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The Study of Electric Quadrupole Transition (E2) in $_{56}$Ba and $_{62}$Sm Nuclei

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Abstract

Transition strengths $|M(E2)|^2_{w.u.}\downarrow$ for gamma transition from first excited 2_1^+ states to the ground states that produced by pure electric quadrupole emission in even –even isotopes of $_{56}$Ba and $_{62}$Sm have been studied through half- lives time for 2_1^+ excited states with the intensities of γ_0- transitions measurements and calculated as a function of neutron number (N). The results thus obtained have shown that; the nuclides with magic neutron number such as $_{56}Ba^{138}$ and $_{62}Sm^{144}$ have minimum value for $|M(E2)|^2_{w.u.}\downarrow$.

Key Words: electric quadruple transitions strength $[M(E2)]^2$.

Introduction

The WeissKoph single-particle transition probability B(EL,ML) is defined by [1] as the ratio of the single-particle half-life time to the experimental half-life time for gamma transition

$$B(EL,ML)_{W.u}\downarrow = \frac{t^{\gamma}_{1/2}(EL,ML)_{SP}}{t^{\gamma}_{1/2}(EL,ML)_{exp}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where L is the multipolarities L=1,2,3,………
$L \neq 0$
While the γ-ray transition strength $[M(EL,ML)]^2$ is defined as the ratio of gamma width to gamma width in Weiss Kopf unit (W.u) [2]

$$[M(EL,ML)]^2_{W.u}\downarrow = \frac{\Gamma(EL,ML)_{exp}}{\Gamma(EL,ML)_{W.u}} \quad \ldots\ldots\ldots\ldots(2)$$

Since $\Gamma_\gamma T \approx \hbar$ …………(3)
Where;
Γ_γ is the total width
$\Gamma_\gamma = \sum \Gamma_{\gamma l}$ …………(4)
$\Gamma_{\gamma l}$ is the partial gamma width
T is the mean life time of initial level

$$T = \frac{\tau_{1/2}}{\ln 2} \quad \ldots\ldots\ldots\ldots(5)$$

$$\hbar = \frac{h}{2\pi} = 0.65822\times 10^{-15}\ \text{eV.s}$$ h is Plank constant.

From eqs. (2, 3 and 4) . can be concluded

$$B(EL,ML)_{W.u}\downarrow = [M(EL,ML)]^2_{W.u} \quad \ldots\ldots\ldots\ldots(6)$$

Specific expression for $B(EL,ML)_{W.u}$ suggested by M.J.Martin [2] is :

$$B(EL,ML)_{W.u}\downarrow = \frac{B(EL,ML)_{exp}}{B(EL,ML)_{s.p.}} \quad \ldots\ldots\ldots\ldots(7)$$

If the transition is of mixed multi polarity M1 and E2 ref.[3] then

$$\delta = \pm\sqrt{\frac{\Gamma(E2)}{\Gamma(M1)}} \quad \ldots\ldots.(8)$$

Where δ is the mixing ratio

and $\Gamma_\gamma=\Gamma(M1)+\Gamma(E2)$ ……..(9)

For a pure E2 transition , δ=0 and hence

$\Gamma(E2)=\Gamma_\gamma$ …………….(10)

Then the transition strength for electric quadruple transition E2 can be calculated by using eq .(2) in the form :

$$[M(E2]^2_{W.u}\downarrow = \frac{\Gamma(E2)_{exp}}{\Gamma(E2)_{s.p.}} \quad \ldots\ldots\ldots\ldots(11)$$

Or eq .(7) in the form :

$$[M(E2]^2_{W.u}\downarrow = \frac{B(E2)_{exp}}{B(E2)_{s.p.}} \quad \ldots\ldots\ldots\ldots..(12)$$

On the basis of an extreme single particle model the value for the $\Gamma(E2)_{W.u}$ in eV. ref.[4]

$$\Gamma(E2)_{W.u} = 4.7907X\ 10^{-23}\ A^{4/3}E_\gamma^5 \ldots(13)$$

Where E γ in keV. for nuclear of mass No. A

and the corresponding reduced transition probability is :

$$B_{W.u.}(E2) = 0.05940\ A^{4/3}\ e^2\ (fm)^4 \ldots\ldots(14)$$

The relation between B(E2) ↓ =B(E2 ;2→1) and B(E2) ↑=B(E2;1→2) as given by ref [2] is:

$$B(E2)\uparrow = \frac{(J_{f+1})}{(J_{i+1})} B(E2)\downarrow \ldots\ldots\ldots(15)$$

Results of Calculations

The electric quadrupole transition strengths $|M(E2)|^2_{w.u.}\downarrow$ for γ –ray from $2_1^+ \rightarrow 0_1^+$ have been calculated as a function of neutron number (N) using eq. (11) with aid of the experimental data reported in ref. [1] to even –even isotopes for; $_{56}$Ba (122≤A≤146) and $_{58}$Ce (124≤A≤148) which have only one transition for γ is γ_0 with intensity (100%)E2.

The results of calculations are presented in table (1) for $_{56}$Ba nuclides and in table (2) for $_{62}$Sm nuclides. . The transition strengths $|M(E2)|^2_{w.u.}\downarrow$ are plotted as a function of neutron number (N) as shown in Fig. (1) and Fig. (2) for $_{56}$Ba and $_{62}$Sm respectively . For the sake of comparison, the $|M(E2)|^2_{w.u.}\downarrow$ values are converted to B (E2) $e^2 b^2\uparrow$ using eq. (12) and then eq.(15), the present B (E2) $e^2 b^2\uparrow$values of γ_0 -transitions in $_{56}$Ba and $_{62}$Sm nuclides are compared with the experimental values as well as with other of various theoretical models. this comparison are presented in tables (3and4) and shown in Figs. (3 and4) respectively.

Discussion

In view of tables (1and2) one can point out that the experimental values of partial gamma width Γ (E2) are larger than that estimated by Weisskopf unit $\Gamma_{w.u.}(E2)$ especially when the nucleon number deviated more and more from the magic neutron number. Since the cooperative effects appear between nucleons. Also, it appears that the single particle shell model is valid particularly near the closed shell, a minimum value for Γ (E2) to $\Gamma_{w.u.}(E2)$ is obtained at magic neutron number so that the calculated $|M(E2)|^2_{w.u.}\downarrow$ which are limited to the even – even nuclides and shown in Fig.(1) and Fig.(2) reproduce the diffraction minimum at the magic neutron number N= 82 which is included in $_{56}$Ba and $_{62}$Sm nuclei.

The discrepancy of the calculated $|M(E2)|^2_{w.u.}\downarrow$ for196.1 keV $2^+_1 \rightarrow 0^+_1$ transition from 196.1 keV level in $^{122}_{56}Ba$ gives an indication that the half life time for 2^+_1 state reported in ref. [1] is inaccurate and that the value of $|M(E2)|^2_{w.u.}\downarrow$ may be ruled out. If the experimental value of B (E2)e^2 b^2 $\uparrow$ for 196.1 KeV. ($2^+_1 \rightarrow 0^+_1$) transition from 196.1KeV. level ref.[5] is used to calculate the half- life time for this level (348.0 ±34.5)Ps. will be obtained instead of the value reported in table (1).

The reduced transition probabilities B(E2) values of γ_0 -transitions for the following nuclides ; $^{140}_{62}Sm$, $^{142}_{62}Sm$, and $^{146}_{62}Sm$ listed in table (2) are not presented because the experimental data such as (half life time $t_{½}$ for 2^+ excited states and the intensities of γ_0-transitions) are not available. The observed location of the diffraction minimum at N=82 are very well reproduced in $_{56}$Ba and $_{62}$Sm nuclei.

Figures(3,4) show the comparison of the present values of B(E2) with those reported in ref.(5) of ; experimental, Global best fit, Single Shell Asymptotic Nilsson Model (SSANM) and Finite –Range Droplet Model(FRDM) values.

The present results together with the other results seem to be a good behavior at all regions of N and close to each other except the SSANM results of ref. [5] are departed by some amount but slightly for Ba nuclides, while the results of FRDM of ref .[5] are deviated for Sm at 80 < N< 84. The observed diffraction minimum is very well reproduced by all models except for FRDM results [5].

Finally the present values together with the Global best fit values are in a good agreement with those of the experimental results so it should be helped in testing the measured electric quadrupole transitions E2 values predicted by different theoretical models.

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Table (1): Transition strengths $[M(E2)]^2_{W.u.}\downarrow$ of γ_0 - rays from the $2_1^+ \rightarrow 0_1^+$ in $_{56}$Ba nuclides with the partial gamma widths in W.u., total gamma widths ,mean life times for first excited states, with experimental values reported in ref.[1]and used in present work

Experimental values Ref. [1]					T (Ps)	$\Gamma_{tot}\times 10^{-6}$ (eV)	$\Gamma_{W.u.}$(E2) × 10^{-6}(eV)	$[M(E2)]^2_{W.u.}\downarrow$
A	N	E_i(keV)	$E\gamma_0$ (keV)	$t_{½}$ (Ps)				
122	66	196.1	196.1	0.297 (27)	0.42857(39)	1535.828(139620)	0.0084	$(18.270\pm1.6)\times10^4$
124	68	229.89	229.9	297 (26)	428.571(37518)	1.5358(1344)	0.01902	80.745±7.069
126	70	256.09	256.1	108 (4)	155.844(5772)	4.2235(1564)	0.0333	126.71±4.69
128	72	284	284	100.0(45)	144.3000(64935)	4.5614(2052)	0.05709	79.89±3.60
130	74	357.38	357.41	37(4)	53.3911(57720)	12.3281(13327)	0.18392	67.028±7.246
132	76	464.588	464.55	15.1 (11)	21.7893(15873)	30.2080(22005)	0.6969	43.346±3.158
134	78	604.723	604.72	5.12 (9)	7.38817(12990)	89.0900(15660)	2.6565	33.636±0.589
136	80	818.515	818.514	1.930(15)	2.78499(2160)	236.3424(18368)	12.3097	19.20±0.15
138	82	1435.818	1435.795	0.195 (5)	0.28139(720)	2339.184(59979)	204.972	11.220±0.288
140	84	602.35	602.35	9.7(41)	13.9971(59163)	47.0248(198764)	2.7615	17.029±7.198
142	86	354.597	354.598	66 (4)	95.2381(57720)	6.9112(4188)	0.21338	32.389±1.963
144	88	199.32	199.326	700 (30)	1010.10(4329)	0.6516(279)	0.01137	57.275±2.455
146	90	181.05	181.02	860(30)	1240.98(4329)	0.5303(165)	0.00715	74.030±2.582

Table (2): Transition strengths $[M(E2)]^2_{W.u.}\downarrow$ of γ_0 - rays from the $2_1^+ \rightarrow 0_1^+$ in $_{62}$Sm nuclides with the partial gamma widths in W.u., total gamma widths ,mean life times for first excited states, with experimental values reported in ref.[1]and used in present work

Experimental vales Ref.[1]					T (Ps)	× 10^{-6} Γ_{tot} (eV.)	$\Gamma_{W.u.}$(E2) × 10^{-6} (eV.)	$[M(E2)]^2_{W.u.}\downarrow$
A	N	E_i(keV)	$E\gamma_0$ (keV)	$t_{½}$ (Ps)				
134	72	163	163	420 (40)	606.06(5772)	1.0860(1034)	0.00378	287.3247 ± 27.3643
136	74	254.91	254.9	88 (9)	126.980(987)	5.18340(53011)	0.036062	143.7366± 14.7002
138	76	346.9	346.9	33(7)	47.619(10101)	13.8224(29320)	0.17163	80.5365 ±17.0835
144	82	1660.2	1659.8	0.084(3)	0.1216(36)	5410.924(16046)	454.740	11.8646 ± 0.3519
148	86	550.265	550.284	7.7 0 (15)	11.1110(2165)	59.239(1154)	1.89199	31.3103 ± 0.6099
150	88	333.863	333.97	48.4 (11)	69.8410(15873)	9.4240(2141)	0.1583	59.5351 ± 1.3531

Table (3):The calculated reduced transition probabilities B (E2) e^2b^2 ↑ values are compared with that of experimental, Global best fit and, theoretical predications for $_{56}$Ba nuclides.

A	N	(keV) E_{γ_0}	B(E2; $2_1^+ \rightarrow 0_1^+$) $e^2 b^2$				
			Experimental values of Ref[5]	Present work values	Theoretical values Ref.[5]		
					Global Best fit of	SSANM	FRDM
118	62	194	-	-	1.72±0.30	1.882	2.448
120	64	183	-	-	1.82 ± 0.32	1.881	2.254
122	66	196	2.81 ± 0.28	(3289.63±299.05)	1.67 ± 0.29	1.854	2.06
124	68	229	2.09 ± 0.10	1.486± 0.130	1.41 ± 0.25	1.821	2.031
126	70	256	1.75±0.09	2.382±0.088	1.25 ±0. 22	1.787	1.753
128	72	284	1.48 0.07	1.533± 0.690	1.11 ± 0.19	1.595	1.287
130	74	357	1.163±0.016	1.313± 0.142	0.88 ± 0.15	1.336	0.797
132	76	464	0.86 ±0.06	0.867 ± 0.063	0.67 ±0.12	1.092	0.555
134	78	604	0.658±0.007	0.684± 0.012	0.51 ±0.09	0.874	0.281
136	80	818	0.410±0.008	0.400± 0.065	0.37 ± 0.06	0.682	< 0.001
138	82	1435	0.230±0.009	0.238 ± 0.006	0.210±0.037	0.468	< 0.001
140	84	602	0.45±0.19	0.368± 0.156	0.50 ± 0.09	0.907	< 0.001
142	86	359	0.699±0.037	0.714 ± 0.021	0.82 ± 0.14	1.256	0.631
144	88	199	1.05 ±0.0 6	1.286± 0.055	1.47 ± 0.26	1.634	0.989
146	90	181	1.355±0.048	1.694± 0.059	1.60 ±0.28	1.886	1.584
148	92	141	-	-	2.03 ± 0.35	2.115	2.467

Table (4): The calculated reduced transition probabilities B (E2)$e^2 b^2$ ↑values are compared

A	N	(keV) E_{γ_0}	$B(E2;\ 2_1^+ \rightarrow 0_1^+)\ e^2 b^2$				
			Experimental values of Ref[5]	Present work values	Theoretical values Ref .[5]		
					Global Best fit of	SSANM	FRDM
130	68	122	-	-	3.1 ± 0.6	3.143	4.107
132	70	131	-	-	2.9 ± 0.5	3.096	3.889
134	72	163	4.2 ± 0.6	5.863± 0.558	2.31 ± 0.40	2.824	3.714
136	74	254	2.73 ± 0.27	2.991± 0.306	1.46 ± 0.26	2.451	2.027
138	76	346	1.41 ± 0.23	1.710± 0.363	1.06 ± 0.19	2.093	1.253
140	78	530	-	-	0.69 ± 0.12	1.764	0.606
142	80	768	-	-	0.47 ± 0.08	1.467	< 0.001
144	82	1660	0.262 ± 0.006	0.266 ± 0.008	0.216 ± 0.038	1.122	< 0.001
146	84	747	-	-	0.48 ± 0.08	1.815	< 0.001
148	86	550	0.720 ± 0.030	0.729 ± 0.014	0.64 ± 0.11	2.337	1.161
150	88	333	1.350 ± 0.030	1.412± 0.032	1.05 ± 0.18	2.886	2.019
152	90	121	3.46 ± 0.06	-	2.8 ± 0.5	3.246	3.059

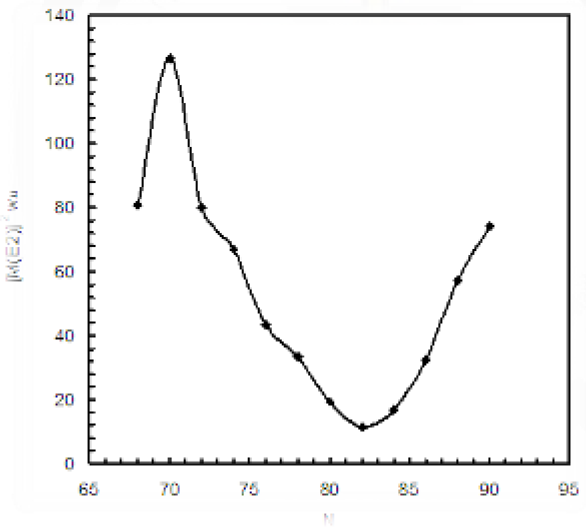

Fig. (1): The transition strengths $|M(E2)|^2_{w.u.}\downarrow$ for γ_0-transition as a function of neutron number (N) in $_{56}$Ba nuclides.

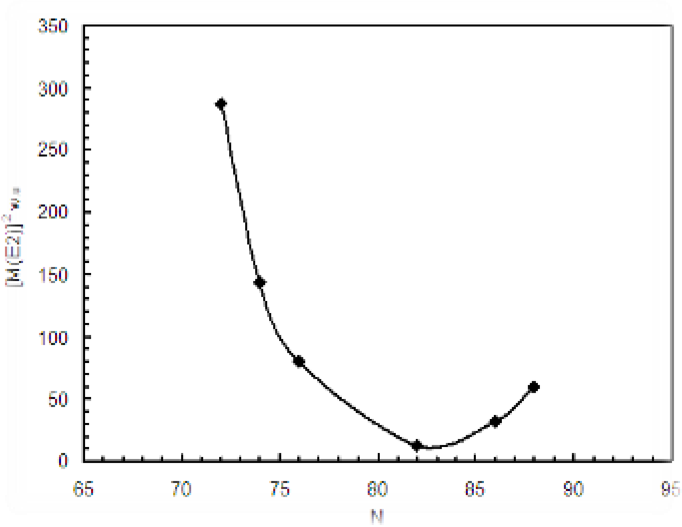

Fig. (2): The transition strengths $|M(E2)|^2_{w.u.} \downarrow$ for γ_0 -transition as a function of neutron number (N) in $_{62}$Sm nuclides.

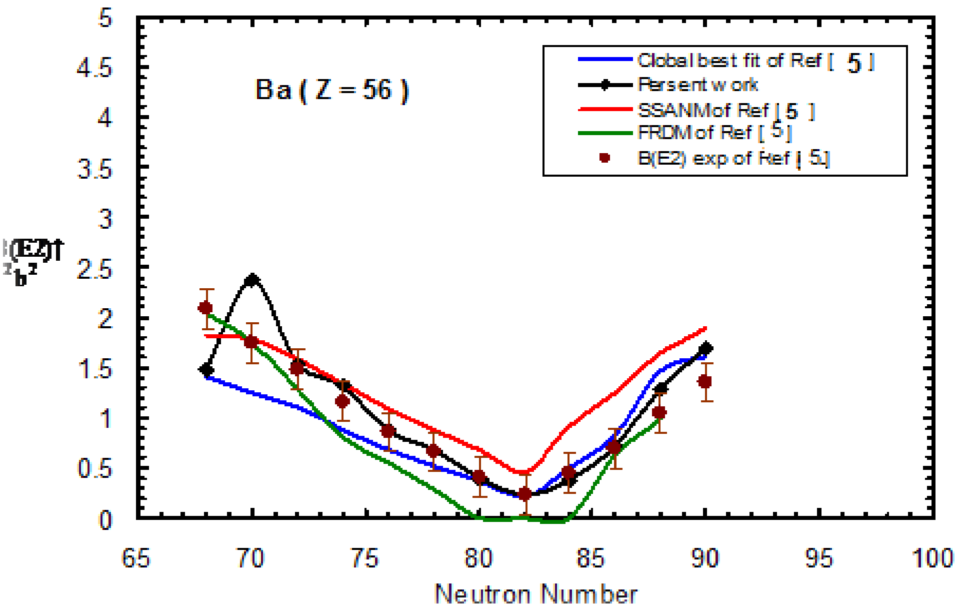

Fig.(3): Comparison between the B (E2) ↑ values of the present work for 56Ba nuclides with Global , experimental and other theoretical results

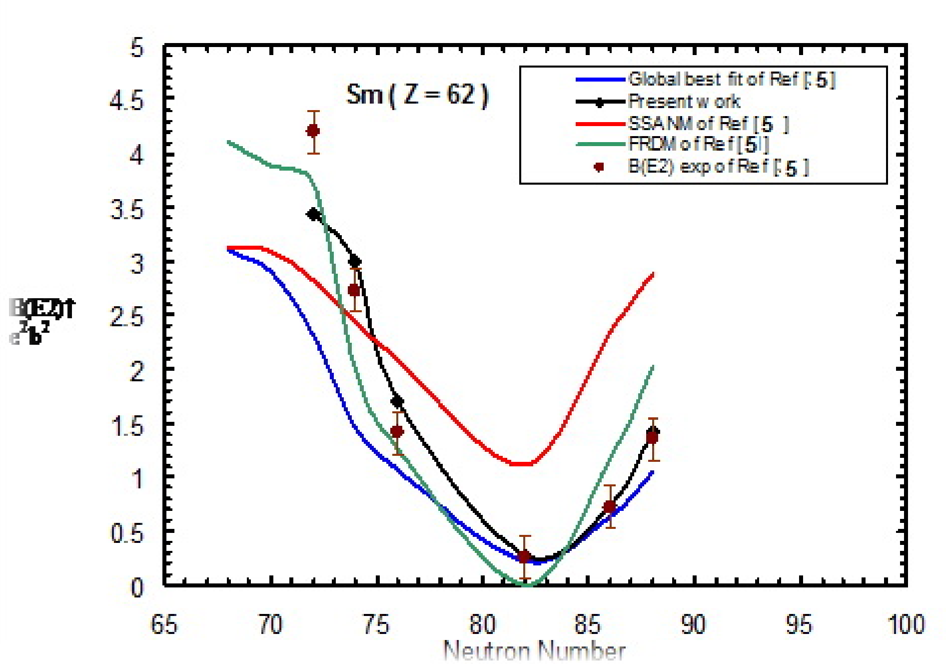

Fig. (4): Comparison between the B (E2) ↑ values of the present work for $_{62}$Sm nuclides with Global , experimental and other theoretical results.

دراسة لانتقالات رباعي القطب الكهربائي $_{56}$Ba, $_{62}$Sm في نويدات (E2)

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الخلاصة

حسبت قوى الانتقال $|M(E2)|^2_{w.u.}\downarrow$ لانتقالات أشعة كاما من المستوي المتهيج الأول 2_1^+ إلى المستوي الأرضي والناتج من إشعاع رباعي قطب كهربائي نقي في النويدات الزوجية– زوجية لكل من $_{56}$Ba , $_{62}$Sm, كدالة إلى العدد النيوتروني اذ حسبت قوى الانتقال $|M(E2)|^2_{w.u.}\downarrow$ بالاعتماد على معدل عمر المستوي المتهيج الأول 2_1^+ والشدة النسبية لأشعة كاما المنبعثة من ذلك المستوي المحفز إلى المستوي الأرضي وقد لوحظ أن اصغر قيمة لـ $|M(E2)|^2_{w.u.}\downarrow$ تكون في النويدات الآتية ($_{56}$Ba^{138} , $_{62}$Sm^{144}) التي لها العدد النيوتروني السحري82 . ولغرض المقارنة فقد حولت قيم قوى الانتقال $|M(E2)|^2_{w.u.}\downarrow$ الى احتمالية الانتقال المختزلة $B(E2)e^2b^2\uparrow$ لتلك الانتقالات.أن عملنا الحالي يعطي مجموعة كاملة لاحتمالية الانتقال المختزلة في النويدات المذكورة لغرض المقارنة مع نتائج تم حسابها عمليا .

الكلمات المفتاحية : قوى الانتقال لرباعي القطب الكهربائي $|M(E2)|^2_{w.u.}\downarrow$