The Collective Rotation Motion of Even-Even ${}^{188}_{76}Os$ 112, ${}^{182}_{74}W$108 Isotopes

Ali K. Aobaid[1], Saad A. Manthor[2]

Abstract

Here in this research, B(E2) the probability of electric transition values , energy levels, and the quadrupole moments values for even-even deformed isotopes ${}^{188}_{76}Os$ 112, ${}^{182}_{74}W$108 were found by using the interacting boson model IBM-1, Both isotopes have dynamic symmetry SU(3). The results were comparedwith the experimental values.

KeyWords:IBM-1, Quadrupole Moments , B(E2) Values , Energy Levels .

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Introduction

One of the properties of the deformed nuclei is the presence of specific rotational bands in their excitation spectra . the excitation nuclear energy levels which have high angular momentum decay to low energy levels by emitted γ-ray .such nuclei tell us to know new facts about their nuclear structure . the detailed examination of the nuclear rotational spectra enables to judge the appearance and the development of deformation to clear the basic feature of the collective nuclear motion in deformed nuclei .[1]

The collective rotational motion of deformed nuclei depends on nucleons motion in a way coherently with the nuclear motion causing rotation of some nucleons around an axis different from nuclear symmetry axis . for this reason , we can explain two types of deformation as follows [2,3] :

1.Prolate : In this deformation the nucleusrotating around a vertical axis to the nuclear symmetry axis . this rotation is called (collective rotation).[2,3]

2.Oblate : In this deformation the nucleus rotating around a parallel axis to the nuclear symmetry axis . this rotation is called (non- collective rotation).[2,3]

Interacting Boson Model

Interacting Boson Model (IBM) was suggested by Arima &Iachello (1974)[4].the IBM of Arima and Iachello is mode for description the collective structure of the heavy and the medium of even – even deformed nuclei[5] . they supposed that the shell model reveals that the low lying collective states such nuclei arises from interacting nucleon pairs coupled s-boson has angular momentum L=0 and d-boson has angular momentum L=2 with energies ε_s , ε_d respectively ,the energy difference for s-boson and d-boson is $\varepsilon_d - \varepsilon_s$where $\varepsilon_s$is almost zero[6,7].The IBM is rooted in the spherical shell model and geometrical collective model of atomic nucleus [8].there are four versions of IBM , called IBM-1,2,3 and 4. In this work will concerned with IBM-1 model, This version doesn't distinguish between neutron and proton bosons .this model depends on the total number of bosons N :

N=$N_\pi + N_\nu$

where:

N_π number of proton boson

$N_\nu$number of neutron boson [9]

The s-boson and d-boson, the bosons of IBM-1 they have six states and can define a six- dimensional space , it can be describe in terms of the unitary group in six dimensions U(6) .

Corresponding author: Ali K. Aobaid
Address: [1,2]Physics department / college of education for pure sciences / Al-Anbar university
E-mail: esp.alik.obaid@uoanbar.edu.iq[1], saad_pd@yahoo.com[2]

This leads to drive many of the characteristic properties of the IBM-1 by group theoretical methods and express it analytically [10] . The reductions of U(6) go to three dynamical symmetries SU5 , SU3 , and O6 . This is related to the geometrical idea of the spherical vibrator , deformed rotor and asymmetric γ-soft , respectively . the previous three are identical dynamical symmetries group chains of U(6) as [6, 11] :

1.U(6) ⊃ SU(5) ⊃ O(5) ⊃ O(3) ⊃ O(2)
2.U(6) ⊃ SU(3) ⊃ O(3) ⊃ O(2)
3.U(6) ⊃ O(6) ⊃ O(5) ⊃ O(3) ⊃ O(2)

The IBM-1 Hamiltonian operator

The Hamiltonian operator of the IBM-1 write in the form of Creation ($s^\dagger d_m^\dagger$) and Annihilation operators (s,d_m) [6] :

$$H = \varepsilon_S(SS) + \varepsilon_d \sum_m d_m^\dagger d_m + \sum_{L=0,2,4} \frac{1}{2}(2L+1)^{1/2} C_L \left[(d^\dagger d^\dagger)^{(L)} (dd)^{(L)} \right]^{(0)}$$
$$+ \frac{1}{\sqrt{2}} \nu_2 \left[(d^\dagger d^\dagger)^{(2)} (ds)^{(2)} + (s^\dagger d^\dagger)^{(2)} (dd)^{(2)} \right]^{(0)}$$
$$+ \frac{1}{2} \nu_o \left[(d^\dagger d^\dagger)^{(0)} (ss)^{(0)} + (s^\dagger s^\dagger)^{(0)} (dd)^{(0)} \right]^{(0)}$$
$$+ u_2 \left[(d^\dagger s^\dagger)^{(2)} (ds)^{(2)} \right]^{(0)} + \frac{1}{2} u_o \left[(s^\dagger s^\dagger)^{(0)} (ss)^{(0)} \right]^{(0)}$$

Where :
uL(L=0,2) ,υL(L=0,2) , CL(L=0,2,4) , $\varepsilon_L (L = 0,2)$ parameters represents the boson energies and interactions , the parenthesis denotes angular momentum couplings . The most commonly used from of the IBM-1 Hamiltonian is [7, 12] :

$$H = \varepsilon_{nd} + \alpha_O P^2 + \alpha_1 L^2 + \alpha_2 Q^2 + \alpha_3 T_3^2 + \alpha_4^2 T_4^2$$

Where the boson energy is :
$\varepsilon = \varepsilon_d - \varepsilon_s$

Where the operators :
$n_d = (d^\dagger . d)$ d-boson number operator
P=$\frac{1}{2}(d.d) - \frac{1}{2}(s.s)$ pairing operator
L=$\sqrt{10}[d^\dagger \times d]^{(l)}$ angular momentum operator
Q=$[(d^\dagger \times s) + (s^\dagger \times d)] - \frac{\sqrt{7}}{2}[d^\dagger \times d]^{(2)}$ quadrupole moment operator
$T_3 = [d^\dagger \times d]^{(3)}$ octupole operator
$T_4 = [d^\dagger \times d]^{(4)}$hexadecapole operator
and $a_\circ, \ldots \ldots a_4$ are the strengths of P,L,Q,T_3,T_4 interacting between bosons respectively .

Calculated Results

The symmetry shape of a nucleus can be predicted from the energy ratio$R = E(4_1\ )$/E(2_1) where $E(4_1)$ is the energy level at (4_1) and $E(2_1)$ is the energy level at (2_1) In fact, R has a limit value of ≈ 2 for the vibration nuclei U(5), ≈ 2.5 for the γ-unstable nuclei O(6) and ≈ 3.33 for the rotational nuclei SU(3) ,The R values of the low-lying energy levels of ${}^{182}_{74}W$ and ${}^{188}_{76}Os$isotopes are 3.33, 3.33 and the experimental values are 3.29, 3.08 respectively. We have SU(3) dynamic symmetry in even-even ${}^{182}_{74}W$ and ${}^{188}_{76}Os$ isotopes . the number of bosons are 13 and 10 for ${}^{182}_{74}W$ and ${}^{188}_{76}Os$ isotopes respectively. the following calculations were made:
E(L) energy levels .
E_γ gamma transition .
$B(E2)$ electric quadrupole probability
Q_L electric quadrupole moments
Here we used the (IBM.For) program to perform the above calculations in the language of Fortran through the (BOS.inp) input file, which contains seven parameters $(\epsilon, a_\circ, a_1, a_2, a_3, a_4)$ to get the best fitting between the theoretical data and experimental values.[13,14] The Hamiltonian operators of IBM-1 are depends the number of bosons. As shown in table (1).

Table1: the parameters of Hamiltonian operators (MeV) are used in IBM.

Nuclei	ε	$a_\circ$	a_1	a_2	a_3	a_4	CHI
${}^{182}_{74}$W108	0.0000	0.0000	0.0166	-0.0170	0.0000	0.1000	1.3210
${}^{188}_{76}$Os 112	0.0001	0.0409	0.0201	0.0080	-0.0086	0.0448	0.0000

The(IBST.FOR) program and the (BE2.DAT) input file to get best fitting by the parameters (α_2, β_2) were also used to calculate the electric quadrupole probability B(E2) and the electric quadrupole moments Q_L as shown in table (2).

Table2: the parameters (α_2, β_2) in (eb) are used in IBST.FOR program

Nuclei	α_2	β_2
${}^{182}_{74}$W108	0.054510	0.135000
${}^{188}_{76}$Os 112	0.018000	-0.580000

In table (3-a) we can see Comparison between the IBM-1 calculations with the available experimental data [13,14] of the energy levels E(L) (MeV), transition energy Eγ(MeV) and B(E2) (eb)2 of the g-band for ${}^{182}_{74}W$108 same for ${}^{188}_{76}Os$ 112 as shown in table (3-b).

Table3-a: Comparison between the IBM-1 calculations with the available experimental data [13,14] of the energy levels E(L) (MeV), transition energy Eγ(MeV) and B(E2) (eb)2 of the g-band for ${}^{182}_{74}W$108

Nuclei	L_i^+	Energy level E(L) (MeV)		Spin sequence	Transition energy Eγ (MeV)		B(E2) (eb)2	
		Exp.	IBM-1	$L_i^+ - L_f^+$	Exp.	IBM-1	Exp.	IBM-1
${}^{182}_{74}W$108	0_1^+	0.0000	0.0000	---	---	---	---	---
	2_1^+	0.10010	0.11150	$2_1^+ \to 0_1^+$	0.10010	0.11150	0.34025	0.3487
	4_1^+	0.32942	0.32990	$4_1^+ \to 2_1^+$	0.22932	0.21840	0.49	0.5092
	6_1^+	0.68042	0.65520	$6_1^+ \to 4_1^+$	0.35100	0.32530	0.5025	0.6007
	8_1^+	1.14432	1.08740	$8_1^+ \to 6_1^+$	0.46390	0.43220	0.5225	0.6546
	10_1^+	1.71199	1.62650	$10_1^+ \to 8_1^+$	0.56767	0.53910	0.5075	0.6824

Table(3-b): Comparison between the IBM-1 calculations with the available experimental data [13,14] of the energy levels E(L) (MeV), transition energy Eγ(MeV) and B(E2) (eb)2 of the g-band for ${}^{188}_{76}Os$ 112.

Nuclei	L_i^+	Energy level E(L) (MeV)		Spin sequence	Transition energy Eγ (MeV)		B(E2) (eb)2	
		Exp.	IBM-1	$L_i^+ - L_f^+$	Exp.	IBM-1	Exp.	IBM-1
${}^{188}_{76}Os$112	0_1^+	0.0000	0.0000	---	---	---	---	---
	2_1^+	0.155043	0.14501	$2_1^+ \to 0_1^+$	0.155	0.145	0.00628	0.0040
	4_1^+	0.477959	0.44003	$4_1^+ \to 2_1^+$	0.323	0.295	0.0035	0.0020
	6_1^+	0.94034	0.88277	$6_1^+ \to 4_1^+$	0.462	0.442	0.0030425	0.0029
	8_1^+	1.5148	1.47194	$8_1^+ \to 6_1^+$	0.574	0.589	0.003025	0.0030
	10_1^+	2.1701	2.20677	$10_1^+ \to 8_1^+$	0.655	0.735	0.003675	0.0040

In figure (1) and figure (2) we can see Comparison between the IBM-1 calculations with the available experimental data [13,14]. of the energy levels E(L) (MeV) for ${}^{182}_{74}W$108 and ${}^{188}_{76}$Os 112isotopes ,We can see here a good agreements between the theoretical data and experimental values.

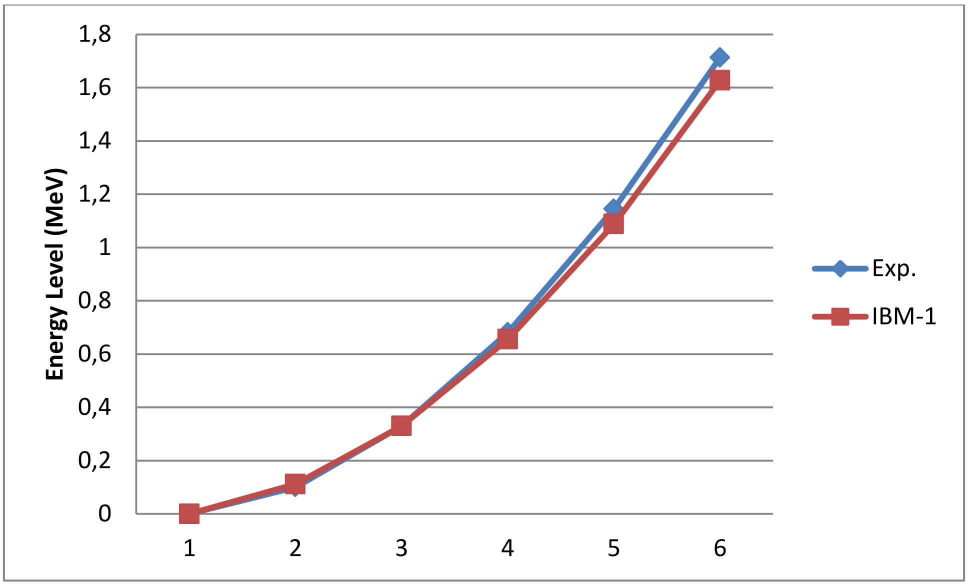

Figure 1: Comparison between the IBM-1 calculations with the available experimental data [13,14] of g-band for $^{182}_{74}W$108.

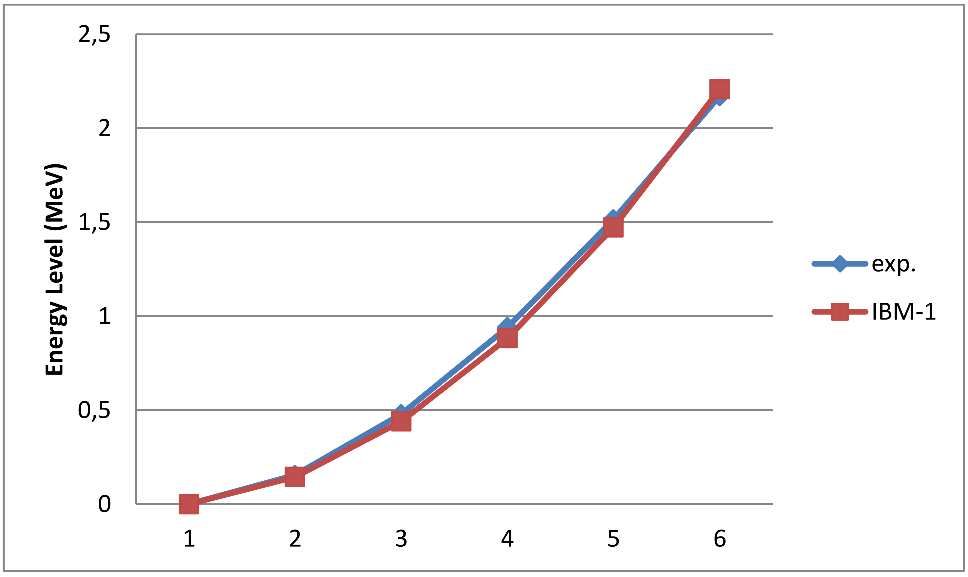

Figure 2:Comparison between the IBM-1 calculations with the available experimental data [13,14] of g-band for $^{188}_{76}$Os 112

In figure (3) and figure (4) we can see Comparison between the IBM-1 calculations with the available experimental data [13,14]. of the energy levels E(L) for $^{182}_{74}W$108 and $^{188}_{76}$Os 112 isotopes ,We can see here a good agreements between the theoretical data and experimental values.

Studying the electric quadrupole moment(Q_L) is good feature to measuring the deformation of the nucleus.

The spherical nucleus have electric quadrupole moment (Q=0) , the Prolate have electric quadrupole moment (Q>0) and the Oblate have electric quadrupole moment (Q<0).[15]

The table (4) show the theoretical and experimental values of electric quadrupole moments .

Table 4: the electric quadrupole moments Q_{2_1} (eb).

Nuclei	Q_{2_1}(eb) Exp. [13,14]	Q_{2_1}(eb) IBM-1
$^{182}_{74}W$108	- 2.13	- 1.9

$^{188}_{76}Os112$	- 1.46	- 1.5111

Summary

The interacting boson model IBM-1,is used in this work to calculate energy levels E(L), gamma transitionE_{γ} ,electric quadrupole probability$B(E2)$ and electric quadrupole momentsQ_L for even – even deformed isotopes $^{182}_{74}W108$ and $^{188}_{76}Os$ 112.the Comparison between the IBM-1 calculations with the available experimental data [13,14] show a good agreements between the theoretical data and experimental values. From the results of the calculations, we can see that these nuclei are highly oblate deformed .

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