Nuclear Structure Study of ($^{122}_{56}Ba$) isotope using the interacting Bosons Model-1

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Abstract
In this research, the energy bands (ground, beta and gamma) and electrical transitions probability for $_{56}{}^{122}$Ba isotope have been studied using the interacting boson model-1. The results indicate that agreement between theoretical predictions and experimental values are fairly good. In the present research, The spin and party for some energy levels which is not specified practically have been affirmed According to the theoretical calculations and it was found these isotopes involved belong to symmetry of SU(3).
Key words: isotopes, interacting boson model-1, energy levels.

الخلاصة
تم في هذا البحث دراسة حزم الطاقة للحالات (الأرضية وبيتا وكاما) واحتمالية الانتقالات الكهربائية للنظير $_{56}{}^{122}$Ba باستعمال نموذج البوزونات المتفاعلة الأول النتائج تشير إلى تطابق جيد بين القيم العملية والنظرية المحسوبة. وفي هذا البحث تم تأكيد البرم والتماثل لبعض مستويات الطاقة غير المحددة عملياً ووفق الحسابات النظرية وجد أن النظير قيد الدراسة تنتمي إلى التحديد الدوراني SU(3)
الكلمات المفتاحية : النظائر ، نموذج البوزونات المتفاعل الاول ، مستويات الطاقة.

1. Introduction
Some of the scientists studied the nuclear structure of $_{56}{}^{122}$Ba isotope through using different theoretical and practical models so some of the researchers were dealing with this subject. In (2003) M. Q. Cai etal studied first principles of optical properties barium titan at. In (2008) B. S. Aray etal studied structure and elastic of in (2012) M. Ameri et al studied structure and electronic for barium chalcogenide by using FP-MTO method.

2. Theoretical Details
(2.1) Energy levels
According to the Interacting boson model-1 low lying collective states of energy levels in (even-even) nucleus which can be described by (s) boson when (J=0$^+$) and (d) boson when (J=2$^+$) . The Hamiltonian employed present is calculated using computer code phint with input parameters EPS, ELL, QQ, OCT, HEX.

$$H = EPS_{.nd} + PAIR.(P^2) + \frac{1}{2}ELL.(L^2) + \frac{1}{2}QQ(Q^2) + 5\,OCT.(T_3^2) + 5\,HEX.(T_4^2) \qquad ....(1)$$

where

$$P^2 = \frac{1}{2}\begin{bmatrix} \left\{(s^\dagger s^\dagger)_0^{(0)} - \sqrt{5}(d^\dagger d^\dagger)_0^{(0)}\right\} x \\ \left\{(ss)_0^{(0)} - \sqrt{5}(\tilde{d}\tilde{d})_0^{(0)}\right\} \end{bmatrix}_0^{(0)} \qquad .... (2)$$

$$L^2 = -10\sqrt{3}\left[(d^\dagger\tilde{d})^{(1)} x (d^\dagger\tilde{d})^{(1)}\right]_1^{(1)} \qquad .... (3)$$

$$Q^2 = \sqrt{5}\begin{bmatrix} \left\{(s^\dagger\tilde{d} + d^\dagger s)^{(2)} - \frac{\sqrt{7}}{2}(d^\dagger\tilde{d})^{(1)}\right\}x \\ \{(s^\dagger\tilde{d} + +\tilde{d}s)^{(2)} - \frac{\sqrt{7}}{2}(d^\dagger\tilde{d})^{(2)}\} \end{bmatrix}^{(0)}_{0} \quad \text{.... (4)}$$

$$T_3^2 = -\sqrt{7}\left[(d^\dagger\tilde{d})^{(2)}x(d^\dagger\tilde{d})^{(2)}\right]^{(0)}_{0} \quad \text{.... (5)}$$

$$T_4^2 = 3\left[(d^\dagger\tilde{d})^{(4)}x(d^\dagger\tilde{d})^{(4)}\right]^{(0)}_{0} \quad \text{.... (6)}$$

In Eq.(1), nd is the number of bosons P^2,Q^2,T_3^2 and T_4^2 represent pairing, angular momentum, quadrupole , octupole and hexadecupole interaction between the bosons ε is the boson energy and PAIR, ELL, QQ, OCT, HEX is strengths of the pairing, angular momentum, quadrupole , octupole and hexadecupole interaction.

The SU(3) dynamic symmetry based on the boson energy ε is smaller than the reaction potential V (V• • ε). Both of the reactions electric quadrupole momentum Q and the reaction angular momentum L2 have control on the rotational limit SU (3) therefore the general Hamiltonian for this limit is:

$$H^I = a_1 L^2 + a_2 Q^2 \quad \text{.... (7)}$$

The eigen value for Hamiltonian of eq. (7) is:

$$E|N,(\lambda,\mu),K,L,M> = \frac{a_2}{2}(\lambda^2 + \mu^2 + \lambda\mu + 3(\lambda+\mu)) + \left(a_1 - \frac{3a_2}{8}\right)L(L-1) \quad \text{.... (8)}$$

Where

{(λ, μ), K, L, M is the quantum numbers, but (λ, μ) determined the rotational limit SU (3)

(2.2) Electrical transition probability

Electric quadrupole transition operator is given by:

$$T^{(E2)} = E2SD.(s^\dagger\tilde{d} + d^\dagger s)^{(2)} + \frac{1}{\sqrt{5}}E2DD.d^\dagger\tilde{d})^{(2)} \quad \text{.... (9)}$$

The reduced electric quadrupole transition rates between $(I_i \rightarrow I_f)$ states are given by:

$$B(E2{:}I_i \rightarrow I_f) = \frac{|<I_f||T^{E(2)}||I_i>|^{(2)}}{2I_i + 1} \quad \text{.... (10)}$$

The transition operator $T_m^{(E2)}$ for this limit is given by the following formula:

$$T_m^{(E2)} = a_2^2\left[(d^\dagger s + s^\dagger d)^{(2)}_m - \frac{\sqrt{7}}{2}(d^\dagger d)^{(2)}_m\right] \quad \text{.... (11)}$$

3. Results and Discussion

(3.1) Energy levels calculation

The energy of the positive party states of $_{56}^{122}Ba$ even-even isotopes is calculated using computer code phint and table(1) shows parameters used in this program for calculation energy levels and electromagnetic transitions probability it was found (Q^2) and (L^2) dominate on other parameters also there are three indicia refer to $_{56}^{122}Ba$ even-even isotopes in SU(3) limit. A comparison between the experimental spectra and our calculated for ground state, beta band and gamma band in table (2) and fig (1) shown the energy levels of $_{56}^{122}Ba$ even-even isotopes found experimental compared with IBM-1for positive party calculation. The model parameters given in table (1) are free parameters and adjusted to reproduce as closely as possible to the excitation energy .The agreement between the calculated energy levels and their correspondence experimental values for the nucleus is slightly higher for the higher excited.

Table (1) parameters used in IBM-1Hamiltonian (MeV)

Nπ Protons bosons numbers.
Nν Neutrons bosons numbers.
N Total bosons numbers.

Nucleus	Nπ	Nν	N	EPS	P.P.	L.L.	Q.Q.	$T_3.T_3$	$T_4.T_4$	CHI	SO6
$^{122}_{56}Ba$	3	8	11	0.0	0.0	0.0256	-0.009	0.001	-0.003	-1.322	1.00

Table (2) the energy the ground, beta and gamma bands of $_{56}{}^{122}$Ba even-even isotopes found experimental compared with IBM-1 for positive party calculation

Isotopes	Bands	Study	J^{π}					
			0^+	2^+	4^+	6^+	8^+	10^+
$^{122}_{56}Ba$	Ground	Theo.	0	0.1758	0.5861	1.2305	1.5557	1.8823
		Exp.	0	0.197	0.570	1.083	------	------
	Beta	Theo.	0.5679	0.7436	1.1535	1.5013	1.6884	1.8104
		Exp.	------	0.6182	1.2052	------	------	------
	Gamma	Theo.	0.5432	0.7491	1.1597	1.5501	1.7437	1.9723
		Exp.	------	------	------	------	------	------

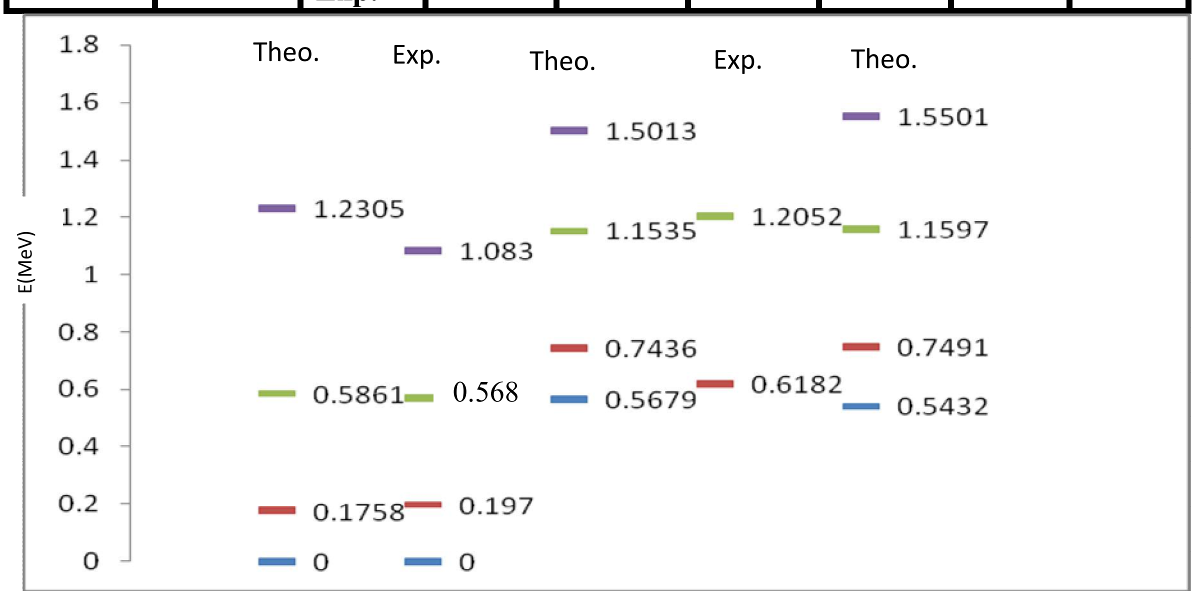

Fig .1: Shows the energy bands of $^{122}_{56}Ba$ using IBM-1 in comparison with the experiment of data.

(3.2) electromagnetic transitions probability

The values of electromagnetic transitions probability B(E2) were calculated by using program IBMT-1, depending on the value of parameters (E2SD E2DD) which in this study determination of these parameters depends on the experimental value for transition (BE2;$2_1^+ \rightarrow 0_1^+$). A comparison between the experimental values and our calculations for the electromagnetic transitions probability presented in table (3)

Table (3) the values of theoretical B (E2) and Quadrapole moment in ${}_{56}^{122}$Ba by using IBMT-code compared with the values of experiment.

Transition	${}_{56}^{122}$Ba	
	Theo.	Exp.
$2_1 \rightarrow 0_1$	0.9324	0.9314
$0_2 \rightarrow 2_1$	0.0658	------
$2_2 \rightarrow 0_1$	0.0929	------
$2_2 \rightarrow 2_1$	0.1479	------
$3_1 \rightarrow 2_1$	0.1615	------
$3_1 \rightarrow 4_1$	0.0869	------
$4_1 \rightarrow 2_1$	1.3119	1.3822
$4_2 \rightarrow 4_1$	0.1704	------
$4_2 \rightarrow 2_1$	0.0468	------
Q	1.636	1.636

4. Conclusions

Interacting boson model-1(IBM-1) has been applied successfully on ${}_{56}^{122}$Ba isotopes and we have got:

1- Energy levels: the ratio of energy levels ($\frac{E0_2^+}{E2_1^+}, \frac{E8_1^+}{E2_1^+}, \frac{E6_1^+}{E2_1^+}, \frac{E4_1^+}{E2_1^+}$) refers to a good nearly to SU (3) limit after comparison with exemplary value as shown in table (4).

2- Electrical transition probability: the levels decay 2_1^+ to 0_1^+ and 4_1^+ to 2_1^+ in one band and don't decay between bands.

Table (4) the ratio of energy levels.

Nucleus	$\frac{E4_1^+}{E2_1^+}$	$\frac{E6_1^+}{E2_1^+}$	$\frac{E8_1^+}{E2_1^+}$	$\frac{E0_2^+}{E2_1^+}$	$\frac{E4_1^+}{E2_1^+}$	$\frac{E6_1^+}{E2_1^+}$	$\frac{E8_1^+}{E2_1^+}$	$\frac{E0_2^+}{E2_1^+}$
	Theo.				**EXP.**			
$^{122}_{56}Ba$	**3.33**	**6.99**	**8.85**	**3.23**	**2.89**	**5.49**	**----**	**----**

5. References

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