A Deformed Shapes in Isobars Nuclei $^{126}Te, ^{126}Xe, ^{126}Ba, ^{126}Ce$

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Abstract

The research studies energy levels and possibility of electromagnetic transmission for a group of isobars $^{126}Te, ^{126}Xe, ^{126}Ba, ^{126}Ce$ in order to obtain deformation effort V(β,γ) and drawing of contourian and analogical shapes and to show deformation extance which are undergone from it in the case of increasing number of protons for it through transmission from spherical shape with nucleus ^{126}Te to γ-soft state then reaching rounding state in the case of ^{126}Ce isobar and the drawings are impressionistic about regions of IBM for every isobar .

الخلاصة

تمت دراسة مستويات الطاقة واحتمالية الانتقال الكهرومغناطيسي لمجموعة من الآيزوبارات $^{126}Te, ^{126}Xe, ^{126}Ba, ^{126}Ce$ لغرض الحصول على جهد التشوه V(β,γ) ورسم الأشكال الكنتورية والتناظرية ولإظهار مدى التشوه الذي يحصل لها في حالة زيادة عدد البروتونات وذلك بالانتقال من الشكل الكروي بنوية ^{126}Te إلى γ-soft ثم الوصول إلى الحالة الدورانية عند الآيزوبار ^{126}Ce وكانت الأشكال معبرة عن مناطق IBM لكل آيزوبار.

Introduction

This study investigates the effect of protons over groups of isobars ^{126}Te, ^{126}Xe, ^{126}Ba, ^{126}Ce, and deformed cases which every isobar is undergone it.

Shell model has much successfulness in describing number description but this model does not submit complete description for all types of all nuclei though it submits successful description for stable nuclei of closed shell type which contains additional nucleon or little more, in the case of closed shell nucleus, the nucleus is spherical and in the case of adding additional nucleon or more produces little deformation and thereat these nuclei are moving by significant quantity in comparison to spherical case and assembling movements are taking place, including or containg some nucleons (Cohen,1971).

Particle shell model is preferable for its successfulness in spin and parity calculation and beta and gamma deformations which belong ground levels and also succeeds in magnetic moment calculation for nuclei in its ground levels but is fails in quadruple moment calculation and averages of transition especially in transition regions between two closed shells failures emerge geometrical collective models and are supposed in these models that large number of nucleons are moved in cooperative assembling movement submitting description by several nuclei characteristics and are capable to describing composition of rounding and oscillating bands (Enge,1966).

Interacting Boson Model (IBM)

There are rounding and oscillating anxieties in the nuclei, oscillating anxieties in the nuclei, oscillating anxieties come from elasticity of nuclear surface and rounding movement represents rounding of deformed surface which include a freely particles and both of two (oscillation and rounding movements) include systematic replacements for large nucleons number that describing the two kinds of movement as a class of nuclear collective motion and the second kind of anxieties which leads to create large quadrupole deformations for low anxieties cases of nuclei (Enge 1966).

This study investigates the affect of protons on the group of isobars $^{126}Te, ^{126}Xe, ^{126}Ba, ^{126}Ce$, and shapes of deformations which obtains for each isobar.

Interacting Boson Model (IBM) starts basically by an idea of describing static electrical quadrupole moments for nuclei of great mass numbers which lay among closed shells. Nuclear collective motion which cause permanent nuclear deformation is necessary taking place (Iachello,1987).And there are number of ways for writing Hamiltonion function of energy, and one of these forms which widely is used is (Casten,1988).

$H=\in n_d+a_0 p^{\dagger}.p+a_1 L^2+a_2 Q^2+a_3 T_3^2+a_4 T_4^2$................................ (1)

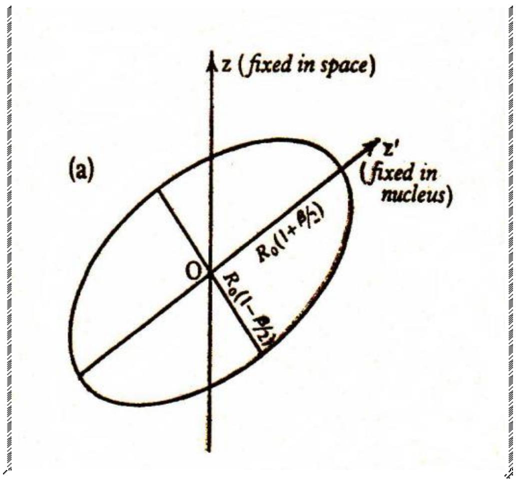
$\in=\in_d-\in_s$ denotes to energy of bosons and to make it easy the study supposes that an energy of boson equals zero so that $\in=\in_d$ .The factors a_0 , a_1 , a_2 , a_3 denote to power of double interaction, angular moment, quadrupole moment, octupole moment, and hexadecapol moment among bosons successively.

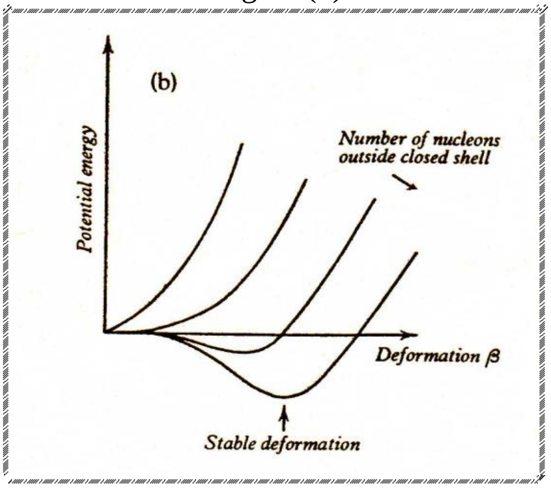
The five resultants for bosons d extend as well as the single resultant for boson s over six dimensional space and create the aggregate for the problem, and for the figure N of bosons is SU(6) .

This model is able to calculate energies, in addition to another characteristics such averages of electromagnetic transition which for one particle in its quantitative formula is the following (Abrahams,1981).

$T_m^{(E2)}=\alpha_2[d^{\dagger}s+s^{\dagger}d]_m^{(2)}+\beta_2[d^{\dagger}d]_m^{(2)}$..(2)

And the origin of permanent deformation is discussed by the following method : suppose that nucleon has a deformation of the kind as in the figure (1)





Figure(1) The origin of permanent deformation. Figure(2) Function of deformation.

And they are symmetrical over the pole OZ' which is constant in the body and denotes by deformation factor β there at:

$\beta=\dfrac{\Delta R}{R_0}$......................(3) R is the radius of nucleon

$R=R_0 A^{\frac{1}{3}}$.....................(4) A is the mass number of nucleon

ΔR represents the difference between main pole and secondary one for ellipse and potential energy for nuclei as a function of deformation factor (Burcham,1962) is noticeable in figure(2).

Potential Energy Surface

The essential concepts for nuclear structure defines which the so called potential energy surface which represents potential energy of nucleon as a function for amassment coordination and all feasible nuclear shapes can be determined by two given factors β , γ or a_o, a_2 for the relations (Bondatsos,1988).

$$V(N,\beta,\gamma)=\frac{<N,\beta,\gamma|H|N,\beta,\gamma>}{<N,\beta,\gamma|N,\beta,\gamma>}\text{..............................(5)}$$

By derivation of potential energy surface equation) V(N,β,γ) related to (β,γ) results the following general equation (Iachello,1987).

$$V(N,\beta,\gamma)=\frac{N}{1+\beta^2}(\varepsilon_s+\varepsilon_d\beta^2)+\frac{N(N-1)}{(1+\beta^2)}(A_1\beta^2+A_2\beta^3Cos3\gamma+A_3\beta^2+A_4)\text{......(6)}$$

N is aggregative boson number, β is magnitude of nuclear deformation and takes values (0,2,4), γ is asymmetry angle and its value is between (0^0-60^0), A_1,A_2,A_3,A_4 are coefficients conduct potential surface function.

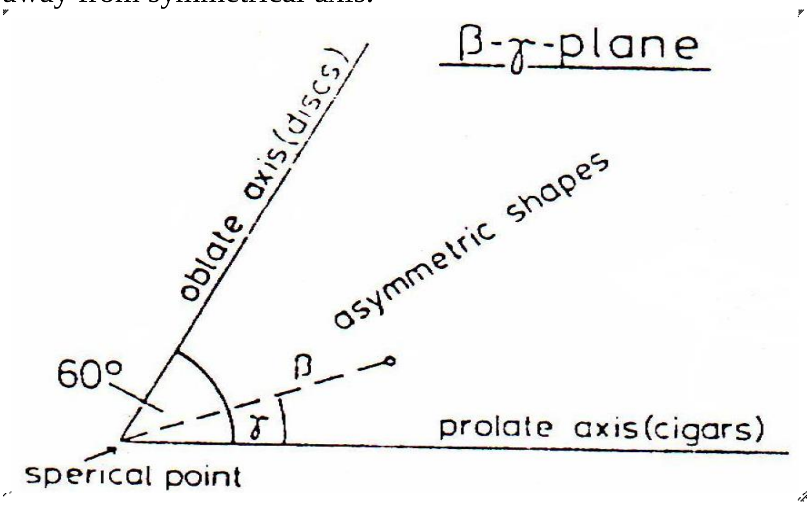
The nucleon formation designates by both deformation factors (β,γ) whereas β approaches to 0 for spherical nuclei in the same time it can not be zero for deformed nuclei , when γ equals 0^0,the deformation takes prolate shape and when γ equals 60^0 the deformation takes oblate shape, potential energy surface equation for the three symmetries can be given by the following equations (Casten,1988).

$$E\ (N;\beta,\gamma)=\varepsilon_d N\frac{\beta^2}{1+\beta^2}\text{ ....SU(5)........(7)}$$

$$E(N;\beta,\gamma)=kN(N-1)\frac{1+\frac{3}{4}\beta^4-\sqrt{2}\beta^3\cos3\gamma}{(1+\beta^2)^2}\text{ ....SU(3)...........(8)}$$

$$E(N;\beta,\gamma)=k'N(N-1)\left[\frac{1-\beta^2}{1+\beta^2}\right]^2\text{ ....O(6).........(9)}$$

Whereas k harmonizes with a_2 and k′ harmonizes with a_0 which is given by equation (1).Figure (3) shows some information which help in realization of aggregative potential and β represents expulsion certain potential away from spherical potential nucleus and measures aggregative deformation of nucleus and γ represents magnitude of variance away from symmetrical axis.

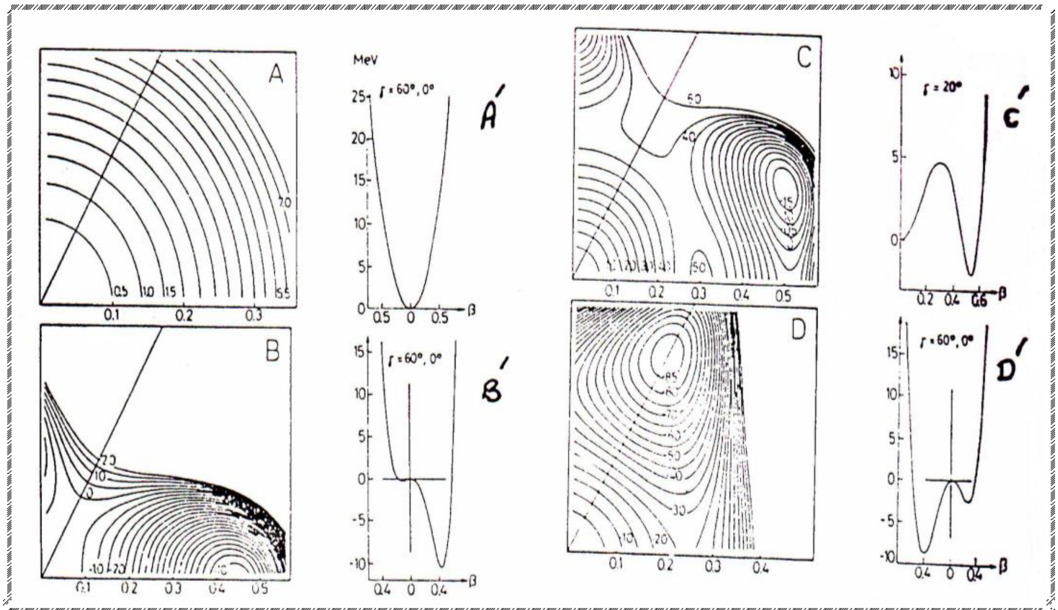


Figure(3): β-γ-Plane

By reason of symmetrical characteristics it may can define the range of value which is taken by γ $[0^0 \le \gamma \le 60^0]$ and γ is chosen to be 0^0 (zero) because the shape of nucleus is lengthened resembles the cigar and has three symmetrical axes . And in the case of $\gamma = \pi$ $\gamma = \pi/3$, $\gamma= 5\pi/3$ and the nuclear shape is oblate ellipse and therefore the values of γ are chosen as mentioned above (Burcham,1962).

Figure (4) shows counter maps for four kind of aggregative potential energy surfaces , in the level β-γ, there are quite different four kinds of nuclei .The first surface A is aggregative potential energy surface for consistent vibrations and the section round prolate axis (γ=0) and oblate axis (γ=60) parabola besides an existent of lowering region in potential in the point which represents spherical potential curve $V(\beta,\gamma)$ is shown in the figure (A′) and it is obvious that aggregative potential belongs for spherical vibrations .But surface B has deep lower potential region on the axis which represents lengthened side for nucleus thus it represents symmetrical axes nuclei and which were experienced severe deformation as cigar as for nuclei which have potential surface as in figure (c) and declining potential region between two axes, such nuclei have the less potential energy when their shapes are asymmetric and therefore figure (C′) is an example for rounding asymmetric nuclei .For figure(D) represents axially asymmetric nuclei which analogize the disc in their ground cases because that declining potential region locate on the axis which represents oblate shape for nucleus in addition to deformation of ground state it can be found additional data about aggregative potential energy surface and of these examples that depth of the minimum potential region gives stability for nucleus which determines surface shape , also that valleys in the surface denotes that every variation in the shape is preferable also that existence of states of isometric shape structures may are shown clearly if nuclei have aggregative potential in two or more of declining potential regions.

In view of the fact that surfaces of potential equality are using easily and have long sighted imagination about nuclear structure therefore formed these surfaces for all even-even nuclei and these surfaces are predicted or expected that aggregative potential for neighboring nuclei are symmetrical (Wood ,1992).



Figure(4): Counter maps for four kind of aggregative potential energy surfaces.

Results and Calculation

Isobars	The parameters									
	Eps	a_0	a_1	a_2	a_3	a_4	CHI	$B(E2;2_1^+\rightarrow 0_1^+)$ (e^2b^2)	E2SD (eb)	E2DD (eb)
$^{126}_{52}Te$	0.5940	0.0	0.0050	0.0	-0.0305	0.0480	0.0	0.0994	0.1410	-0.09880
$^{126}_{54}Xe$	0.0	0.0206	0.0181	-0.0586	0.0001	0.0019	-0.0590	0.1511	0.09973	0.0
$^{126}_{56}Ba$	0.0	0.0745	0.0256	-0.0370	0.0	0.0	-0.2900	0.2226	0.10398	0.0
$^{126}_{58}Ce$	0.0	0.0	0.0157	-0.0202	0.0	0.0	-0.0590	0.5405	0.09976	-0.29580

Calculation were performed in the complete Hamiltonian using the IBM-1 computer code IBM for energies and IBMT- code for B(E2) values.

For (Te^{126}, Xe^{126}, $Ba^{126}$and Ce^{126}) there are (five, seven, nine and eleven) active bosons, formed by (one, two, three and four) proton (particle) pairs and (four, five, six and seven) neutron (hole) pairs out side of the closed shells (50, 50) respectively. The values of the parameters which gave the best fit to the experimental date (Moon,1998 and Schiffer,1986) are given in table (1) and calculated level energies are compared with the experimental in fig (5).

For the calculation of the absolute B(E2) the two parameters α_2 and β_2 equ.(2) the equivalent parameters in IBMT-code are $E2SD = \alpha_2, E2DD = \sqrt{5}\beta_2$ Where:

$$\beta_2 = \frac{-0.7}{5}\alpha_2, \beta_2 = -\sqrt{7/2}\alpha_2, and \beta = 0$$

in SU(5), SU(3) and O(6) respectively.

Were adjusted according to the experimental $B(E2:2_1^+ \rightarrow 0_1^+)$value table(1), the B(E2), $Q_{21}^+$and B(E2) ratios values calculated these parameters are shown in table(2) together with experimentally(Moon,1998 and Schiffer,1986) determined values .

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

Table (2):_ experimental (Moon,1998 and Schiffer,1986) B(E2) values (e^2b^2) and Q_{21}+(eb) in Te, Xe, Ba and Ce isobars nuclei are compared with IBM-1 results.

$i \rightarrow f$	B(E2) e^2b^2							
	Te^{126}		Xe^{126}		Ba^{126}		Ce^{126}	
	p.w	Exp	p.w	Exp	p.w	Exp	p.w	Exp
$2_1^+ \rightarrow 0_1^+$	0.0994	0.095	0.1511	0.154	0.2226	0.245	0.5405	0.54
$2_1^+ \rightarrow 0_2^+$	0.0318	-	0.0001	-	0.0005	-	0.0753	-
$2_2^+ \rightarrow 0_1^+$	0	0.0008	0.0018	0.002*	0.0222	0.0212	0.1154	0.1624
$2_2 \rightarrow 0_2^+$	0	-	0.0428	-	0.0578	-	0.0388	-
$2_1 \rightarrow 2_2$	0.159	0.1314	0.1871	0.2064	0.0757	-	0.01566	-
$4_1 \rightarrow 2_1$	0.159	-	0.2029	-	0.3148	0.3275	0.035	0.0443
$4_2 \rightarrow 2_1$	0	-	0.0001	-	0.0038	-	0.0136	-
$4_2 \rightarrow 2_2$	0.0937	-	0.1134	-	0.1665	0.0987	0.0171	0.0261
$Q21^+$	0. 22 -eb	-0. 2 eb	-0.29	-	-1.15	-	-2.0783	-

Table (3) represents variables relate by deformation value which is represented by β and γ (asymmetric angle) and A_1, A_2, A_3, A_4 are coefficients relate with surface potential function according to equation (6) which an equation of potential energy surface V(β, γ) which is by using in the program , the values of β and γ are obtained for each isobars of ^{126}Te,^{126}Xe,^{126}Ba,^{126}Ce and figures (6-9) are drawn and they are shown isometric potential lines , on the other hand the value of deformation in each isobar are shown in figures (10-13).

Table (3) the parameters were obtained by IBM-1 code.

Isobars	**The parameters**						
	N	ε_s	ε_d	A_1	A_2	A_3	A_4
$^{126}_{52}Te$	5	0.000	0.668	0.025	0.000	0.000	0.000
$^{126}_{54}Xe$	7	-0.293	0.053	0.006	-0.007	-0.245	0.000
$^{126}_{56}Ba$	9	-0.185	0.113	0.018	-0.023	-0.185	0.000
$^{126}_{58}Ce$	11	-0.101	0.074	0.000	-0.003	-0.081	0.000

Discussion and Conclusion

To comprehend figure (5) this belongs to theoretical and practical energy levels (moon,1998 and Schiffer,1986) figures A(6-9) are drawn to show isometric potential lines V(β,γ) for the isobars,^{126}Xe,^{126}Ba,^{126}Ce progressively, and the study of potential energy surface for each nucleus which represents nuclear potential energy as a function of collective coordination's for coefficients nuclear shape β, γ are helpful to realize principal conceptions of nuclear structure for that nucleus (Gotthard,1971) . This study starts its discussion by discusses isobar which is proton number p=52 and continues in the discussion of others isobars which have increase number of neutrons and considers that (β_{min}=0) for spherical shape and (β_{max}=2.4)for both lengthened prolate sides is ($\gamma = 0^0$) and oblate is ($\gamma=60^0$) (Kumar,1984) and in the drawing figure of nuclear potential energy surface of $^{126}_{52}Te$ (A6) which to be considered a good sample for nucleus which has spherical shape whereas least potential for this nucleus in its ground case be represented by potential of spherical case which takes place in (β=0) so that nucleus has no deformation factor and this is shown in figure (B6) in the nucleus $^{126}_{52}Te$ so that this **خطأ! ارتباط غير صالح.** has a vibrating shape (Ginocohio,2000).

On the other hand figure (A7) isomeric potential lines of isobar $^{126}_{54}Xe$ where be considered that potential of each line of these lines are measured relating to potential of spot which represents V_{min} nuclear surface and which in the same time is measured relating to isometric potential lines which represent spherical shape. The potential of ground state for this nucleus is (V_{min}= 4.49MeV) and locates on the side that represents prolate shape at β=1.2 .And this is shown that the shape of studied nucleus is prolate and inclines towards γ-soft at ground state and this is shown in figure (B7), where the depth of inclined potential region is greater at the side, where the difference in potential between then is (0.17 MeV)(Tamura,2003).

As to figure (A8) represents potential energy surface for isobar, which has the least potential at the side which represents prolate shape of nucleus and this nucleon is far – off spherical shape (V_{min}= 4.54 MeV),since that the depth of declining region is deep and the deformation of it great (β=10),But the oblate side has potential V_{min} =3.7 MeV, whereas the difference between the potential of the former and its of the later is (0.83 MeV) as shown in figure (B8).Thus denotes that nucleon inclining to γ-soft, considering that its potential depth is larger in the prolate side of it in comparison with the former nucleon $^{126}_{54}Xe$ .Since figure (A9) represents potential energy surface for isobar $^{126}_{58}Ce$ and least potential for nucleon surface in its ground state is (V_{min} 3.33 MeV) measuring by spherical shape and locates on prolate side but by little difference from oblate side (0.16 MeV) as is shown in figure (B9),which its value is little relatively which offers nucleus some rounding characteristics which are rised through studying energy levels and probability of electromagnetic transmission (Tamura,2003).

References

Abrahms, K., Allaar, K. and Dieperink A. (1981) Nuclear Structure, B. phys. ,67: 53-89.

Bondatsos, D.(1988) Interacting Boson Model of Structure ,pub. In the United state ,By Oxford University Press, New York.

Burcham, W.E.(1962) Nuclear Physics an introduction , London , Beccles and Colchester.

Casten, R. ,and Warner D. (1988) Interacting Boson Model ,Rev. Mod. Phys. 960: 389-469.

Cohen., B. (1971) Concepts of Modern Phys., McGraw Hill Book Company , New York.

Enge , H.(1966) Introduction to Nuclear Phys., Addison Wesley , U.S.A.

Ginocchio, J.N., and Kirson M.W. (2000) The Interacting Boson Model, Nucl. Phys. A ,12,43-51.

Gotthard Gneuss and Walter Greiner (1971) Potential Energy Surface, Nuclear Physics A,171, 449-479.

Iachello, F., and Arima A. (1987) The interacting Boson Model (Cambridge University Press, Cambridge England).

Kumar, K .(1984) Nuclear Models and search for unity in nuclear physics ,University of Bergen press.

Moon, C. (1998)The interacting boson Model ,Journal of the Korean Physical Society, 32,666-681

Schiffer, K.(1986) Nuclei near to closed shells, Z. physics, 323,487-503.

Tamura ,T. ,and Weeks K.J. (2003) Analysis of Nuclear Collective Motion in Terms of the Boson Expansion Theory ,Phys. Rev.C,20,360-387.

Wood, J.L., and Heyde K. (1992) Coexistence in Even –Mass Nuclei ,Physics Reports,

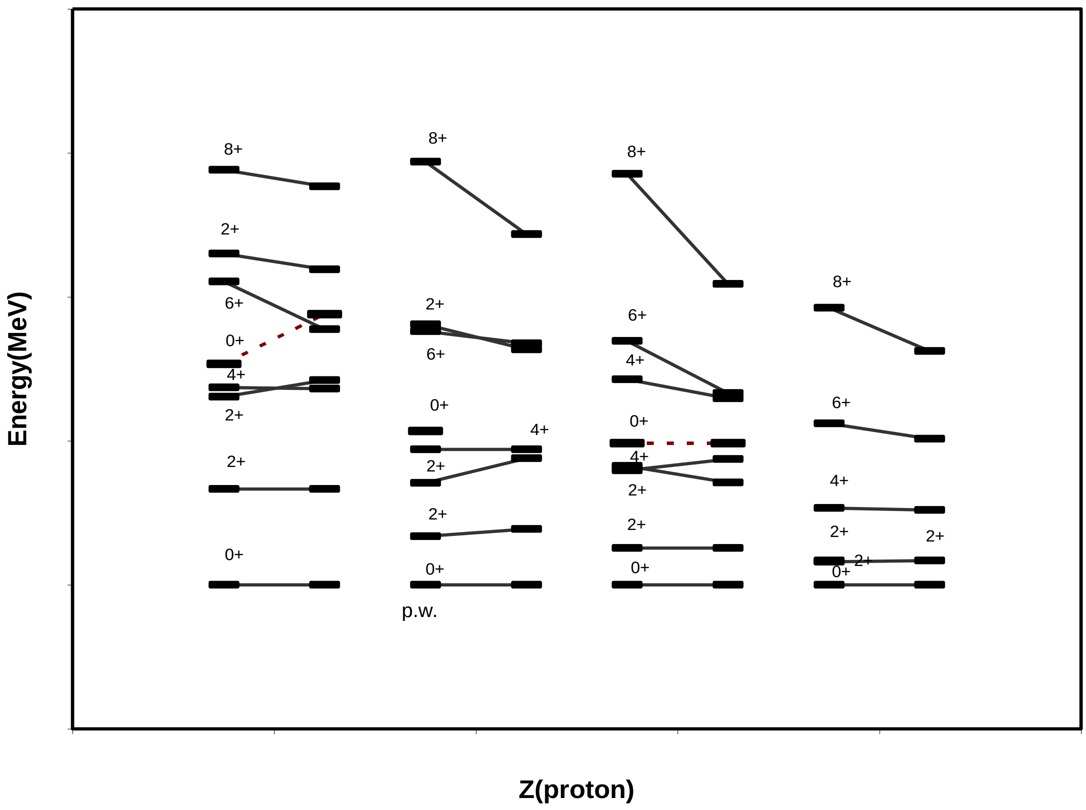
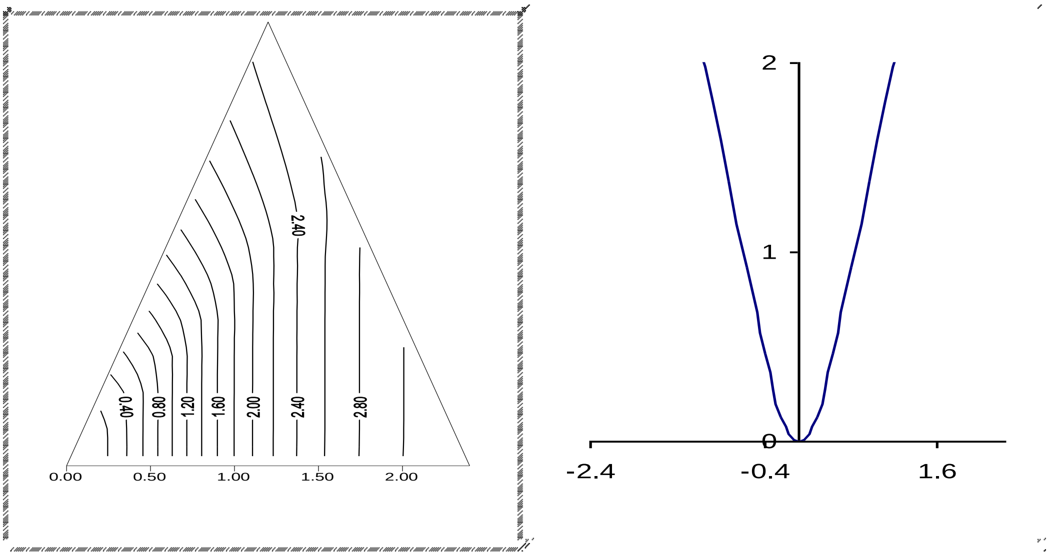
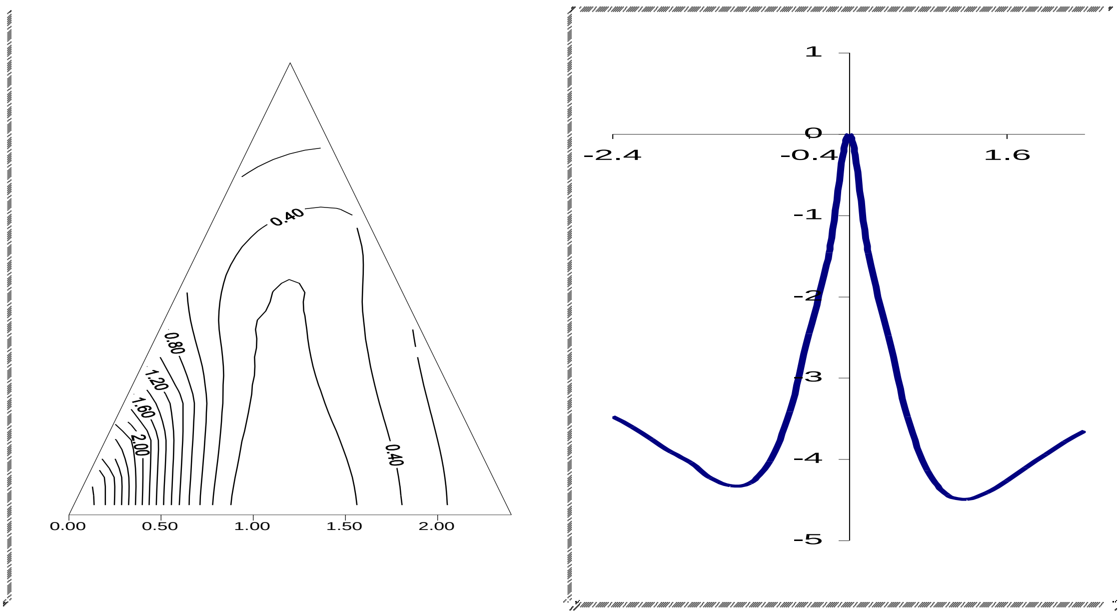


Fig:(5) Comparison of experimental (Moon,1998 and Schiffer,1986) and theoretical energy levels of ^{126}Te,^{126}Xe,^{126}Ba,^{126}Ce.



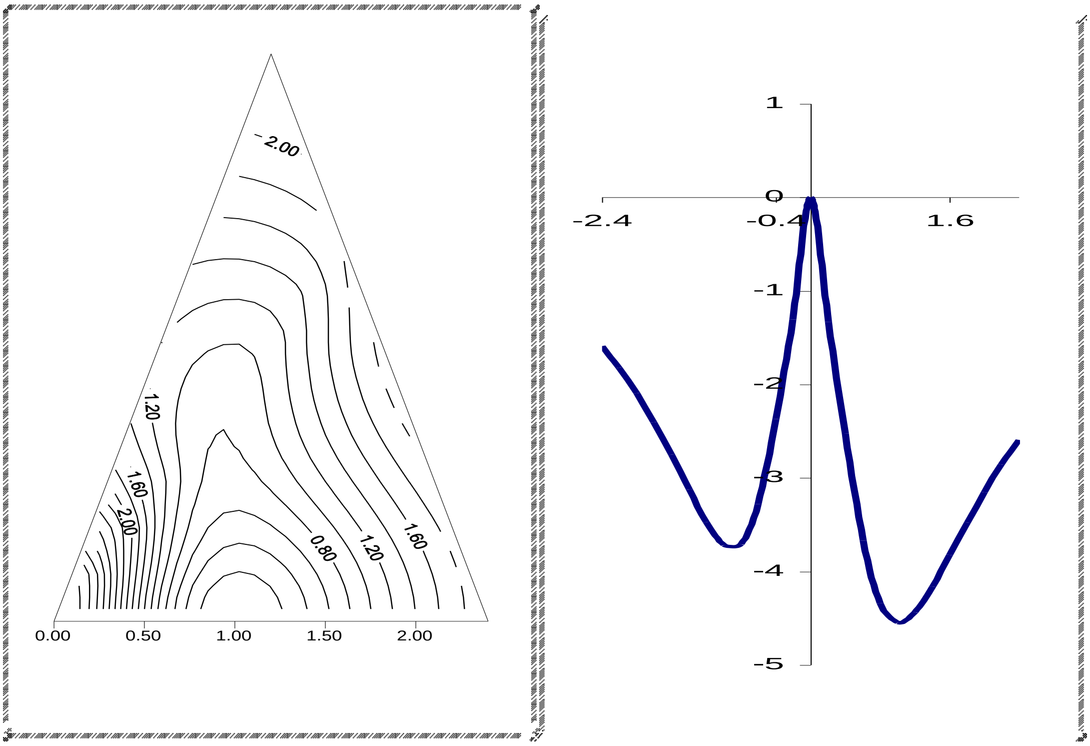
A B

Fig. 6. (A , B): The β - γ plot for ^{126}Te isobars



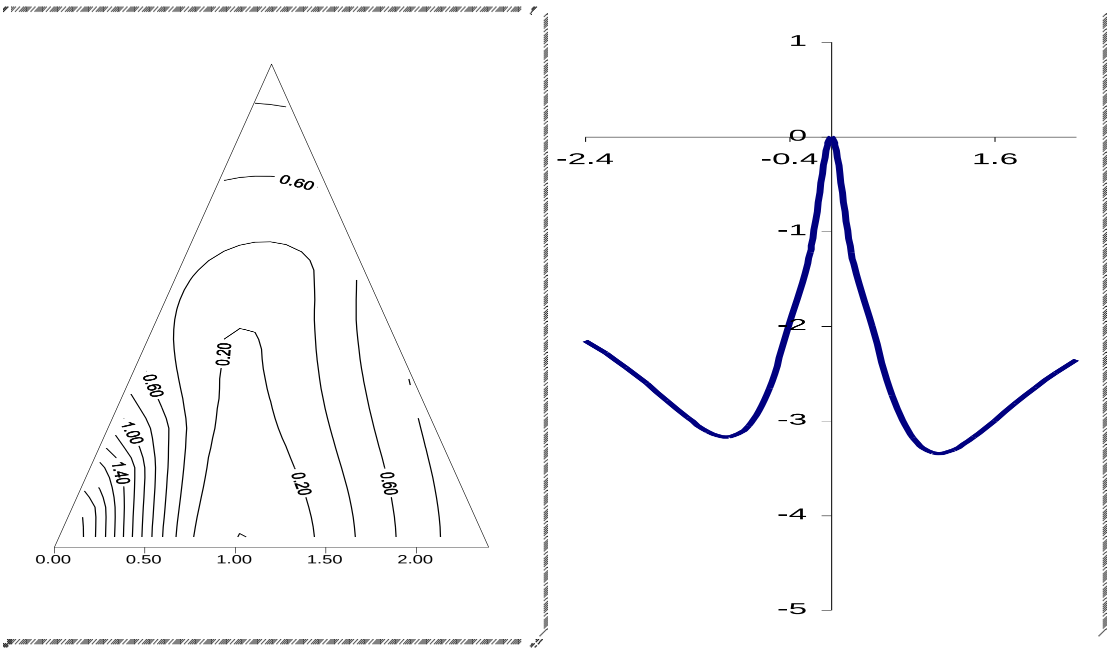
A B

Fig. 7. (A , B): The β - γ plot for ^{126}Xe isobars



A B

Fig. 8. (A , B): The β - γ plot for ^{126}Ba isobars



A B

Fig. 9. (A , B): The β - γ plot for ^{126}Ce isobars