |
| | $4_1^+$ | 710.4 | 691 |
| | $6_1^+$ | 1324.0 | 1278 |
| | $8_1^+$ | 2052.6 | 1864 |
| | | | |
| $^{132}Ce$ | $0_1^+$ | 0 | 0 |
| | $2_1^+$ | 325.5 | 306 |
| | $4_1^+$ | 859.1 | 811 |
| | $6_1^+$ | 1497.6 | 1337 |
| | | | |
| $^{134}Ce$ | $0_1^+$ | 0 | 0 |
| | $2_1^+$ | 409.2 | 394 |
| | $4_1^+$ | 1048.9 | 988 |
| | $6_1^+$ | 1863.2 | 1705 |

**Table2.** B(E2) values for $^{130-134}$Ce isotopes in $e^2b^2$
Experimental values are taken from refs. 3, 4, 5 and 7.

| Nucleus | Transition | Experiment | This Work (IBM-1) |
|---|---|---|---|
| $^{130}$Ce | $2_1^+ \rightarrow 0_1^+$ | 0.340<br>0.319 | 0.33 |
| | $4_1^+ \rightarrow 2_1^+$ | 0.559<br>0.656<br>0.52 | 0.58 |
| | $6_1^+ \rightarrow 4_1^+$ | 0.342<br>0.39 | 0.42 |
| | $8_1^+ \rightarrow 6_1^+$ | >0.39 | 0.51 |
| | | | |
| $^{132}$Ce | $2_1^+ \rightarrow 0_1^+$ | 0.376<br>0.39<br>0.320 | 0.36 |
| | $4_1^+ \rightarrow 2_1^+$ | 0.35<br>0.446 | 0.38 |
| | $6_1^+ \rightarrow 4_1^+$ | 0.55<br>0.54<br>0.494 | 0.53 |
| | $8_1^+ \rightarrow 6_1^+$ | >0.27 | 0.33 |
| | | | |
| $^{134}$Ce | $2_1^+ \rightarrow 0_1^+$ | 0.213<br>0.197 | 0.21 |
| | $4_1^+ \rightarrow 2_1^+$ | 0.168<br>0.117 | 0.15 |
| | $6_1^+ \rightarrow 4_1^+$ | 0.075 | 0.11 |
| | $8_1^+ \rightarrow 6_1^+$ | >0.106 | 0.12 |

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