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Some Studies in Nature of Excited states of Isotones Nuclei (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg)

بعض الدراسات في طبيعة المستويات المتهيجة للنوى الآزوتونية (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg)

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Abstract

The protons effect on the nuclear structure of isotones nuclei (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) have been studied using the interacting boson model-1.

The present results have been appeared that the nuclei stay constant on the transition region from SU(3) to O(6) with increase the proton number from (72) in ^{180}Hf nucleus to (80) in ^{188}Hg nucleus which refer no effect of increasing protons in isotones nuclei .

The calculated energy spectra and the properties of electric transition ratios are in reasonable agreement with experimental data.

The potential energy surface for isotones nuclei have been studied using the IBMP–code where the isometric potential lines are plotted to explain the deformations forms of these nuclei.

الخلاصة

تمت دراسة تأثير البروتونات على التركيب النووي للنوى الآزوتونية (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) باستخدام نموذج البوزونات المتفاعلة -1.

أظهرت النتائج الحالية ثبوت النوى في المنطقة الانتقالية SU(3)-O(6) مع زيادة عدد البروتونات من 72 في نواة ^{180}Hf إلى 80 في نواة ^{188}Hg وهذا يشير إلى عدم تأثير زيادة البروتونات في النوى الآيزوتونية و أن حساب طيف الطاقة وخصائص نسب الانتقالات الكهربائية متوافقة بشكل مقبول مع القيم العملية كذلك تمت دراسة سطوح تساوي الجهد للنوى اللآيزوتونية باستعمال برنامج *IBMP –code* حيث رسمت خطوط تساوي الجهد لتوضيح أشكال التشوه لتلك النوى.

Introduction

The IBM approach has proved useful for describing the collective behavior of medium and heavy nuclei of protons and neutrons pairs (Beser,1973) .We shell study and analyze the possible application of the (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) isotones in Z=82 region.

In this mass region , ample evidence has been obtained for the presence of low –lying bands characterized by a rather well developed deformed structure .Within a geometrical language, the coexistence and coupling of slightly oblate and more strongly deformed prolate system is one of the salient features in the Hg , Pt nuclei (Iachello,1987).

In the present work the even –even isotones (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) are systematically studied using the IBM-1 model , the active bosons number are (14,13,12,11and 10) formed by (5,4,3,2 and 1) hole protons and (9) hole neutrons pairs outside the closed shells (50 and 82) respectively.

Interacting Boson Model (IBM)

Since the interacting boson model (IBM) was proposed by Arima and Ichello (Ichello, 1974 and Casten,1988) in the 1970,a wide variety of collective properties of low-lying energy levels in even–even nuclei have been explained successfully by the model .The basic assumption of the original version of the interacting boson model (IBM-1) are that low-lying quadruple excitations of the even-even nuclei can be studied by considering a system of N interacting boson with the angular momentum L=0 (s-boson) and L=2 (d-boson) and no distinction is made between the proton and neutron bosons . The important extension of IBM-1 is the neutron-proton interacting boson model (IBM-2) in which the proton and neutron degree are explicitly taken into account (Decoster,2000).

The dynamic symmetries have provided a useful tool to describe properties of several physics systems , in the common definition (Jabber,1989) a dynamic symmetry is that situation in which the Hamiltonian operator, H, can be written in terms of Casmir operators Ci of a chain of algebras $G \supset G' \supset G''$ …………………

The most notable examples are dynamic symmetries of the interacting boson model (Abrahams,1981) which can be easily recognized by analyzing the algebraic structure of the problem .

By breaking the algebra G into all it′s sub algebra chains , one can find all possible dynamic symmetries of G. in the interacting boson model, where G=U(6) , there are three possible dynamic symmetries , usually labeled by the first sub algebra U(5) , SU(3) and O(6) appear in the chain .

Dynamic symmetries are related to exactly solvable problems and produce all results for observable in explicit analytic form (Iachello, 1987) in the IBM-1 it is assumed that the Hamiltonian contains only one-body and tow-body terms, thus introducing creation ($s^\dagger$, $d^\dagger_m$) and annihilations (s, d_m) operations , where the index m=0, ±1, ±2 . the most general Hamiltonian , which include one-boson terms in boson- boson interaction is (Iachello, 1974 and Casten, 1988)

$$H = \varepsilon_s (S^+ S) + \varepsilon_d \sum_m d^+_m d_m + V .... (1)$$

Where ε_s, ε_d are S and d-boson energies and V represent the boson – boson interacting and can written as (Iachello, 1974 and De Coster,2000)

$$H = \varepsilon \hat{n}_d + a_0 \hat{P}^+ . \hat{P} + a_1 \hat{L}^2 + a_2 \hat{Q}^2 + a_3 \hat{T}_3{}^2 + a_4 \hat{T}_4{}^2 .... (2)$$

Where $\varepsilon=\varepsilon_d-\varepsilon_s$ the boson energy for simplicity , ε_s was set equal to zero only $\varepsilon=\varepsilon_d$ appears.

The parameters a_2,a_1,a_0,a_3 and a_4 designate the strengths of the quadruple, angular momentum , pairing , octupole and hexadecapole interaction between bosons, respectively .the eigenvalues and eigenstate can be diagonalizing the Hamiltonian in table(1).

In order to calculate the transition rates one must specify the transition operators . in the simplest form of the (IBM) the one body transition operator which has the second quantized form is (De Caster,2000).

$$T_m^{(L)} = \alpha_2 \delta_{12} \, [d^\dagger \times s + s^\dagger \times d]^{(2)}_m + \beta_L [d^\dagger \times d]^{(L)}_m + \gamma_0 \delta_{Lo} \delta_{mo} [s^\dagger \times s]^{(0)}_0 \; ………………… (3)$$

Where α_2, β_L , γ_0 are the coefficients of the various terms in the operator ,this equation yields transition operators for E_0,M_1, E_2 ,M_3 and E_4 transition with appropriate values of corresponding parameters.

The $T_m^{(E2)}$ operator which has enjoyed a widespread application in the analysis of γ-ray transition can thus take the form:

$$T_m^{(E2)} = \alpha_2 \, [d^\dagger \times s + s^\dagger \times d]^2_m + \beta_2 [d^\dagger \times d]^2_m \; …………………………………………… (4)$$

it is clear that for the E2 multipolarity two parameters α_2 and β_2 are need in addition to the wave function of initial and final states.

The quadrupole moments of the states in the g.s band are given by (De Coster,2000).

$$Q^+_{2_1} = \beta_2 \left(\frac{32}{35} \right)^{\frac{1}{2}} \quad \text{in SU(5),}$$

$$Q^+_{2_1} = -\alpha \sqrt{\frac{2\pi}{5}} \frac{2(4N+3)}{7} \quad \text{in SU(3) limit and}$$

$$Q_L = 0 \quad \text{in O(6) limit.}$$

The nucleon formation designations by both deformation factors (β,γ) whereas β approaches to 0 for spherical nuclei in the same time it can not be zero for deformed nuclei , when γ equals 0^0 , the deformation takes prolate shape and when γ equals 60^0 the deformation takes oblate shape see fig.(a) Nuclei are expected to be soft and flexible, i.e. the shape of a nucleus may strongly deviate from a sphere. Experimentalists found many nuclei with a remarkably deformed charge distribution in large regions of N and Z between the magic numbers

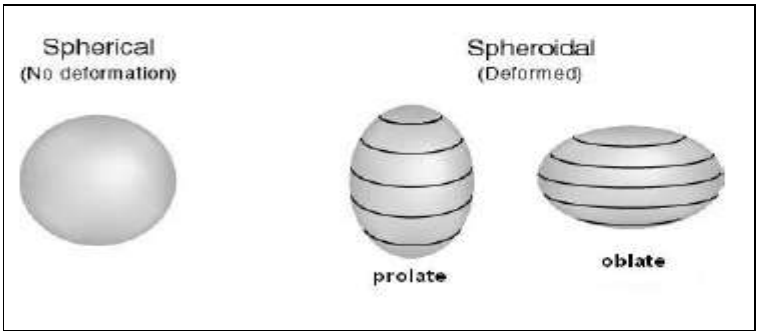

fig.(a):The shapes of some deformed and non deformed nuclei.

Then the potential energy surface equation for the three symmetries can be given by the following equations [F.Iachello,1987]

$$E^{(I)}(N;\beta,\gamma)=E_0+\varepsilon_d N\frac{\beta^2}{1+\beta^2}+f_1 N(N-1)\frac{\beta^4}{(1+\beta^2)^2}$$

$$E^{(II)}(N;\beta,\gamma)=E_0-k^2\left[\frac{N}{(1+\beta^2)}(5+\frac{11}{4}\beta^2)+\frac{N(N-1)}{(1+\beta^2)^2}\times(\frac{\beta^4}{2}+2\sqrt{2}\beta^3\cos 3\gamma+4\beta^2)\right]$$

$$-k'\frac{6N\beta^2}{(1+\beta^2)}$$

$$E^{(III)}(N;\beta,\gamma)=E_0+(2B+6C)\frac{A}{4}N(N-1)(\frac{1-\beta^2}{1+\beta^2})^2.$$

....(10)

it is convenient to plot in each case the energy surface as a contour plot in the β-γ plane fig (b) , since E in (6) depends only on cos3 γ, it is sufficient to consider the portion of the β-γ plane with $0^o \le \gamma < 60^o$

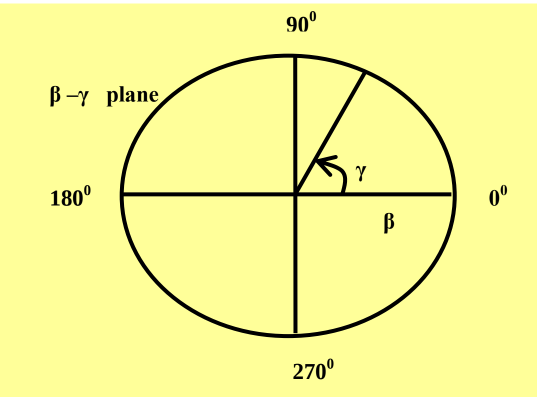

fig.(b):The β-γ plane.

The IBM Calculation and Results

The calculations were done using the IBM computer codes PHINT for energies and FBEM for B(E2) values (Scholton,1980).

The number of bosons implied by the number valence neutrons and protons in (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) is (14,13,12,11,10,) respectively.

In the framework of the interacting boson model (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) is considered as transitional nucleus between SU(3) and O(6) and calculations were made with transitional Hamiltonian Eq.

$$H = a_0 \hat{P}^{+}.\hat{P} + a_1 \hat{L}^2 + a_2 \hat{Q}^2$$

In the calculation of B(E2) values the two parameters α_2 and β_2 of Eq.(4) were adjusted to approximately reproduce the measured B(E2:$2_1 \rightarrow 0_1$) for excitations of 2_1^+ members of the ground state.

The result of the calculations for the energy levels are shown in Fig.(1) and compared with experiment , while Table (1) the values of the parameters used to calculate the energy levels as shown in Fig.(2&3) and the B(E2) values which is compared with data experimental transitions shown in Fig.(5) and Fig.(6) shows the energy levels as function of angular momentum of (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) isotones.

Table (2) shows a remarkable agreement between theory and experiment for transitions originating within the ground state .

Table (3)for potential energy surface which illustration in figs.(7-11).

The present IBM calculation predicts all isotones (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) lies in the region same SU(3) - O(6)although from change the protons number this means no effect of increasing protons in isotones nucleus.

Table (1): The parameters obtained from the programs IBM- 1 and IBMT- 1 using the IBM-1 Hamiltonian.

Isotones	The parameters									
	N	**Eps**	**a_0**	**a_1**	**a_2**	**a_3**	**a_4**	**CHI**	**E2SD (eb)**	**E2DD (eb)**
${}^{180}_{72}Hf_{108}$	14	0.0000	0.0127	0.0082	-0.0135	0.0649	0.1174	-1.320	0.1115	-0.3298
${}^{182}_{74}W_{108}$	13	0.0000	0.0016	0.0113	-0.0139	0.0000	0.0000	-1.5200	0.0734	-0.2173
${}^{184}_{76}Os_{108}$	12	0.0000	0.0016	0.0024	-0.0339	0.0000	0.0000	-0.0436	0.0974	-0.2881
${}^{186}_{78}Pt_{108}$	11	0.0000	0.0476	0.0134	-0.0235	0.0000	0.0000	-0.0920	0.1390	-0.0009
${}^{188}_{80}Hg_{108}$	10	0.0000	0.0016	0.0179	0.1800	0.0000	0.0000	-0.1577	0.0751	-0.2223

Table (2): experimental B(E2) values (e^2b^2)(from Venkova,1981) and Q_{21^+}(eb) in (^{180}Hf , ^{182}W , ^{184}Os , ^{186}Pt and ^{188}Hg) isotones nuclei are compared with IBM-1 results.

$i \to f$	**B(E2) e^2b^2**									
	Hf^{180}		W^{182}		Os^{184}		Pt^{186}		Hg^{188}	
	p.w	Exp	p.w	Exp	p.w	Exp	p.w	Exp	p.w	Exp
$2_1^+ \to 0_1^+$	0.930	0.96	0.807	0.84	0.570	0.57	0.596	0.596	0.261	0.26
$2_1^+ \to 0_2^+$	0.052	–	0.002	–	0.085	–	0.003	–	0.031	–
$2_2^+ \to 0_1^+$	0.008	–	0.001	–	0.141	–	0.036	–	0.051	–
$2_2 \to 0_2^+$	0.148	–	0.668	–	0.050	–	0.182	–	0.109	–
$2_1 \to 2_2$	0.021	–	0.002	–	0.217	–	0.464	–	0.440	
$4_1 \to 2_1$	1.338	1.30	1.138	1.16	0.807	0.84	0.849	0.82	0.210	0.20
$4_2 \to 2_1$	0.023	–	0.001	–	0.162	–	0.001	–	0.268	–
$4_2 \to 2_2$	0.398	–	0.935	–	0.202	–	0.511	–	0.067	–
$Q_{2_1^+}$	-2.639	–	-2.415	–	-2.101	–	-1.444		-0.639	–

Table(3):The parameters obtained from the programs IBM-1 code for (Hf^{180} ,W^{182} Os^{184} ,Pt^{186} ,Hg^{188}) isotones potential energy surface.

Isotones	**Parameters in(Mev)**						
	N	ε_s	ε_d	f_1	f_2	f_3	f_4
Hf^{180}	14	-0.068	0.314	0.057	-0.038	-0.060	0.000
W^{182}	13	-0.070	0.022	-0.009	-0.045	-0.057	0.000
Os^{184}	12	-0.169	-0.020	0.000	-0.003	-0.136	0.000
Pt^{186}	11	-0.117	0.057	0.012	-0.005	-0.118	0.000
Hg^{188}	10	0.900	0.292	0.002	-0.061	0.720	0.000

Discussion and conclusions

Nuclei which lie in the mass number range 155 < A < 185 are considered as strongly deformed and therefore possess rotational spectra .The(^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) lies within this range, hence it should show rotational characteristics .The rotational theory was applied to (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) and the results are given in Table(1).

The SU(3) rotational limit of the IBM was applied with the addition of a very small amount of the pairing (p.p) interaction this allowed the energy of the first state of the β-band ($k^{\pi}=0^+$) to be raised above the first excited state of the γ-band ($k^{\pi}=2^+$) and to get the best fit to the experimental values (Casten ,1980 and Frank , 1979) .

The agreement between both the rotational theory and the SU(3) limit of the IBM calculations with the experimental values of the energy levels supports the assumption that (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) is a deformed nucleus and is very much like an axially symmetric rotor (Janssen,1974 and Aaga ,1955) as is suggested by the energy ratios R , R′, R″ (1.4, 0 , 0) the assumption that the transition between β and γ bands and the ground state band is absolutely forbidden as stated in the SU(3) limit was investigated and experimentally supported .

The (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) nucleus is considered as a deformed nucleus . Nuclei possessing a non spherical shape show a rotational spectra (Alder, 1956) .In axially symmetric deformation nuclei , the calculation based on rotational theory will be applied to it .

The parameter in table (1) were determined by fitting the experimental energy values of the first two excited states of the bands. Table(1) shows together the energies found experimentally and also the theoretical calculation Fig (1) shows the experimental and theoretical (rotational) energy levels as determined in this study.

The ratio $\frac{E(4^+)}{E(2^+)}$ of the ground band is (3.2 , 3.3 , 2.6 , 3 , 1.75) while the ratio $\frac{E(6^+)}{E(2^+)}$ is (6.7 , 7 , 4.9 , 6 , 3.3) these two ratios are in agreement with theoretical predictions of the symmetric rotor (Alder,1956 and Larsen,1967) as shown in Fig.(4) .

The general feature of the calculations of the rotational spectra is the good agreement between theory and experimental which indicates that (^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) is true deformed nucleus with axial symmetry (Arima , 1978 and Daval ,1981).

The pairing and the quadrupole forces are important in deformed nuclei .These forces especially influence the particles in the unfilled states .The pairing force keeps the nuclei in spherical symmetry .The quadrupole charge distribution causes what is known as the quadrupole force . This force take the nuclei to the deformed state .The relation between the pairing and the quadrupole forces determines the form of the nuclei. Figs.(7-11) are drawn to show isometric potential lines

E(β,γ) for(^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg) isotones to study the potential energy surface for each nucleus which represented nuclear potential energy as a function of collective coordination's for coefficients nuclear shape β,γ are helpful to realizing principal conceptions of nuclear structure for that nucleus.

The present results have been appeared that the nuclei stay constant on the transition region from O(6) to SU(3) with increase the proton number from (72) in ^{180}Hf nucleus to (80) in ^{188}Hg nucleus which refer no effect of increasing protons in isotones nuclei .

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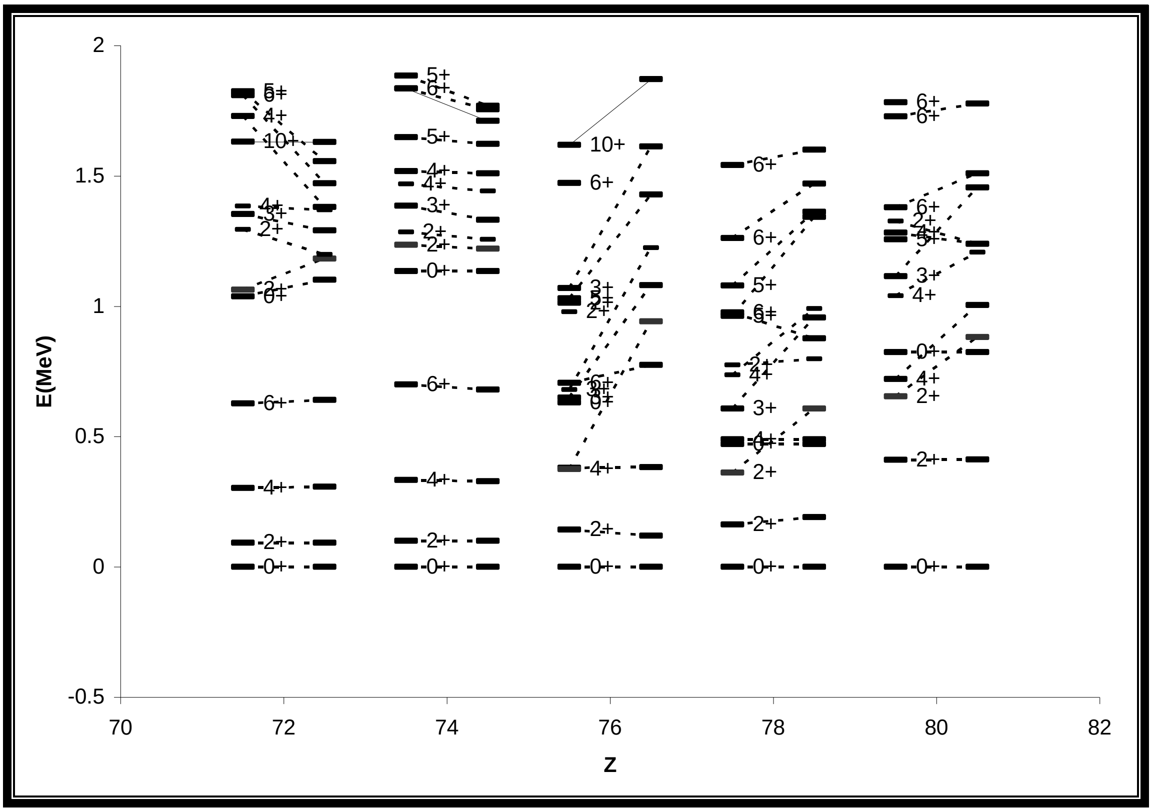


Fig.1.Coparsion between experimental (from Edgardo Browne,1978) and theoretical spectrum in (^{180}Hf , ^{182}W , ^{184}Os , ^{186}Pt and ^{188}Hg).

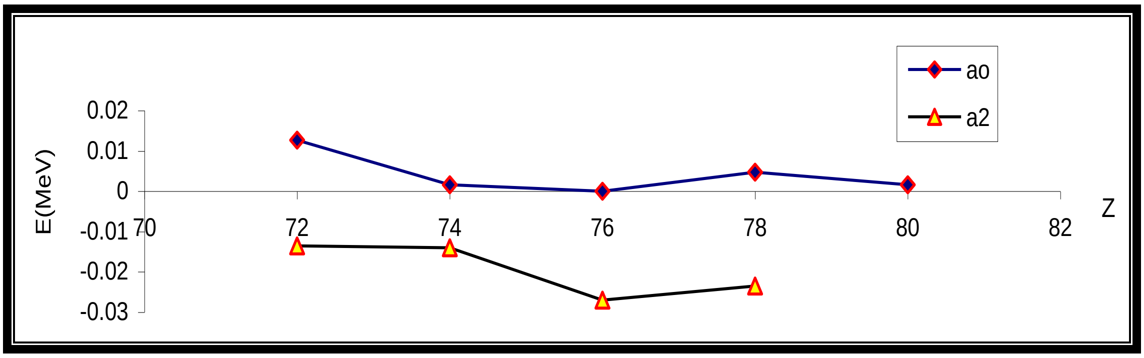


Fig.2.The values of the parameters which gave the best fit to the experimental (from Edgardo Browne, 1978).

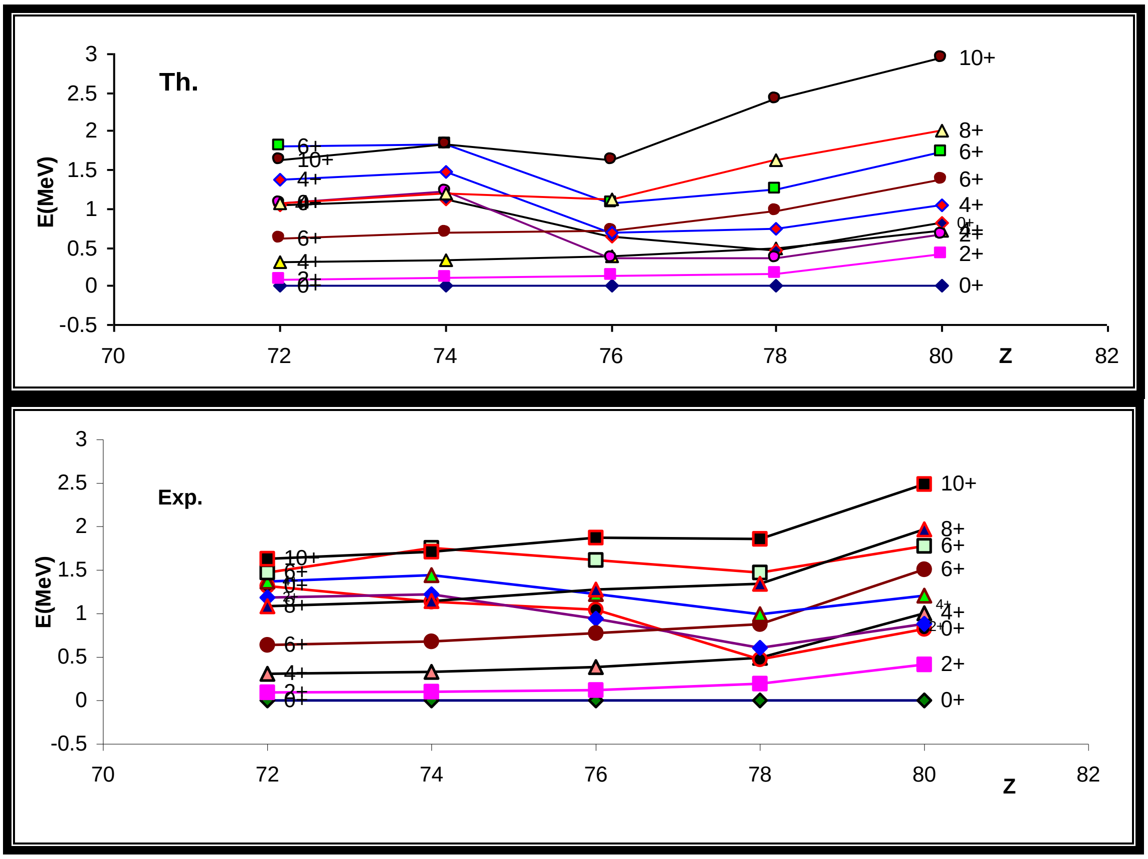


Fig. 3. comparison between calculated and experimental (from Edgardo Browne, 1978) energy spectra of (^{180}Hf , ^{182}W , ^{184}Os , ^{186}Pt and ^{188}Hg).

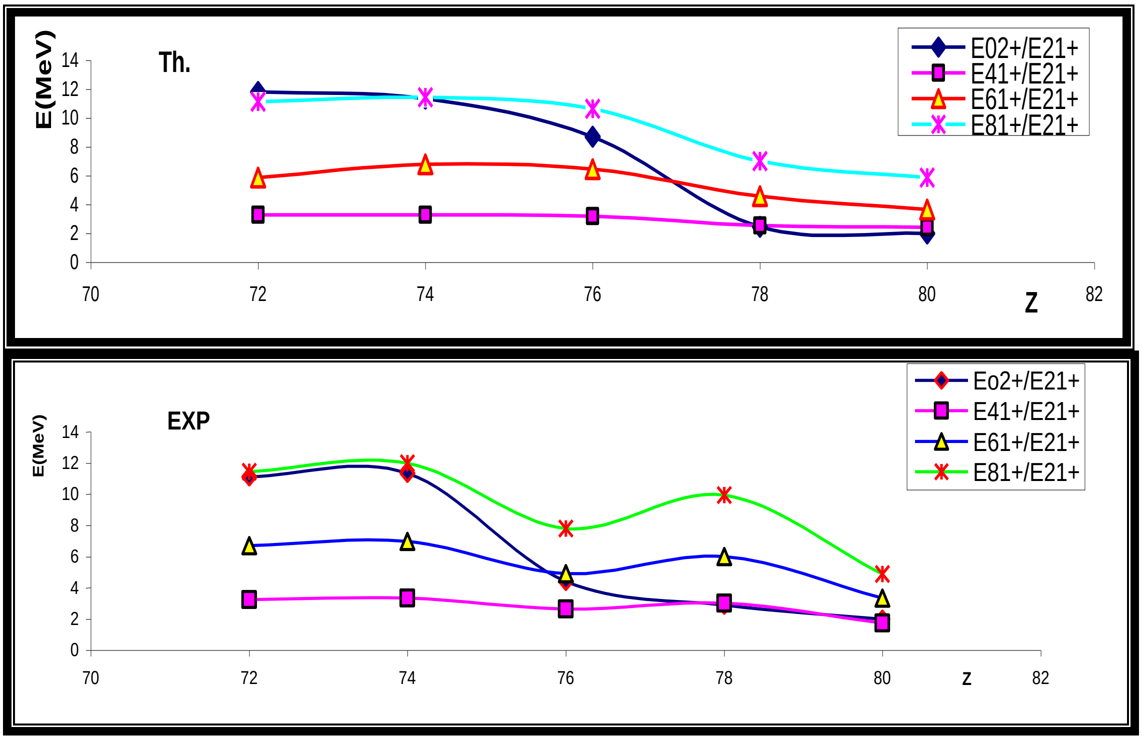


Fig.4. Calculated and experimental (from Edgardo Browne, 1978) ratios for(^{180}Hf , ^{182}W , ^{184}Os , ^{186}Pt and ^{188}Hg).

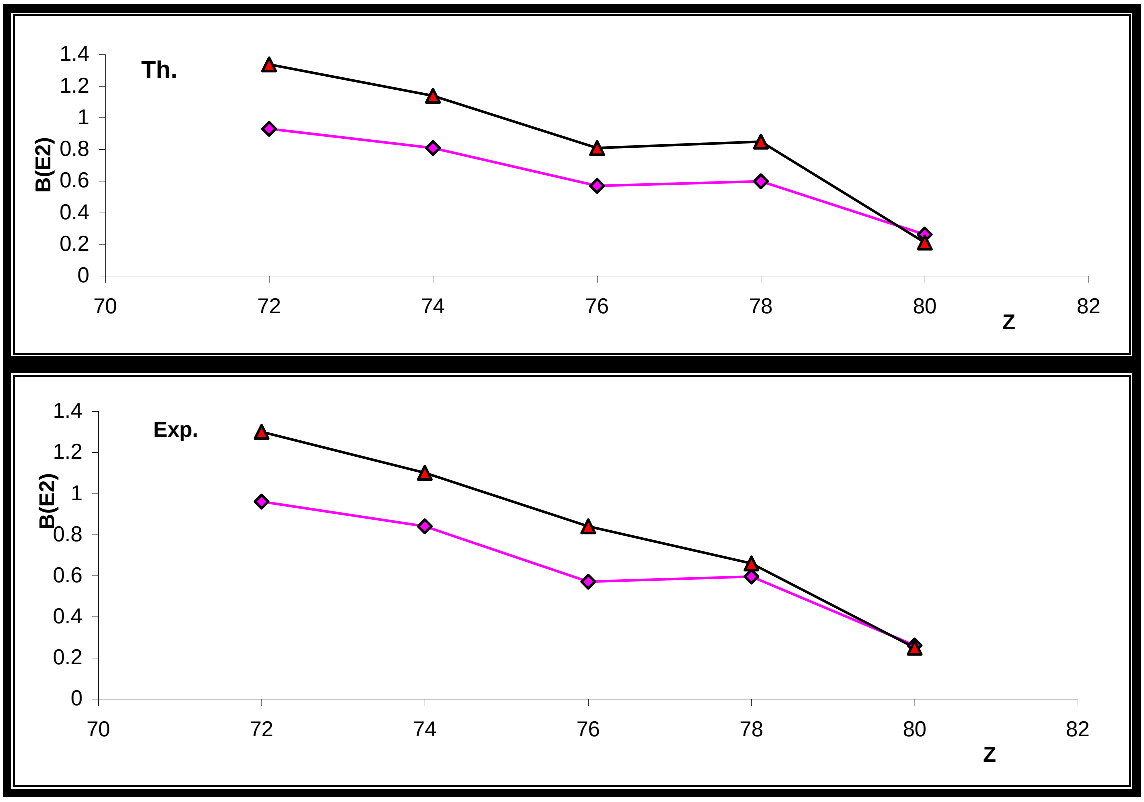


Fig.5. Comparison between experimental B(E2; $2_1^+ \rightarrow 0_1^+$) and B(E2; $4_1^+ \rightarrow 2_1^+$) values (from Venkova, 1981) and those calculated in interacting boson model-1 for(^{180}Hf ,^{182}W ,^{184}Os ,^{186}Pt and ^{188}Hg).

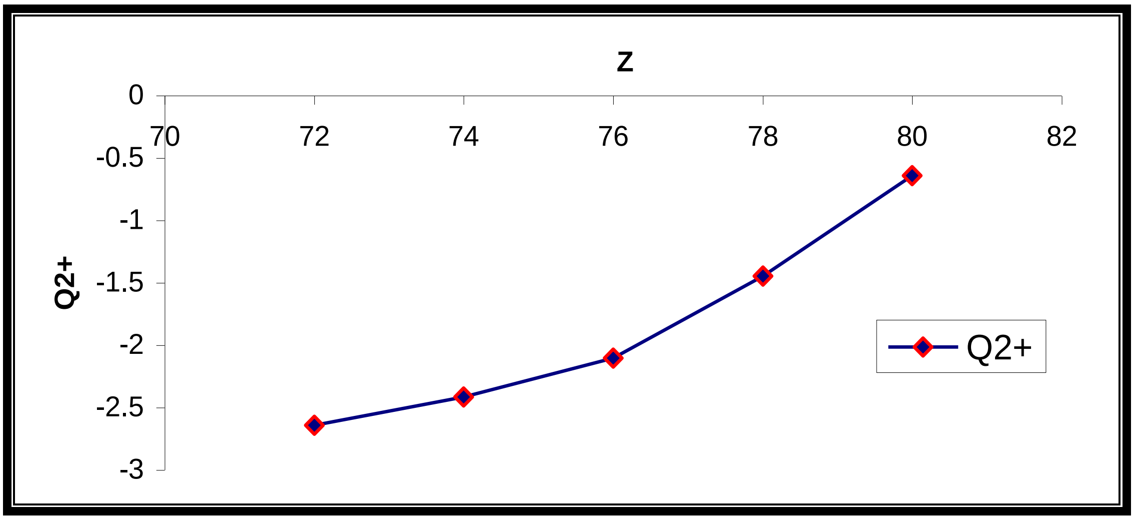
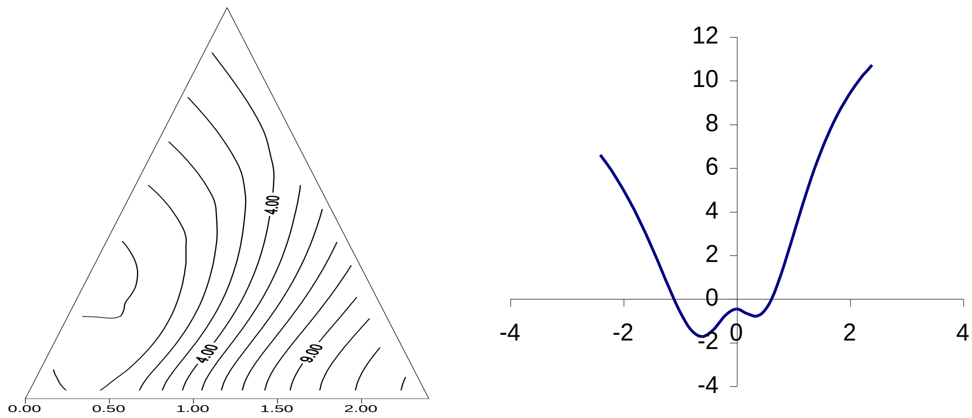
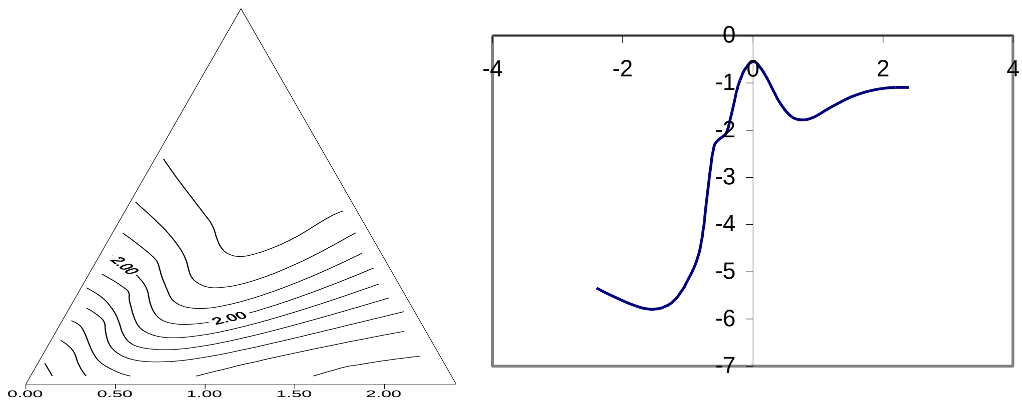


Fig. 6. calculated electric quadrupole moments in (eb) of the first excited 2^+ state.



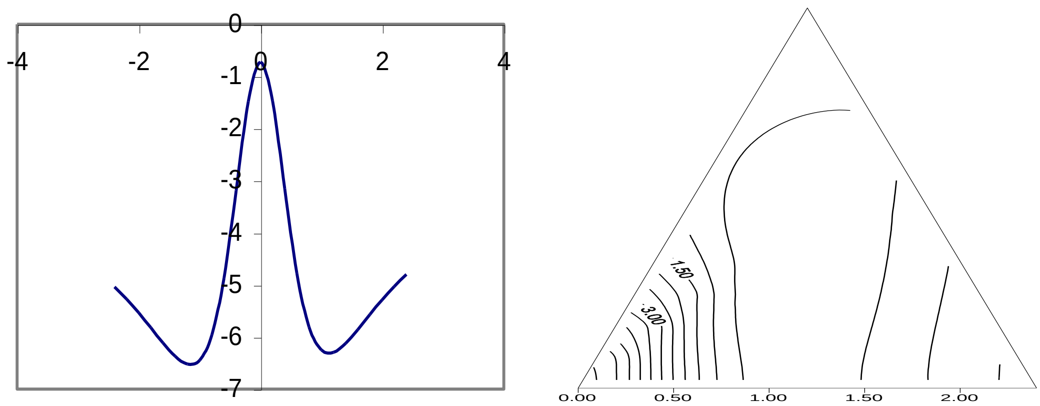
(b) (a)

Fig .(7-a):The corresponding β-γ plot for Hf-180 isotones
(7-b) The energy functional E(N; β,γ) as a function of β for Hf-180 isotope.



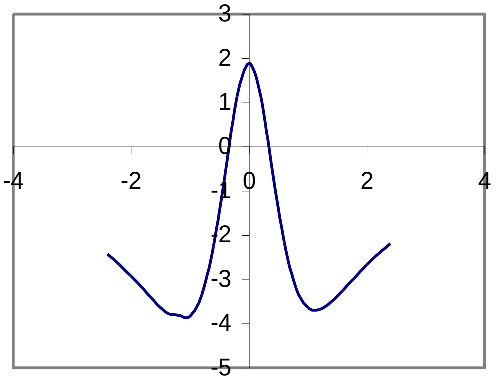
(b) (a)

Fig .(8-a):The corresponding β-γ plot for W-182 isotones
(8-b) The energy functional E(N; β,γ) as a function of β for W-182 isotope.

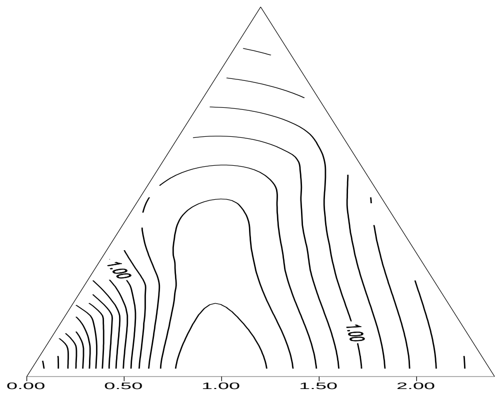


(b) (a)

Fig .(9-a):The corresponding β-γ plot for Os-184 isotones
(9-b) The energy functional E(N; β,γ) as a function of β for Os-184 isotones.



(b)



(a)

Fig .(10-a):The corresponding β-γ plot for Pt-186 isotones
(10-b) The energy functional E(N; β,γ) as a function of β for Pt-186 isotones

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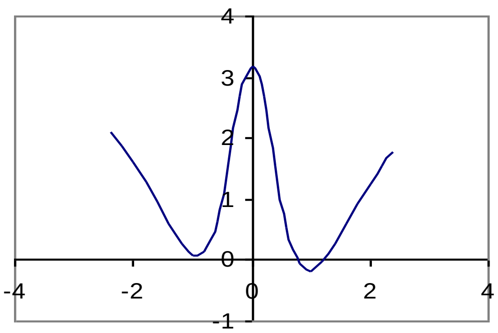
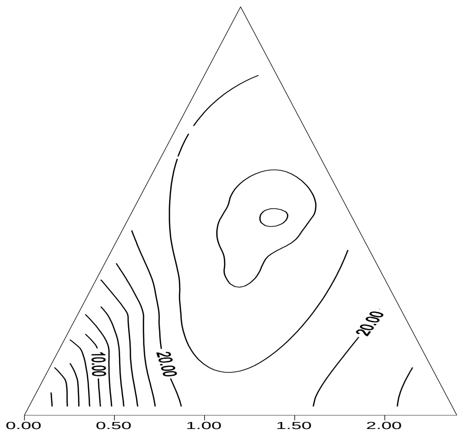


(b)



(a)

Fig .(11-a):The corresponding β-γ plot for Hg-188 isotones
(11-b) The energy functional E(N; β,γ) as a function of β for Hg-188 isotones.
