ISSN 2347 - 3983
Volume 8. No. 3, March 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter17832020.pdf
https://doi.org/10.30534/ijeter/2020/17832020

# General Properties for $^{114\text{-}118}$Te Isotopes by Using IBM-1

**Ahmad Abd Al Hussien Salah Mehdi** [1], **Mohammed Abd Almeer Al Shareef** [1]
[1] Department of Physics, faculty of Science, University of Babylon, Iraq, Ahmedmaster915@gmail.com

## ABSTRACT

In this proposal study, the mainly fitting Hamiltonian have been determined, to is wanted used for the near calculations of power levels also B(E2) values of even - even for $_{52}$Te with mass number (114≤ A ≤ 118 nuclei using the interacting boson type (IBM-1). Using the best fixed values of parameters in the Hamiltonian of the IBM-1, the energy levels, B(E2) and the electric quadruple moment value for a numeral of transitions in even-even isotopes series will be calculated. The results will be compare with a recent experimental data also with the theoretical calculated by using (IBM-1) and must it was observe so that they are in excellent concord. It will turn out that the interacting boson estimate (IBA) is fairly reliable for calculating spectra in the entire set of even-even $^{114\text{-}118}$Te isotopes. Also the branching ratios R', R'', R''' will be study it and the importance of studying the branching ratios is to locate the position of our isotopes $^{114\text{-}118}$Te relative to the dynamical symmetry U(5).Studying the surface potential energy using the equations of the Hamilton function.

**Key words :** IBM-1, B(E2), Potential Energy Surface, Nuclear Structure, Te Isotopes.

## 1. INTRODUCTION

To name nuclear properties like spins and powers of the little levels, decompose probabilities for the emission of gamma quanta's, probabilities (spectroscopic factors) of move reactions, complex moments and so on, a model of the tiny nucleus has to be able to describe them [1]. The IBM (at times named IBA mold) who has established that an main agent to the light nuclei (up to 50 nucleons), it is necessarily firm in shell model and decreases the shape of states deeply. The larger numeral of nucleons falls more shells have to be possessed into consideration and number of nuclear states soon after turns into so big this shield model ought be intractable [2].

## 2- THE IBM EXPLANATION

The pattern of (IBM) has been fairly successful at characterizing the collective properties of numerous medium and weighty nuclei. In the current activity we used the Model to study the low lying collective state of even-even Te isotopes, the Hamiltonian operator can be written down [3,4]

$$\hat{H} = \varepsilon \hat{n}_d + a_0 \hat{P}^{\dagger}.\hat{P} + a_1 \hat{L}.\hat{L} + a_2 \hat{Q}.\hat{Q} + a_3 \hat{T}_3.\hat{T}_3 + a_4 \hat{T}_4.\hat{T}_4 \tag{1}$$

ε is the energy of d_bosons, $\varepsilon = \varepsilon_d - \varepsilon_s$, $\varepsilon_s = 0$, therefore $\varepsilon = \varepsilon_d$, while $(a_0,\ a_1,\ a_2,\ a_3,\ a_4)$ represent the interaction strength for paring, angular momentum, quadruple momentum, couple and hexadecapole between boson respectively. Where $\hat{n}_d$ operator produce the numeral of *d* bosons, $\hat{P}$ stand for the paring operator, $\hat{L}$ represents the angular momentum operator, $\hat{Q}$ , is the quadruple operator, $\hat{T}_3$ and $\hat{T}_4$ stand for the couple and hexadecapole operators. In U(5) the equation of Hamiltonian is [5]

$$\hat{H} = \varepsilon \hat{n}_d + a_1 \hat{L}.\hat{L} + a_3 \hat{T}_3.\hat{T}_3 + a_4 \hat{T}_4.\hat{T}_4 \tag{2}$$

The full strength of quadruple (E2) transitions between low lying states of even-even nuclei is an remarkable observable to experiment nuclear paradigms which term collective phenomena. Fully distorted even nuclei display great quadruple transference forces B(E; $2_1^+$ $0_1^+$) [6]. at a modest form that force rises smoothly because increasing amount of valence nucleons or holes along an isotopic or isotonic chain as collectivity increases. considering symmetry of particles and punctures this model yields a maximum at mid-shell [7]. The equation of electric quadruple transition can be written by using the operators in the following form [8]

$$\hat{T}_m^{(E2)} = \alpha_2 [d^{\dagger}\tilde{s} + s^{\dagger}\tilde{d}]_m^{(2)} + \beta_2 [d^{\dagger}\tilde{d}]_m^{(2)}, \tag{3}$$

Where $\alpha_2$ and $\beta_2$ are two parameters used for fitting the experimental results.

The P.E.S ($V(N,\beta,\gamma)$) affords a final shape to the nucleus that agrees to the function of Hamiltonian, as display in Eq.(4) [9] :

$$E(N,\beta,\gamma) = \langle N,\beta,\gamma|H|N,\beta,\gamma\rangle / \langle N,\beta,\gamma|N,\beta,\gamma\rangle \tag{4}$$

The expectation value of IBM-1 Hamiltonian with the cohesive state $(|N,\beta,\gamma\rangle)$ is utilized to make IBM energy surface[9]. The potential energy surface can be indicate as a function of ( $\beta$) and ( $\gamma$) in following equation [9]:

$$V(N,\beta,\gamma) = \frac{N\varepsilon_d\beta^2}{(1+\beta^2)} + \frac{N(N+1)}{(1+\beta^2)^2}\left(a_1\beta^4 + a_2\beta^3\cos 3\gamma + a_3\beta^2 + a_4\right) \quad (5)$$

$\beta$ is a measure of the total deformation of nucleus, $\gamma$ is the quantity of perversion from centralize symmetry and correlates with the nucleus

## 3.RESULTS AND DISCUSSION

### 3.1 energy levels

The Te isotopes are neutron rich, have Z=52, the numbers of boson proton $N\pi = 1$ and boson neutron $Nv$ different from 7 in $^{114}$Te isotope to 9 in$^{118}$Te isotope (means particle boson). To study the levels in Te isotopes, want to assessment the parameters used in (IBM-1), by applying the IBM1 package, the fitted values of those parameters are listed in Table (1), they were patronized as a free parameters and their values were estimated by appropriate to experimental level. Generally our observation that the (EPS) parameters decreasing with total boson numbers increases.

Figure (1-4) shows a comparison between theoretical and available experimental energy levels for all studied Te isotopes [10]

**Table 1:** IBM-1 Parameters for even-even Te isotopes.

Energy Units are in MeV

| A | N | Eps | $\hat{P}.\hat{P}$ | $\hat{L}.\hat{L}$ | $\hat{Q}.\hat{Q}$ |
|---|---|---|---|---|---|
| $^{114}$Te | 7 | 0.6220 | 0.00 | 0.01 | 0.00 |
| $^{116}$Te | 8 | 0.6000 | 0.00 | 0.01 | 0.00 |
| $^{118}$Te | 9 | 0.5000 | 0.00 | 0.01 | 0.00 |

| A | Exp | $\hat{T}_3.\hat{T}_3$ | $\hat{T}_4.\hat{T}_4$ | Chi | So6 |
|---|---|---|---|---|---|
| $^{114}$Te | …. | 0.0009 | 0.0141 | 0.00 | 1.00 |
| $^{116}$Te | …. | 0.0000 | 0.0060 | 0.00 | 1.00 |
| $^{118}$Te | …. | 0.0300 | 0.0000 | 0.00 | 1.00 |

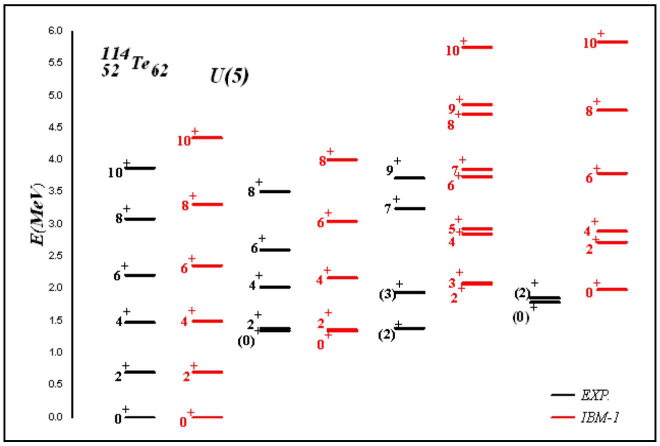

**Figure 1:** Comparison IBM-1 calculations with the experimental data for $^{114}$Te isotope

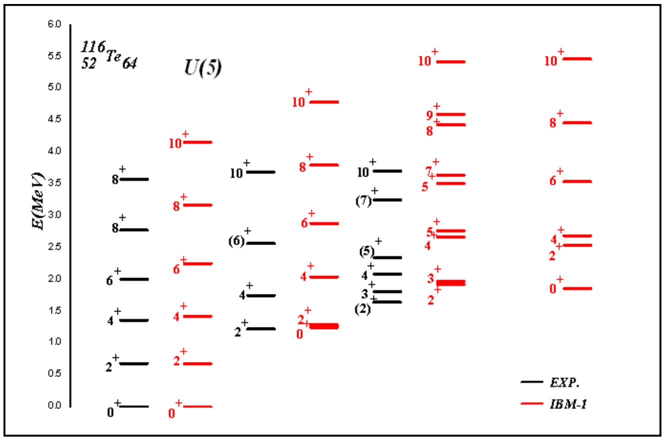

**Figure 2:** Comparison IBM-1 calculations with the experimental data for $^{116}$Te isotope.

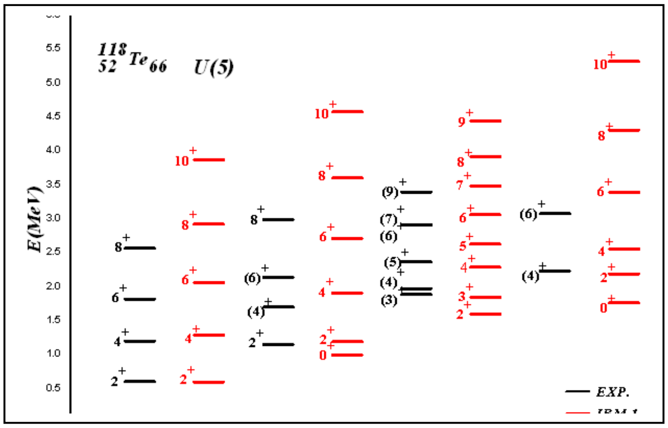

**Figure 3:** Comparison IBM-1 calculations with the experimental data for $^{118}$Te isotope

The energy ratios $E_{4_1^+}/E_{2_1^+}$, $E_{6_1^+}/E_{2_1^+}$, $E_{8_1^+}/E_{2_1^+}$ has been calculated theoretically for the even-even $^{114\text{-}118}$Te isotopes and compared with their corresponding experimental values taken from refs. [82] and with the typical values for each limit [8,9] as shown in Table (2) and shown in figures (5-7).

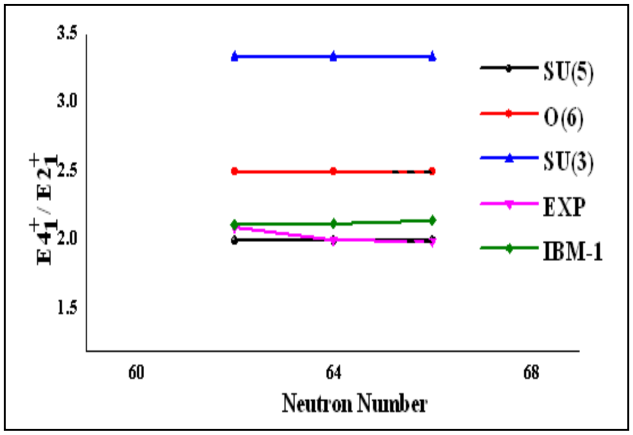

**Figure 5:** The Comparison of $E_{4_1^+}/E_{2_1^+}$ Theoretically, Experimentally and with Typical Values at Every Limit.

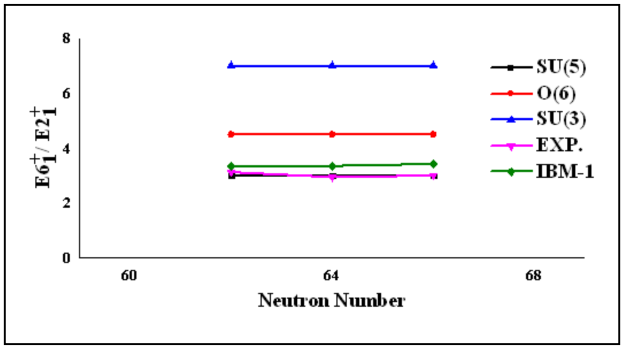

**Figure 6:** The Comparison of $E_{6_1^+}/E_{2_1^+}$ Theoretically, Experimentally and with Typical Values at Every Limit

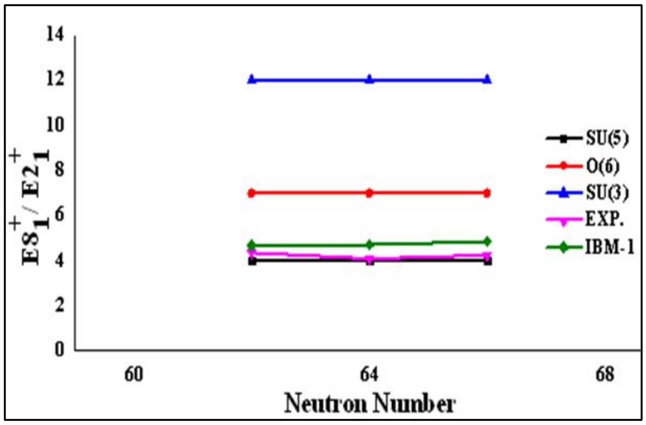

**Figure 7:** The Comparison of $E_{8_1^+}/E_{2_1^+}$ Theoretically, Experimentally and with Typical Values at Every Limit

### 3.2 B(E2) and Quadruple moment $Q_{2_1^+}$

Many datum can be gained by researching reduced transition probabilities B(E2). The (IBMT-code) were employed ($\alpha_2$, $\beta_2$). The parameters (E2SD) and (E2DD) applied in the existent calculations are fixed by the calculated values to the experimentally recognized ones and displayed in (Table 2).

A comparison between the experimental [10] and calculated $B(E2;2_1^+ \rightarrow 0_1^+)$ are shown figure (8) and prove that results are quite well for all isotopes under study

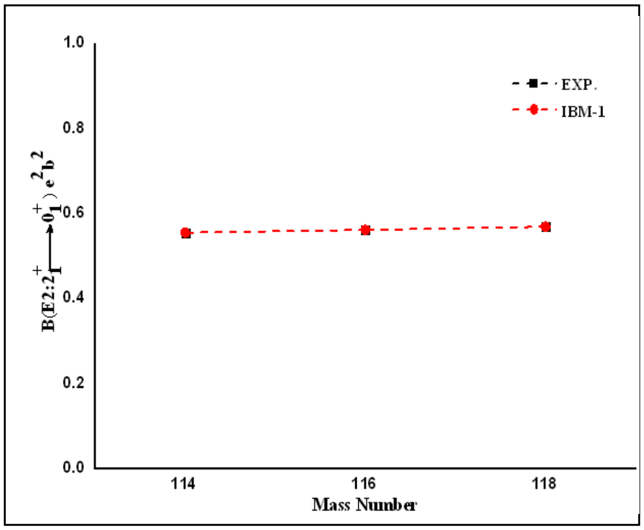

**Figure 8:** Comparison of the Experimental Ref. [10] and Calculated $B(E2;2_1^+ \rightarrow 0_1^+)$ for $^{114-118}$Te

The quadruple moment (Q) is a remarkable property for nuclei and is defined as follows the variation from the spherical charge distribution inside the nucleus and from the quadruple moment we can determine if the nucleus is spherical, deformed oblate or prelate shapes [11-16].

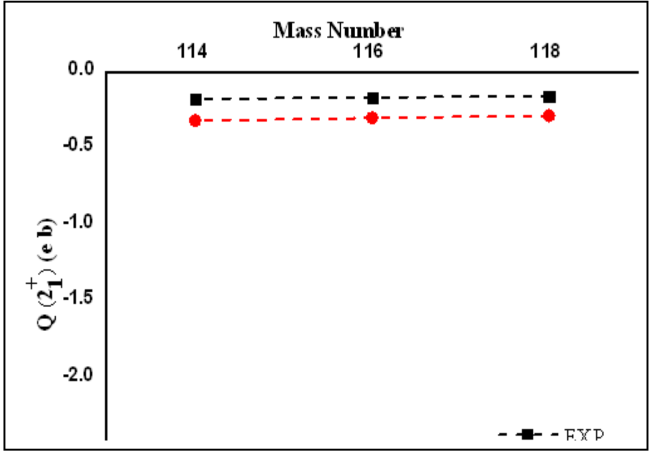

**Figure 9:** The Comparison Between the Experimental Quadruple Moment *Q*(e b) Taken from Refs.[10] and the Calculation from Present Work for $^{114-118}$Te Isotopes.

**Table 2:** The experimental values of B(E2) and the coefficients(E2SD, E2DD) for $^{114-118}$Te used in the present work.

| A | $B(E2:2_1^+ \rightarrow 0_1^+)$ | | E2SD ( eb) | E2DD (EB) |
|---|---|---|---|---|
| | Exp. $e^2b^2$ | Theo. $e^2b^2$ | | |
| $^{114}$Te | 0.556 | 0.556 | 0.281831 | -0.1395 |
| $^{116}$Te | 0.5623 | 0.5623 | 0.265118 | -0.13123 |
| $^{118}$Te | 0.57 | 0.57 | 0.251661 | -0.12457 |

### 3.3The B(E2) branching ratios

The significance to study branching ratios is to research the shape of the nucleus and it's dynamical symmetries and to set which dynamical symmetries. The $R$, $R'$ and $R''$ defined as follows [17, 18]:

$$R = \frac{B(E2;4_1^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)} \tag{6}$$

$$R' = \frac{B(E2;2_2^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)} \tag{7}$$

$$R'' = \frac{B(E2;0_2^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)} \tag{8}$$

The estimated them and their equivalent experimental values are presented in Table (3). The comparison experimental and calculated branching ratios and the typical values at the limits are display in the figure (10).

**Table 3:** Theoretical B(E2) branching ratios for $^{114-118}$Te isotopes

| **B(E2) Ratios** | **$^{114}$Te** | **$^{116}$Te** | **$^{118}$Te** | **SU(3)** | **O(6)** |
|---|---|---|---|---|---|
| $R = \frac{B(E2;4_1^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)}$ | 1.71429 | 1.75 | 1.77778 | 1.4 | 1.4 |
| $R' = \frac{B(E2;2_2^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)}$ | 1.71429 | 1.75 | 1.77778 | 0 | 1.4 |
| $R'' = \frac{B(E2;0_2^+ \rightarrow 2_1^+)}{B(E2;2_1^+ \rightarrow 0_1^+)}$ | ---- | ---- | ---- | 0 | 0 |

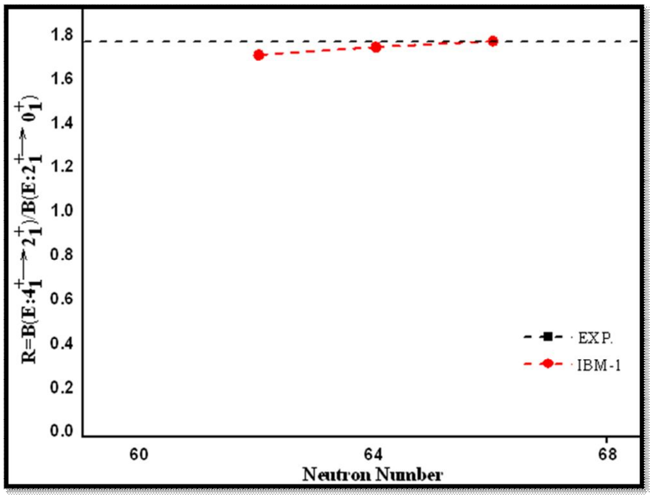

**Figure 10:** Comparison between the Experimental and Calculated B(E2) Branching Ratios for Even-Even $^{114-118}$Te Isotopes with the Typical Values of U(5)

### 3.4 Potential Energy Surface (P.E.S)

The PES.FOR program is applied to calculate P.E.S $V(N,\beta,\gamma)$. In this work, it has been calculated from Eq.(5). In the figures (11-14), the contour plots in the (γ-β) plane resulting from $E(N,\beta,\gamma)$ are shown for $^{114-118}$Te isotopes. The triaxial disfigured assists to know the prelate to oblate shape transition that occurs in the considered Te isotopes.

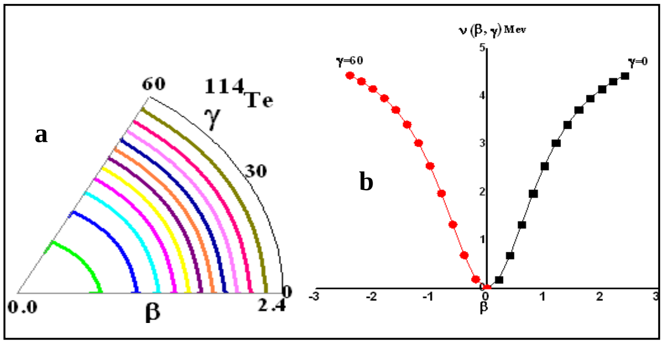

**Figure 11:** The potential energy surface in γ-β plane for $^{114}$Te isotope.

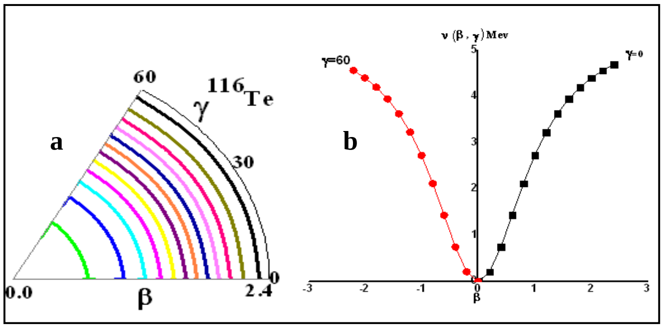

**Figure 12:** The potential energy surface in γ-β plane for $^{116}$Te isotope.

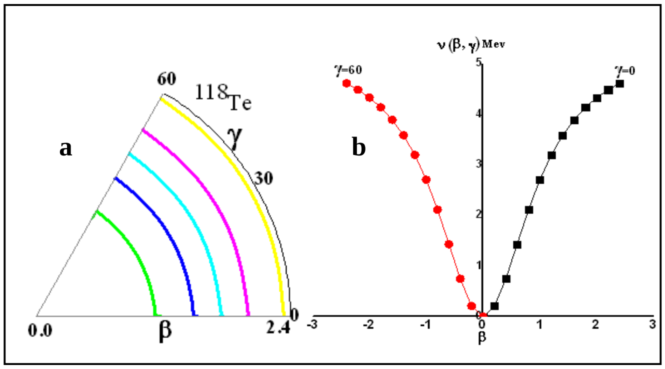

**Figure 13:** The potential energy surface in γ-β plane for $^{118}$Te isotope.

## 4. CONCLUSION

1. the general behavior of even-even $^{114-118}$Te U(5). The Hamiltonian parameter $(\varepsilon)$ has a large descent. This makes $^{114-118}$Te more nearby to vibrational limit. The structure of beta and gamma bands is display up obviously, and fully reproduced

2. The studied structure band of nuclei $^{114-118}$Te where in the region U(5). The level spacing in beta and gamma is larger than that in the ground band indicating a large moment of inertia for the beta band. The present calculation gives a good reproduction of the ground-state band.

3. The energy spectra and the spacing of these nuclei were found to fit good with experimental data . From these figures we can see that very good reasonable agreement between the values of energy ground state (g-band) of sequence $(0_1^+, 2_1^+, 4_1^+, ....)$ and their experimental state best than other bands.

4. There is no fitting in some energy positions of the other bands because of mixed symmetry states for the some excited energy levels, studying in IBM-2

5. The study of the reduced transition probability $B(E2;2_1^+ \rightarrow 0_1^+)$ that it decreases as the neutron number increase, and this is a key signature that the nuclei deformation less when near to closed shell and become stable. The calculations of B(E2) values display a good agreement with the available experimental data.

6. The ratios of the reduced transition probabilities $R$, $R'$ and $R''$ have been found in agreement both experimentally and theoretically also with in consistence with their ideal corresponding limits.

7. The deformation is decreasing as the neutron numbers increase until arrive to magic number of neutron (82). Whereas the neutron number increases, the energy of the first $(2^+)$ state decreases started.

## REFERENCES

[1] W. Pfeifer. ***An introduction to the Interacting Boson Model of the atomic nucleus***, Switzerland, 1998.
[2] R. F. Casten, *Phys. Rev, C*, Vol.41, No.6, p.198, 1990.
[3] A. Subbed, *Turk, J, Phys*, 2011,35,(1),43. https://doi.org/10.25291/VR/35-VR-43
[4] R. F. Casten . ***Nuclear Structure from a Simple Perspective***, Oxford Press, 1990.
[5] D. Banditos and E. David . ***Interacting Boson Models of Nuclear Structure***, Stanford , Pub. In the United State, By Oxford University Press, New York, 1988.
[6] A. Bohr and B. R. Mottelson, *New York, USA*, Vol. 1, Nol.2, p. 45, 1975.
[7] R. F. Casten. ***Nuclear structure from a simple perspective***, Oxford Press, Oxford, England, 2000.
[8] A. Aroma and F. Iachello. ***The Interacting Boson Model***, Cambridge University Press, Cambridge, UK, 1987.
[9] R. F. Casten and D.D Warner, *Rev. Mod. Phys*. 60, 389,1988. https://doi.org/10.1103/RevModPhys.60.389
[10] ENSDF, ***http:// www.nndc.bnl.gov/ensdf, Nuclear data sheet ,*** 2010.
[11] K.S. Krane and J. M. Shobaki , *J. Phys, Rev*, C16, 4, 1977.
[12] R.F. Casten and D.D. Warner. *Rev. Mod. Phys*. 60, 389, 1988.
[13] O.A. Muwaffeq . ***Nuclear structure calculations of some A(even-even) and odd A nuclei using IBM-1 and IBFM-1***, Ph.D. Thesis , Bagdad University 2007.
[14] David Warner, *Nucl.Phy,A*, *Nature* 420, 614-615, 2002. https://doi.org/10.1038/420614a
[15] S. N. Aboud . ***An application of interacting boson model in nuclear***, ***M.Sc***. Thesis, Barsah University 1990.
[16] J.K. Tuli, *Nuclear Data Sheets*, **11**(1), 12, 1998.
[17] F. Iachello, *Phys. Rev. Lett*. 87,052502, 2001.
[18] P. Cejnar, J.Jolie and R. F. Casten, *Rev. Mod. Phys*. 82. 2010. 2155. https://doi.org/10.1103/RevModPhys.82.2155