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CALCULATION OF REDUCED TRANSITION PROBABILITIES B(E2) IN ^{114,116,118,122}Cd BY INTERACTING BOSON MODEL (IBM-1)

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Abstract–This paper reports on the electric quadrupole reduced transition probabilities $B(E2)$ between 6^+ to 4^+ and 4^+ to 2^+ states of ^{114,116,118,122}Cd isotopes using interacting boson model (IBM-1). The values of reduced transition probabilities of ^{114}Cd, ^{116}Cd, ^{118}Cd, ^{122}Cd nuclei from transitions 4^+ to 2^+ and 6^+ to 4^+ are 0.180 and 0.237 e^2b^2, 0.197, and 0.253 e^2b^2, 0.194 and 0.243 e^2b^2, and 0.143 and 0.168 e^2b^2, respectively. In addition, the systematic $B(E2)$ values are studied as a function of neutron numbers from $N = 66, 68, 70, 74$. The calculated results of $B(E2)$ in IBM-1 are in good agreement with experimental values.

***Keywords*:** reduced transition probabilities, Cd, 6^+, 4^+, 2^+ states

1. Introduction

The interacting boson model 1 (IBM-1), developed by Arima and Lachello [1], is a nuclear model developed for the description of collective structures. In the first version, IBM-1, no district ion is made between neutron and proton degree of freedom. There is no clear connection with a microscopic structure that it is important to treat the neutron and proton degrees of freedom independently. It can provide theoretical level energies and transition strengths while including anharmonicities from residual interactions. The IBM employs a severely truncated model space and as such, calculations are possible for nuclei with N nucleons, providing a quantitative mechanism to compare experimental results and calculated values [2,3].

Neutron rich Cd isotopes are particularly interesting because they are existed with two less of protons near the magic number proton 50. It has been considered as an anharmonic vibration-like nucleus. This corresponds to the $U(5)$ limit in the interacting boson model (IBM). The even-even nuclei for $N = 48$ have recently been studied both theoretically and experimentally [4-8]. Therefore it is interesting to study the valance mirror nuclei for $Z = 48$ (Cd). However, a detailed calculation of $B(E2)$ values of Cd isotopes with even neutron $N = 66 - 72$ are not been studied yet. At present we have reported reduced transition probabilities at different stages of even Cd isotopes with mass $A = 114$ to 124 (except $A = 120$) using IBM-1. There is no experimental data on $E2$ transitions for ^{120}Cd.

2. Theory and Method of Calculation

Reduced Transition Probabilities B(E2)

The electric quadrupole reduced transition probabilities in interacting boson model IBM-1 is given for the vibration limit $U(5)$ [9]:

$$B(E2;L+2\to L)\downarrow=\alpha^2\frac{1}{4}(L+2)(2N-L),$$

where N is the boson number, which is equal to half the number of valence nucleons (proton and neutrons). The symbol α is the effective charge of the bosons and L is the state that the nucleus translates to it and from the given experimental value of the transition $(2^+\to 0^+)$, we can calculate the value of the parameter α for each isotopes and use this value to calculate the reduced transition $6^+\to 4^+,\ 4^+\to 2^+,\ 2^+\to 0^+$:

$$1w.u = 5.94\times 10^{-6}\times A^{4/3}\times B(E2)e^2b^2. \tag{2}$$

3. Results and Discussion

The even-even nuclei with $Z=48$ and $N=64-72$ indicate excellent opportunities for studying the behavior of the total low-lying $E2$ strengths in the transitional region from deformed to spherical nuclei. In order to calculate the strengths $B(E2)$ the reduced transition probabilities, one can fit the calculated absolute strengths $B(E2)$ of the transitions within the ground state band to the experimental ones.

Table 1. Reduced transition probability B(E2)↓

Nuclei	Boson #	Transition level	$B(E2)_{Ref}$, W.U.	e^2b^2	$B(E2)_{IBM-1}$, e^2b^2
^{114}Cd	9	$2^+\to 0^+$	31(19)	0.102(62)	
		$4^+\to 2^+$	62(4)	0.204(13)	0.180
		$6^+\to 4^+$	44(17)	0.145(56)	0.237
^{116}Cd	8	$2^+\to 0^+$	33.5(2)	0.113(7)	
		$4^+\to 2^+$	57(14)	0.192(47)	0.197
		$6^+\to 4^+$			0.253
^{118}Cd	7	$2^+\to 0^+$	33(3)	0.113(10)	
		$4^+\to 2^+$	>61	>0.209	0.194
		$6^+\to 4^+$			0.243
^{122}Cd	5	$2^+\to 0^+$	26(14)	0.093(53)	
		$4^+\to 2^+$			0.149
		$6^+\to 4^+$			0.168

Table 1 shows a summary of boson number, $B(E2)\downarrow$ between $B(E2;6^+\to 4^+)$, $B(E2;4^+\to 2^+)$, $B(E2;2^+\to 0^+)$, using IBM-1 framework. At first the value of the effective charge α of the IBM-1 was determined by normalizing the experimental data $B\left(E2;2_1^+ \to 0_1^+\right)$ of each isotope by using Eq. (1). Using known experimental value of the reduced transitions probabilities $(2 \to 0)$ we have calculated the value of the parameter α for each isotope and using these values the reduced transitions $B\left(E2\right)\downarrow$ $(6^+ \to 4^+)$, $(4^+ \to 2^+)$ and $(2^+ \to 0^+)$ were calculated. The calculated reduced transition probabilities from 4^+ to 2^+ levels and 6^+ to 4^+ of ^{114}Cd, ^{116}Cd, ^{118}Cd, ^{122}Cd nuclei are 0.180 and 0.237 e^2b^2, 0.197, and 0.253 e^2b^2, 0.194 and 0.243 e^2b^2, and 0.143 and 0.168 e^2b^2, respectively. The $B\left(E2\right)\downarrow$ values are presented in Table 1, where the available corresponding experimental data is compared with the present IBM-1 calculations and other previous works [4,10-18]. It is important to note that there is no experimental data $(2^+ \to 0^+)$ in literature on $E2$ transitions for ^{120}Cd.

The theoretical and experimental $B\left(E2\right)\downarrow$ values are plotted as a function of neutrons in Fig. 1. For each isotope the calculated reduced transition probabilities from $(6^+ \to 4^+)$ and $(4^+ \to 2^+)$ using IBM-1 are compared with experimental data. The calculated data are in excellent agreement with experimental data. It is shown that $B\left(E2\right)$ value in $(6^+ \to 4^+)$ transition are greater than $(4^+ \to 2^+)$ transition. From the Fig. 1 the values of $B\left(E2\right)$ as a function of neutrons do not vary significantly, one can understand that the electric quadrupole reduced transition probabilities do not strongly depend on the neutron number but strongly depend on the two-hole states of atomic number $Z = 48$.

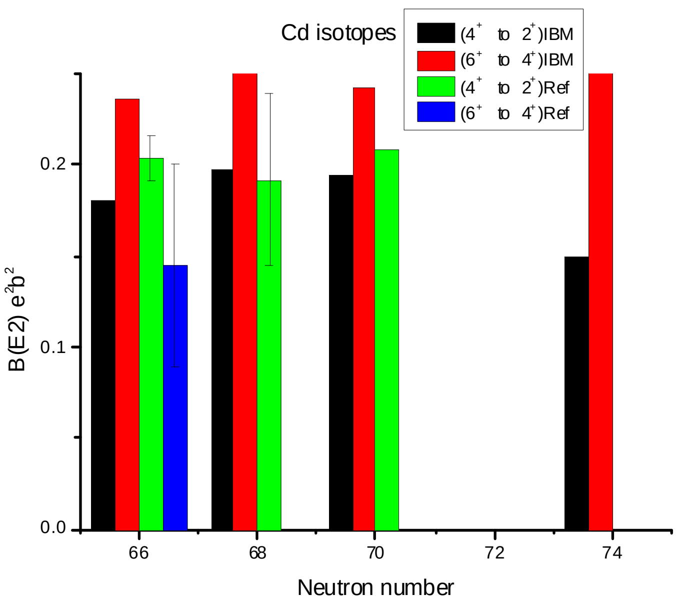

Fig. 1. Reduced transition probabilities $B\left(E2:6^+ \to 4^+\right)$ and $B\left(E2:4^+ \to 2^+\right)$ as a function of even neutron numbers of $^{114,116,118,\,122}$Cd isotopes.

4. Conclusion

The reduced transition probabilities between 6^+ to 4^+ and 4^+ to 2^+ of even-even Cd ($Z = 48$, $N = 66$, to 74) have been studied within the framework of Interacting Boson Model 1. It was found that electric quadrupole reduced transition probability are in good agreement with the previous experimental results for ^{114}Cd to ^{122}Cd [10-18]. The values $B(E2)$ do not vary on the neutron number and strongly depend on the two hole states of proton $Z = 48$. These results are quite useful for compiling to nuclear data table, which makes it a good reference.

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