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M1 TRANSITIONS IN ER ISOTOPES

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ABSTRACT

We presented the results of schematic calculations of Magnetic dipole transitions in Erbium isotopes from 158 to 168 by considering the Hamiltonian of the neutron- proton Interacting Boson Model (IBM-2). New idea for counting bosons number at N=64 has been used. A comparison with available M1 experimental data is presented.

INTRODUCTION

The even-even Er isotopes lie in the mass region between N=90 to N=100, their low lying states have been successfully described within framework of either the phenomenological or microscopic models[1,2,3,4]. Soloviev et.al[5] calculated the reduced probabilities of M1 and M2 in Er isotopes between excited states within the framework of Quasiparticle-phonon nuclear model. The quadrupole properties of k=2 gamma-vibrations in this well deformed nuclei have been extensively studied [6]. But our knowledge of the magnetic dipole properties remain severely limited. In all collective model the M1 transitions are strictly forbidden. However, it is experimentally observed between inter band states and cross band states [7,8,9]. Bohr and Mottelson [1] shown that gamma-ground M1 transitions can't be explained via K=2 mixing alone, but theey require, in addition, the existence of Δk=1 mixing with higher lying K=1 band. Warner [10] shows that the difference in the strength of the pairing for neutron and proton gives rise to different neutron and proton deformations which in term of generate M1 transition. The IBM-1 [11], which deals only with states completely symmetric in the proton-neutron, considered zero terms for M1 transition while IBM-2 gives a complete calculation for M1 matrix elements by considering F-spin $(F(\max) = (N_\pi + N\nu)l2)$ [12-14]. Scholton et.al [15] described the existence of M1 transitions between collective states in deformed nuclei as a nature of states which are not fully symmetric in the neutron and proton degree of freedom.

The aim of this work is to calculate the M1 matrix elements in deformed Er isotopes, using the IBM-2, and to compare the results with the experimental data.

THE MODEL

In the IBM-2 the structure of the collective states in even-even nuclei is calculated by considering a system of interacting neutron (ν) and proton (π) boson s($l = 0$) and d($l = 2$). The boson Hamiltonian can be written as [15]:

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$$H = E_d(n_{d\nu} + n_{d\pi}) + KQ_\nu^{(2)}.Q_\pi^{(2)} + M_{\nu\pi}$$
……………….(1)

where

$$Q_p = (s_p^{+}d_p + d_p^{+}s_p)^{(2)} + X_p(d^{+}{}_p d_p)^{(2)}$$ and $p = \nu, \pi$

$$M_{\nu\pi} = L_2(s_\nu^{+}d_\pi^{+} - d_\nu^{+}s_\pi^{+})^{(2)}(s_\nu d_\pi - d_\nu s_\pi)^{(2)} - 2\sum_{k=1,2} L_k(d_\nu^{+}d_\pi^{+})^k(d_\nu d_\pi)^k$$

The majorana term $M_{\pi\nu}$ introduced the force which creates the K=1 band in deformed nuclei and push up all states with an amount that depends only on their symmetry with respect to interchange of neutron and proton:

$$T(E2) = e_\pi Q_\pi + e_\nu Q_\nu$$
…………………………(2)

Where e_π and e_υ are proton and neutron effective charges.

The M1transition operator is :

$$T(M1) = \sqrt{3/\pi}(g_\pi L_\pi + g_\upsilon L_\upsilon)$$
…………………………..(3)

where $L_\upsilon(L_\pi)$ is the neutron and (proton) angular momentum operator

$$L_p^{(1)} = \sqrt{10}(d^{+}d)^{(1)}$$

where $P = \pi, \upsilon, g_\pi$ and g_υ are the effective boson (proton,neutron) geomagnetic –factors.

THE RESULTS AND DISCUSSION

In Erisotopes the number of valance nucleons outside the closed shell are large(Number of protons 18 and neutrons 8-18).Which means that we have 9 proton bosons and neutron bosons that start from 4 to 9.These numbers are outside the IBM-2 space from the computer point of viewing .To solve this problem we depend on the sub closed shell at 64 ,which suggested by Priston[2] .This idea reduced the total bosons number to 6 for Er^{158} to 11 for Er^{168}. With these bosons number and model parameters listed in table-1.

NPBOS [16] code used to get the best fit for experimental energy level ,then NPBOS code has been used to calculate the transition matrix elements .Electric quadrupole transition probability (E2) have been calculated using the effective charge $e_\pi = 0.17$ eb and $e_\upsilon = 0.225$ eb which have been estimated using the method described in reference [17].These values are slightly different from the general values estimated by Sala at.al[18] $e_\pi = e_\nu = 0.13eb,$ for rare earth nuclei. The results of the calculation of the B(E2) matrix elements are shown in figure(1) and (2). The fitting of E2 matrix elements is essentials for the calculation of the M1 matrix elements, because they share with the $\delta(E2/M1)$. So we should make sure that the calculated E2 reduced transition bribability are doing good, and then staring with the M1 fraction in the transition. As one can see from the samples on both figures the agreement is quite acceptable between calculating and experimental value for B(E2 ; 2_1-----0_1) and B(E2; 2_2-----2_1).

The M1 transition strength has been calculated by using the operator (3).The boson g-factor was determined using the relation shown in reference [19] which is written as :

$$g = (N_\pi / N)g_\pi + (N_\upsilon / N)g_\upsilon = Z / A$$
………………………(4)

One experimental B(M1) also used to generate two relation for g_π and g_υ from which we get $g_\pi = 0.446$ and $g_\upsilon = 0.369$ .These values were then generalized for all Er isotopes. They are different from those of the rare – earth nuclei, $(g_\pi - g_\nu = 0.65)$, suggested by van Isacker et al. However they also used $g_\pi = 1 and\, g_\nu = 0$ to reduce the number of the model parameters in their calculation of M1 properties in deformed nuclei. The results of our calculation are listed in table-2. A good agreement between the theory and the available experimental data is achieved. As can be seen from the table yields to a simple prediction that M1 matrix elements values for gamma to ground and transitions should be equal for the same initial and final spin. Also the size of gamma to ground matrix elements seems to decrease as the mass number increases.

CONCLUSIONS

1- By fitting B(M1) from $2_\gamma to 2_g$ we always get small value for $g_\pi - g_\nu$ compared with the value basis on the microscopic calculations $g_\pi - g_\nu = 1$.
2- There are evidences that M1 small mode exists in all spectra.
3- In the present work we are paying no attention to the sign of M1 matrix elements which might effect the results.

We can not judge on the agreement between theoretical and experimental data from the above table due to the lack of experimental data. However both experiments and theory predicts small M1 component which is due to symmetry and forbiddances of band crossing gamma transitions.

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Table-1- The IBM-2 parameters for Er isotopes

A	E(MeV)	K(MeV)	XN	XP
158	0.43	-0.19	0.29	-0.30
160	0.45	-0.19	0.26	-0.30
162	0.47	-0.18	0.25	-0.30
164	0.47	-0.16	0.15	-0.30
166	0.48	-0.14	0.10	-0.30
168	0.51	-0.13	0.13	-0.30

$L_1=L_3=0.091$; $L_2=0.052$

Table-2-reduced transitions probability B(M1) for gamma to ground and the inter band gamma to gamma transitions in Er Isotopes

A	I_i	I_f	B(M1) Experimental	Theory
158	2_γ	2_g		0.066
	3_γ	2_g		0.0380
	3_γ	2_γ		0.050

	4_γ	3_γ		0.046
160	2_γ	2_g		0.026
	3_γ	2_g		0.017
	3_γ	2_γ		0.044
	4_γ	3_γ		0.031
162	2_γ	2_g		0.041
	3γ	2_g		0.029
	3_γ	2_γ		0.047
	4_γ	3_γ		0.026
164	2_γ	2_g		0.012
	3_γ	2_g		0.012

	3_γ	2_γ		0.022
	4_γ	3_γ		0.012
166	2_γ	2_g	0.000115	0.0082
	3_γ	2_g	0.00054	0.0072
	3_γ	2_γ		0.0144
	4_γ	3_γ		0.0011
168	2_γ	2_g		0.0044
	3_γ	2_g	0.0071	0.0038
	3_γ	2_γ	0.0036	0.0038
	4_γ	3_γ	0.00034	0.0005

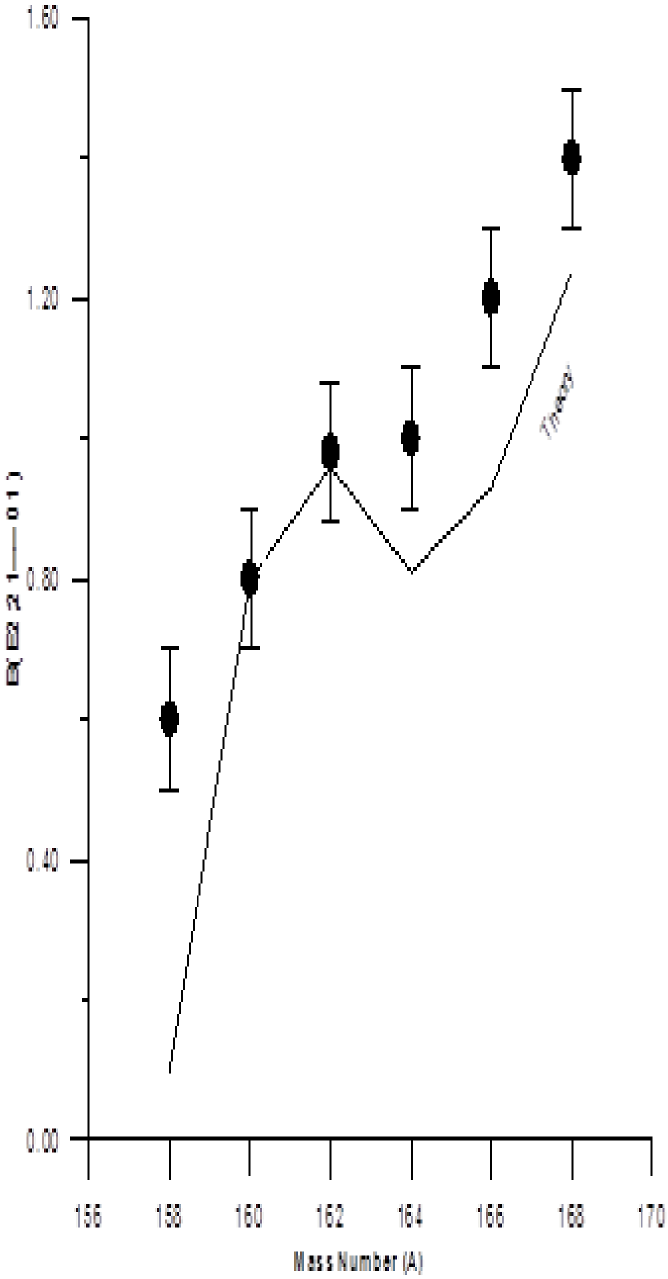

Figure 1 The theoretical and experimental reduced transition probabilities B(E2) in the unit of e^2b^2 between 2^+_g to 0^+_g. The solid line represents the theoretical values and the dots are the experimental values.

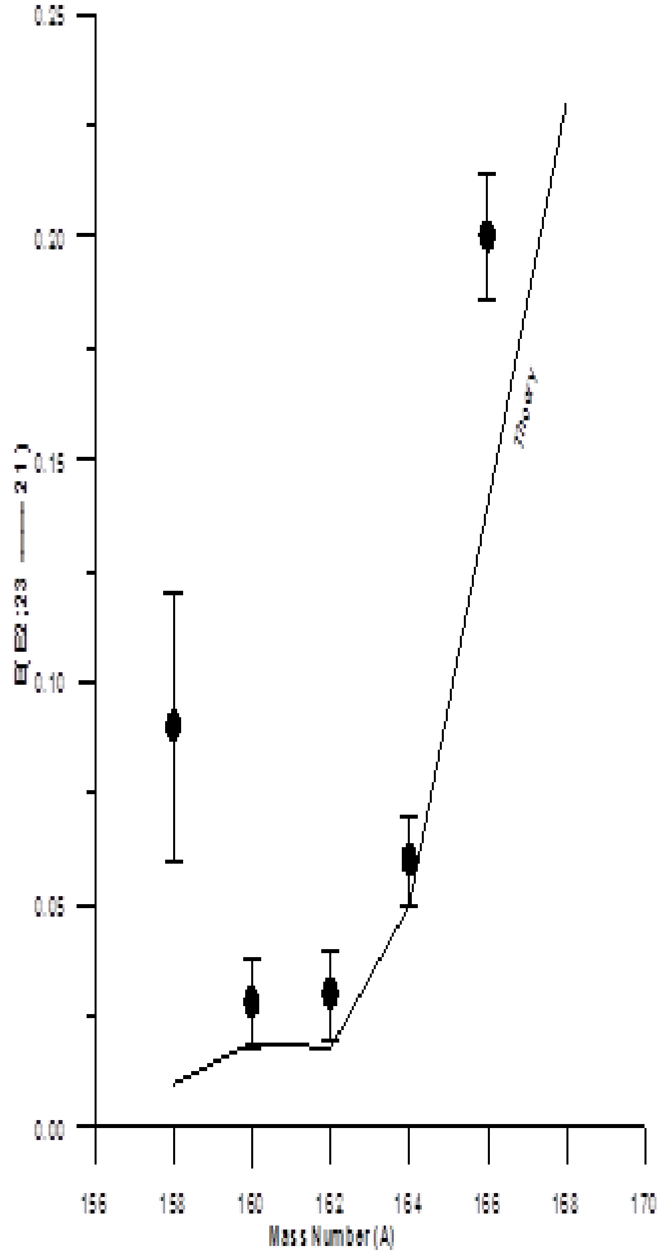

Figure 2 The theoretical and experimental reduced transition probabilities B(E2) in the unit of e2b2 between 2+γ to 2+g. The solid line represents the theoretical values and the dots are the experimental values.

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الخلاصة

في هذه الدراسة تم تقديم نتائج الحسابات النظرية لعناصر مصفوفة الأنتقال المغناطيسي بين مستويات الطاقة في نظائر الأريديوم من 158 الى 168 وذلك باستخدام نموذج البوزونوتات المتفاعلة رقم – 2. لحساب عدد البوزونات تم استحداث فكرة جديدة وهي استخدام القشرة شبه المغلقة عند عدد النيوترونات 64. قورنت جميع النتائج المستحصلة مع النتائج العملية المتوفرة.