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MIXED SYMMETRY STATES IN SAMARIUM ISOTOPES WITH A=146-154 BY USING (IBM-2)

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ABSTRACT
In this work, we used tthe (IBM-2) to study the mixed symmetry state property (MSS) foreven-even$^{146-152}$Sm isotopes, this model gave a good agreementfor the excited energy levels for the g- band and acceptable for quasi (β and γ) bands, Also identified and emphase some states un certain experimentally, Furthermore it have been studied the mixed symmetry state (MSS) for the states (2_3^+,2_4^+,2_5^+,3_1^+,1_1^+) Which received a quick response when changing the Majorana parameters for these isotopes.Well, it was calculated the electromagnetic transition B(E2), B(M1) and mixing ratios

KEYWORDS: IBM-2,Smisotopes, Mixed Symmetry State(MSS),Electomagnetic transition, Mixing ratios.

I. INTRODUCTION
In the interacting boson model (IBM), the nuclear shape for even – even nuclei is characterized as far as interaction among s(L=zero) and d(L=2) bosons. through modifying a little amount of parameter, it creates the overall population of the low-ling condition of such cores [1,2]. The early model of the communicating boson display known as IBM-1, in which no distinction is made among protons (sπ, dπ), neutron bosons (sν,dν), and the quantity of bosons taken to be the assortment of nucleons open air the shut shell partitioned by . the second one variant of the Interacting Boson demonstrate (IBM-2) , recognizes among protons (sπ,dπ) and neutron bosons(sν,dν) . while the principal show has a symmetry issue, similar to; dipole attractive change, blended symmetry states and electric monopole advances, the second one variant has no impediment [3-4].

II. THE (IBM-2) MODEL
The IBM-2 Hamiltonian in this model is given as bellow [5,6];

$$H = \varepsilon_d(n_{d\nu} + n_{d\pi}) + \kappa(Q_\nu . Q_\pi) + V_{\nu\nu} + V_{\pi\pi} + M_{\nu\pi} \qquad \ldots\ldots(1)$$

where $\boldsymbol{\varepsilon_d}$ is the energy difference between s and d boson, n_ρ is the number of d bosons , where ρ corresponds to π (proton) or ν (neutron) bosons , the second term denotes the quadrupole – quadrupole interaction between proton and neutron with strength κ , where the quadruple operator $\boldsymbol{Q_\rho}$ is define as [7] .

$$Q_\rho = [\, d_\rho^\dagger s_\rho + \, s_\rho^\dagger d_\rho]^{(2)} + x_\rho[d_\rho^\dagger\, d_\rho]^{(2)} \quad \ldots\ldots(2)$$

Where $V_{\pi\pi}$and$V_{\nu\nu}$ are represented the interaction of identical bosons which is given as bellow [8] .

$$V_{\rho\rho} = \frac{1}{2}\sum_{L=0,2,4} C_L^\rho([d_\rho^\dagger d_\rho^\dagger]^{(L)} \,.[\tilde{d}_{\,\rho}\tilde{d}_{\,\rho}]) \qquad \ldots\ldots(3)$$

The Majorana term $M_{\nu\pi}$ Includes three parametersξ_1 , ξ_2 and ξ_3 can be written as;

$$M_{\nu\pi} = \frac{1}{2}\xi_2([\, s_\nu^\dagger d_\pi^\dagger - d_\nu^\dagger s_\pi^\dagger]^{(2)}.[s_\nu d_\pi - \, d_\nu s_\pi]^{(2)}) - \sum_{k=1,3}\xi_k([d_\nu^\dagger d_\pi^\dagger]^{(k)}.[d_\nu d_\pi]^{(k)}) \qquad \ldots\ldots(4)$$

The (MSS) happen when the protons and neutrons are not in stage in the quantum state [9]. These states were made by blend of two wave function, one for proton and other for neutron [13]. The blended symmetry states dictated by the F-spinshape, where the F-turn formalism is similar to the isospin quantum number of the nucleons. Proton bosons and neutron bosons have F = 1/2 and z-projection, where Fz = +1/2 , - 1/2 for protons and neutrons separately. For a framework comprise of Nπ proton boson and Nν neutron boson , the most extreme F-turn is F = Fmax = (Nπ + Nν)/2 , while the blended symmetry states described by diminishing F-turn esteem (F = Fmax , F = Fmax – 1, F = Fmax - 2 , . . . , Fmin= |Nπ - Nν |/2). In the F-turn space, one can likewise characterize the creation and obliteration administrators F+ and F− by [10-11];

$$F_{+} = s_{\pi}^{\dagger} s_{\nu} + (d_{\pi}^{\dagger}.\tilde{d}_{\nu}) \quad , F_{-} s_{\nu}^{\dagger} s_{\pi} + (d_{\nu}^{\dagger}.\tilde{d}_{\pi}) . \quad ....(5)$$

The projection operator F_z is given by .

$$F_Z = (N_\pi - N_\nu)/2 \quad ....(6)$$

A state formed by Nπ proton bosons and Nν neutron bosons with F-spin quantum number F = F_{max} can be changed by the progressive activity of the F-spinraising administrator F+ into an express that comprises of proton bosons as it were. This state has still an aggregate F-turn quantum number F=F_{max} since the raising administrator does not change the aggregate F-turn quantum number. This new state has just proton bosons and clearly remains unaltered under a pairwise trade of proton and neutron names. Accordingly, IBM-2 states with F=Fmax are called Full Symmetry States (FSS). These states compare really to the IBM-1 states which are largely symmetric. All others states with F-turn quantum numbers F< Fmax contain sets (no less than one) of proton and neutron bosons that are against symmetric under a pairwise trade of protons and neutrons names. They are called Mixed-Symmetry States(MSS) [12] . The general F-turn choice run is ΔF = 0 , ± 1. Other than , the M1 progress gather between two absolutely symmetric states (F = F_{max}) are prohibited, therefor M1 change happen between low-lying aggregate states , these states must be contain segments with blended symmetry state, when (F < F_{max}), this permits to utilize the quality of M1 progress between low-lying aggregate state and F-turn blending [13-14].

IBM-2 Parameters and Energy Spectrum

The $^{146-154}$Sm isotopes have Z=62 , the boson proton number Nπ = 6 and neutron boson Nν shift from 5 to 1 boson molecule. The parameters in table 1. regarded as a free parameters and their esteems were assessed by fitting to experimental energy level.We used the χ_π = -1.2 and ζ_2= +0.10 fixed for all studied isotopes,as well as to see the systematic of (ε, κ, χ_π, χ_ν, ζ_2, $\zeta_{1=3}$) parameters, ploted these parameters as a function of the neutrons number as shown in figure :1.

Table:1.The even-even $^{146-154}$Sm isotopes parameters in IBM-2

Isotope	N_ν	ε	κ	χ_ν	$CL_{\nu(0,2,4)}$	$CL_{\pi(0,2,4)}$	ζ_2
^{146}Sm	1	0.999	-0.14	-0.14	-0.05, -0.05, -0.05	-0.10, -0.20, -0.28	+0.13
^{148}Sm	2	0.959	-0.13	-0.12	-0.05, -0.05, -0.05	-0.10, -0.20, -0.09	+0.12
^{150}Sm	3	0.910	-0.12	-0.11	-0.05, -0.05, -0.05	-0.35, -0.26, -0.15	+0.11
^{152}Sm	4	0.763	-0.11	-0.10	-0.05, -0.05, -0.05	-0.35, -0.30, -0.19	+0.10
^{154}Sm	5	0.620	-0.10	-0.08	-0.05, -0.05, -0.05	-0.35, -0.30, -0.19	+0.09

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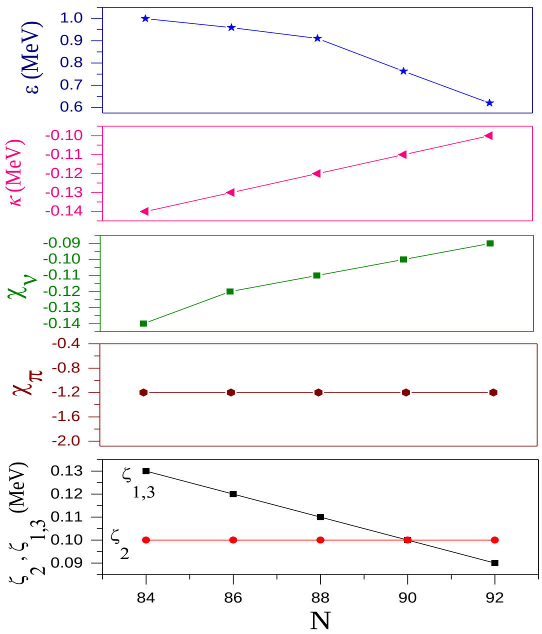

Figure :1.Systematic of (ε, κ, χ_π, χ_ν, ζ_2, $\zeta_{1=3}$) parameterswith neutron numbers

By and large, we watched that the (ε) parameters diminishing with neutron numbers up to mid shell and specifically relative to vitality levels2_1^+, the (*κ*) parameter increments relatively with the expansion the neutrons number, the (χ_ν) esteem continually expanding straightly with expanding neutron numbers. The estimations of Majorana parameters terms ($\zeta_{1,3}$, ζ_2) were chosen for a specific esteems and flexible with the investigation of blended symmetry states (MSS) of the vitality levels. The vitality spectra of$^{146-154}$Smre delivered by utilizing the parameters in Table 1. The best fit to energized vitality levels have been watched uniquely for the ground state groups, while the semi β groups and semi γ groups it was found to have satisfactory understanding, Figure:2. demonstrates a correlation amongst hypothetical and accessible exploratory vitality levels[15-16-17-18-19] for all examined Samarium isotopes.

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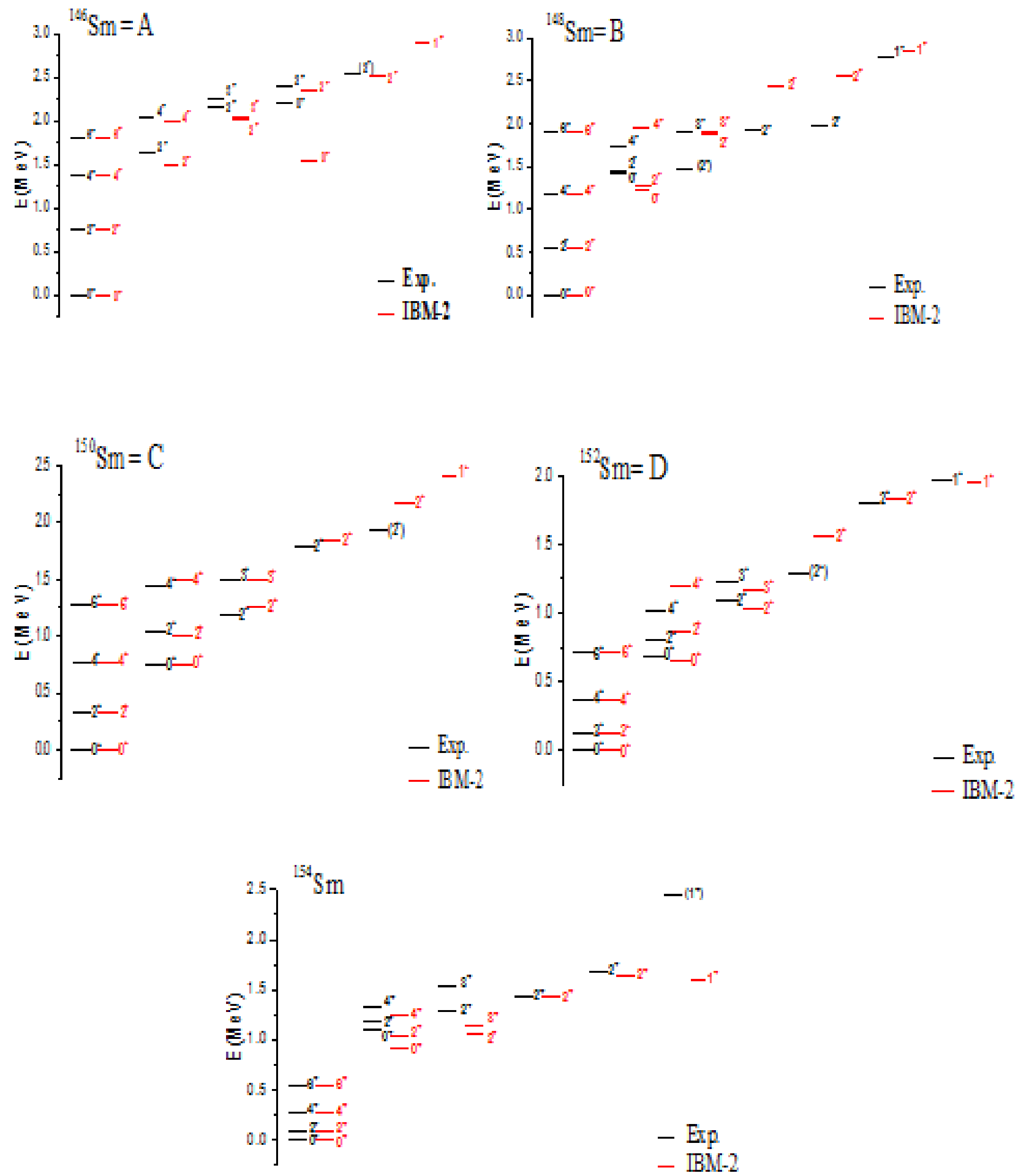

Figure 1. Comparison between calculated energy level and the available experimental for all considered Samarium isotopes.(^{146}Sm=A,^{148}Sm=B,^{150}Sm=C,^{152}Sm=D, ^{154}Sm=E)

The experimental energy ratio between (4_1^+,2_1^+) and (6_1^+,2_1^+) states which have limiting values of (2 , 3) for vibrator rotor, (2.5 , 4.5) for gamma-soft and 3.33, 7 for rotational symmetry respectively, we deduced that these nuclei has many dynamic symmetries, which begin close to U(5) vibrator limit for ^{146}Sm nuclues, transition region U(5)-O(6) for $^{147-150}$Sm neuclei, but ^{148}Sm nearly close to vibrator roter and ^{150}Sm nearly close to gamma soft, as well as a transition limit between O(6)-SU(3) for ^{152}Sm nucleus and finally ^{152}Sm close to rotational limit U(3). Similar outcomes are additionally anticipated by the IBM-2 comes about, likewise to demonstrate the decent variety of the dynamic symmetries for these cores and all the more obviously, has been drawing vitality proportions ($E4_1^+/2_1^+$and $E6_1^+/2_1^+$)as a function of the number neutrons, as shown in Figure:3.

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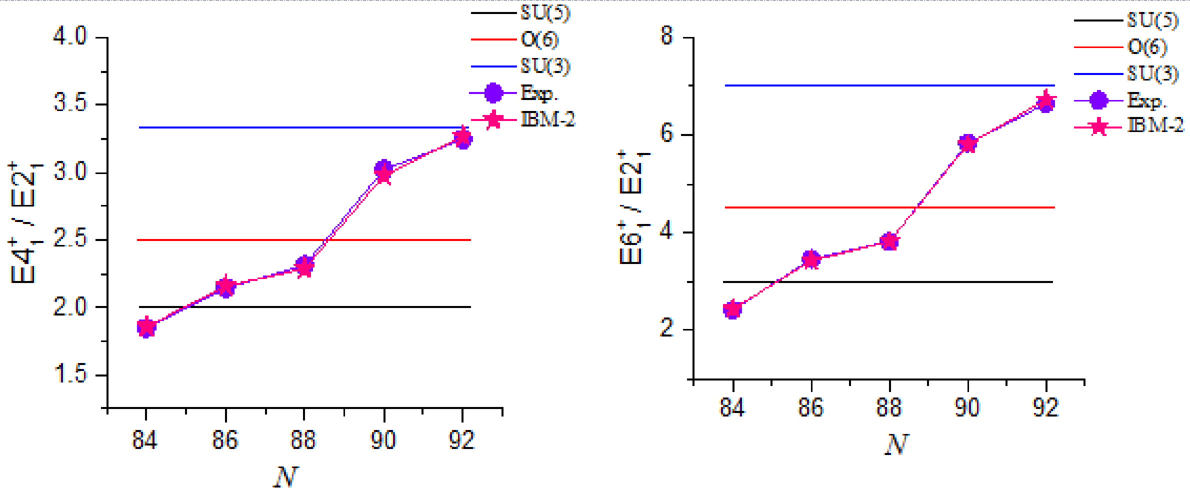
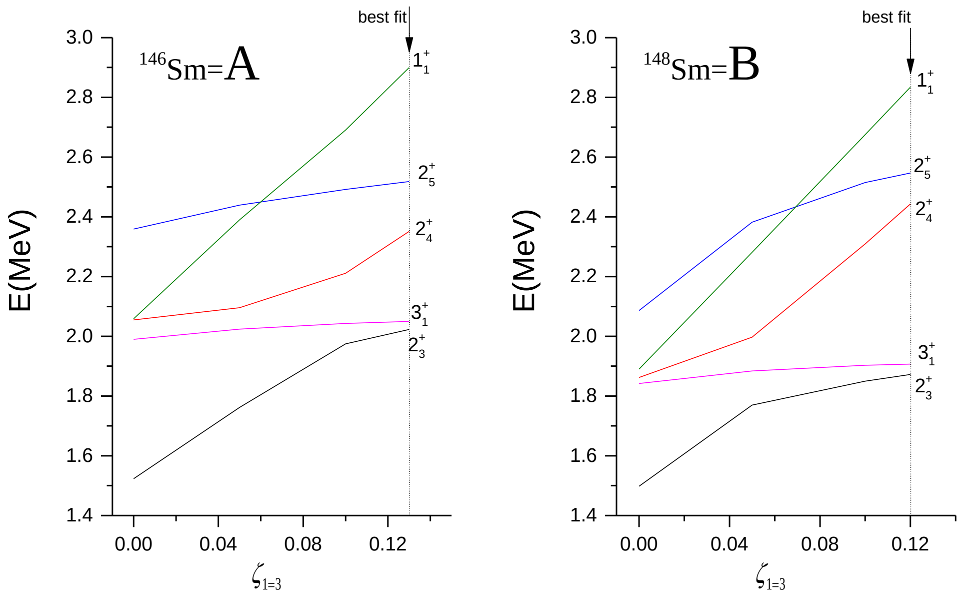


Figure 1. Thecomparison experimental ratio $E4_1^+/2_1^+$and $E6_1^+/2_1^+$ with IBM-2 result.

III. THE MIXED SYMMETRY STATE (MSS)

At the point when think about the impact of Majorana parameter ($\zeta 1,3$, $\zeta 2$) on the ascertained excitation vitality level, we settled the estimation of ζ_2= +0.10for all isotopes and fluctuate the $\zeta_{1,3}$. t is discovered that the vitality estimations of the state; 2_3^+, 2_4^+ , 2_5^+ , 3_1^+ ,$1_1^+$are reacted quickly to the progressions of the theζ1,3 parameters, hence these states are checked the primary property of the Mixed symmetry state (MSS). Figure:4. clarify the vitality variety of these state as an element of the Majorana parameter $\zeta_{1,3}$.



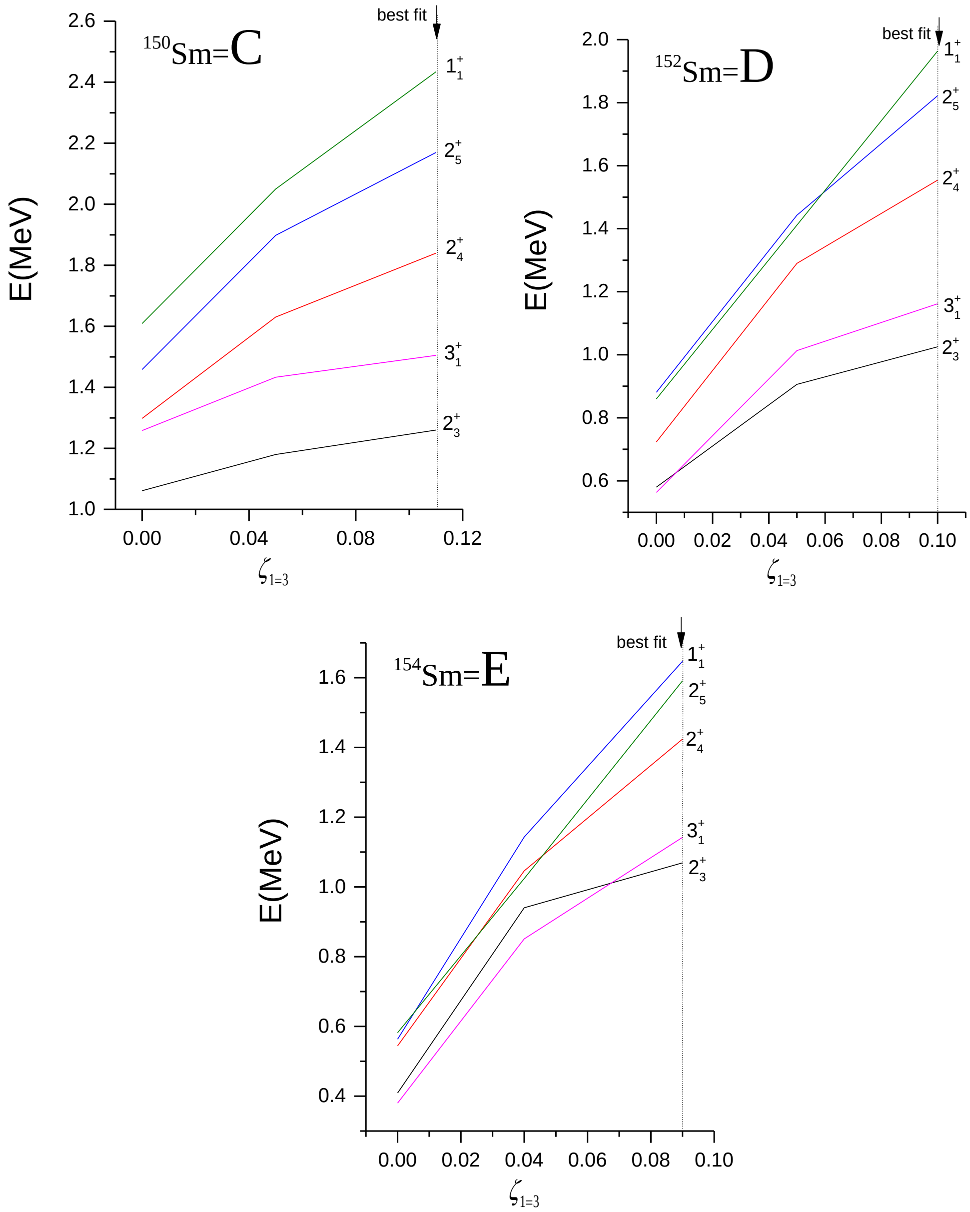


Figure 2.variety of (MSS) as a function of the Majorana parameter $\zeta_{1,3}$.(^{146}Sm=A,^{148}Sm=B,^{150}Sm=C,^{152}Sm=D, ^{154}Sm=E)

IV. ELECTROMAGNETIC TRANSITION

Electric quadrupole

The electromagnetic transition operator ($T^{(E2)}$)In IBM-2,is given by [10,11].

$$T^{(E2)} = e_\pi Q_\pi + Q_\nu e_\nu \qquad \ldots\ldots\ldots\ldots (7)$$

where e_π and $e_\nu$are boson effective charges, dep finishing on the boson number $N\rho$, those parameters are free and can take any an incentive to suit the test information. In this work, the successful charge of proton eπ = 0.0026 (eb) and neutron ev = 0.329 (eb) (got from test information of$B(E2; 2_1^+ \rightarrow 0_1^+)$. The computed decreased electric quadrupole probabilities B(E2) of 146-154Sm isotopes are demonstrated inside the table:2. The ascertained esteems are proper in contrast with the accessible trial esteems [15-16-17-18-19] and they appearance to have a decent systematism

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Table:2. The B(E2) transition of $^{146-154}$Sm isotopes , units $(eb)^2$

Transition	^{146}Sm		^{148}Sm		^{150}Sm	
	Exp.	IBM-2	Exp.	IBM-2	Exp.	IBM-2
$2_1^+\rightarrow 0_1^+$	0.0338	0.0338	0.1477	0.1451	0.2131	0.2704
$0_2^+\rightarrow 2_1^+$	0.0140	-----	0.0540	----	0.1166	0.2535
$2_2^+\rightarrow 0_1^+$	0.0013	-----	0.0140	0.0155	0.0284	0.0038
$2_2^+\rightarrow 2_1^+$	0.0293		0.0933		0.0770	-----
$2_3^+\rightarrow 2_1^+$	0.0011		0.0034	0.0008	0.0315	-----
$2_4^+\rightarrow 2_1^+$	0.0004		0.0046		0.0029	-----
$2_5^+\rightarrow 2_1^+$	0.0017	-----	0.0057		0.0013	
$3_1^+\rightarrow 2_2^+$	0.0251		0.0999		0.1003	-----
$4_1^+\rightarrow 2_1^+$	0.0343	0.0091	0.2626	0.2399	0.3136	0.5216
$4_1^+\rightarrow 2_2^+$	0.0011		0.0021		0.0101	-----
$6_1^+\rightarrow 4_1^+$	0.0353	0.0438	0.1575		0.5048	0.7125
Transition	^{152}Sm		^{154}Sm			
	Exp.	IBM-2	Exp.	IBM-2		
$2_1^+\rightarrow 0_1^+$	0.4045	0.6700	0.6437	0.9220		
$0_2^+\rightarrow 2_1^+$	0.0316	0.1760	0.0046	0.2350		
$2_2^+\rightarrow 0_1^+$	0.0075	0.0046	0.0181	0.0600		
$2_2^+\rightarrow 2_1^+$	0.0102	0.0258	0.0339	0.0120		
$2_3^+\rightarrow 2_1^+$	0.0328	0.0417	0.0125	0.0200		
$2_4^+\rightarrow 2_1^+$	0.0021	-----	0.0096	------		
$2_5^+\rightarrow 2_1^+$	0.0705	-----	0.0409	-----		
$3_1^+\rightarrow 2_2^+$	0.0114	-----	0.4706	-----		
$4_1^+\rightarrow 2_1^+$	1.0406	1.0170	0.9147	1.1860		
$4_1^+\rightarrow 2_2^+$	0.0057	-----	0.00008	-----		
$6_1^+\rightarrow 4_1^+$	0.6330	1.179	0.9952	1.3740		

Magnetic dipole

To calculate M1 transition probability, one have to assess the successful g_ factors for proton and neutron. It is found that amid this circumstance Sambataro connection [12-13] is helpful and composed as;

$$g = \frac{g_\pi N_\pi + g_\nu N_\nu}{N_\pi + N_\nu} \qquad \dots\dots\dots..(8)$$

where g_π , g_ν are g-factors of nuclear proton and neutron separately. The aggregate g – factor related with attractive energy, is μ=2g, and in this work we utilize the test estimation of attractive force for the 2^+_1state to gauge the g factor, where$\mu(2^+_1)=2g(2^+_1)$ = 0.775 (μ_N).it is watched that the foreseen esteems areg_π=0.73(μ_N) and g_ν= 0.27(μ_N), and (g_π -g_ν) = 0.46(μ_N). However, the M1 operator can be written as bellow[20];

$$T^{(M1)} = 0.77\left[(d^\dagger d^\sim)^{(1)}_\pi - (d^\dagger d^\sim)^{(1)}_\nu\right](g_\pi - g_\nu) \quad \dots\dots\dots..(9)$$

The calculated values for *B(M1)*is appropriate to some degree contrasting and the accessible trials esteems which may be generally not very many in atomic data sheet. The B(M1) progress of $^{146-154}$Sm isotopes is computed and exhibited in Table (3).

Table (3) The magnetic transition B(M1) of $^{146-154}$Sm isotopes, units $(\mu_N)^2$

Transition	^{146}Sm		^{148}Sm		^{150}Sm	
	Exp.	IBM-2	Exp.	IBM-2	Exp.	IBM-2
$1_1^+\rightarrow 0_1^+$	----	0.00842	0.02103	----	----	0.0437
$1_1^+\rightarrow 0_2^+$	----	0.01449	0.02486	----	----	0.0420
$3_1^+\rightarrow 2_2^+$	----	0.00009	0.00005	----	----	0.00003
$2_2^+\rightarrow 2_1^+$	----	0.00027	0.00064	0.0082	----	0.00146
$2_3^+\rightarrow 2_1^+$	----	0.00099	0.00498	----	----	0.00059
$2_4^+\rightarrow 2_1^+$	----	0.03280	0.04233	0.0320	----	0.00036
$2_5^+\rightarrow 2_1^+$	----	0.00167	0.00897	0.0690	----	0.0020

Transition	^{152}Sm		^{154}Sm		
	Exp.	IBM-2	Exp.	IBM-2	
$1_1^+ \rightarrow 0_1^+$	0.09985	----	0.15349	0.0338	
$1_1^+ \rightarrow 0_2^+$	0.03869	----	0.02811	----	
$3_1^+ \rightarrow 2_2^+$	0.00006	----	0.00025	----	
$2_2^+ \rightarrow 2_1^+$	0.00063	----	0.00009	0.00004	
$2_3^+ \rightarrow 2_1^+$	0.00001	0.00134	0.00057	----	
$2_4^+ \rightarrow 2_1^+$	0.00022	----	0.01211	----	
$2_5^+ \rightarrow 2_1^+$	0.01765	----	0.22694	----	

Mixing ratio δ (E2/M1)

The multipole mixing ratio between E2 and M1 transition is given as bellow [20-21];

$$\delta(E2/_{M1}) = 0.835\ E\gamma\ \Delta(E2/_{M1}) \qquad \ldots\ldots\ldots\ldots(10)$$

Eγ is the transition energy between the two states units (MeV) and Δ(E2/M1) is the proportion between lessened framework component for E2 and M1 change which is communicated in the shape [21];

$$\Delta(E2/_{M1}) = \frac{|\langle I_f \| T^{E2} \| I_i \rangle|}{|\langle I_f \| T^{M1} \| I_i \rangle|} \qquad \ldots\ldots\ldots\ldots(11)$$

In Table:4. we show the estimations of the mixing ratio for for the chose Samarium isotopes in examination with the accessible exploratory esteems. It is seen that both the size and indication of δ are effectively gotten for the greater part of the chose isotopes. The assention between trial esteems and those of IBM-2 looks satisfactory in correlation with the accessible trial information.

Table:4.Mixing ratios(eb/μ_N)for $^{146\text{-}154}$Sm

Nucleus	Transition	E_γ (MeV)	δ(E2/M1) (*eb/μ_N*)	
			Exp.	IBM-2
^{146}Sm	$2_2^+ \rightarrow 2_1^+$	0.9008	-----	-5.091
	$2_3^+ \rightarrow 2_1^+$	1.4087	----	+0.540
	$2_4^+ \rightarrow 2_1^+$	1.6538	----	-0.129
	$2_5^+ \rightarrow 2_1^+$	1.7970	----	+0.647
	$3_1^+ \rightarrow 2_2^+$	0.6219	---	32.36
^{148}Sm	$2_2^+ \rightarrow 2_1^+$	0.9039	+2.32	+4.023
	$2_3^+ \rightarrow 2_1^+$	0.9108	-----	+0.4469
	$2_4^+ \rightarrow 2_1^+$	1.1140	-0.565	-0.3488
	$2_5^+ \rightarrow 2_1^+$	1.4222	-0.556	-2.199
	$3_1^+ \rightarrow 2_2^+$	1.3535	+8.21	+3.608
^{150}Sm	$2_2^+ \rightarrow 2_1^+$	0.7134	-----	-4.322
	$2_3^+ \rightarrow 2_1^+$	0.8598	----	+5.250
	$2_4^+ \rightarrow 2_1^+$	1.0840	----	-2.571
	$2_5^+ \rightarrow 2_1^+$	1.4603	----	+1.003
	$3_1^+ \rightarrow 2_2^+$	1.1705	---	-5.911
^{152}Sm	$2_2^+ \rightarrow 2_1^+$	0.6889	8^{+9}_{-3}	+5.321
	$2_3^+ \rightarrow 2_1^+$	0.9641	$-11^{+0.7}_{-0.8}$	-10.354
	$2_4^+ \rightarrow 2_1^+$	1.1042	----	-2.897
	$2_5^+ \rightarrow 2_1^+$	1.1709	----	-1.955
	$3_1^+ \rightarrow 2_2^+$	0.4232	---	+5.103
^{154}Sm	$2_2^+ \rightarrow 2_1^+$	1.0958	$+56^{+130}_{-25}$	+17.688
	$2_3^+ \rightarrow 2_1^+$	1.2043	$+0.8^{+15}_{-6}$	+22.734
	$2_4^+ \rightarrow 2_1^+$	1.3580	----	-3.1993
	$2_5^+ \rightarrow 2_1^+$	1.5919	----	+0.5643
	$3_1^+ \rightarrow 2_2^+$	0.3612	----	+13.096

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V. CONCLUSION

In the current work, we've calculated the some properties of the nuclear strucure for $^{146-154}$Sm, right off the bat, recognized and accentuation some energized vitality states un certain tentatively, which get a decent understanding between the IBM-2 result and test esteems, secodary distinguished the (MSS) states(2_3^+, 2_4^+ , 2_5^+ , 3_1^+ ,1_1^+)which got a brisk reaction while changing the Majorana parameters for these isotopes, thirdly the E2 and M1 decreased progress probabilities are ascertained and contrasted and the accessible exploratory information. At last, the estimations are reached out to δ(E2/M1) demonstrated worthy concurrence with the accessible trial information, exceptionally the indication of the blending proportion.

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