THE STUDY OF ELECTRIC QUADRUPOLE TRANSITION (E2) IN $_{58}$Ce AND $_{60}$Nd 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 nuclei of $_{58}$Ce and $_{60}$Nd have been calculated as a function of neutron number (N). The life times for 2_1^+ excited states together with the intensities of γ_0- transitions measurements are used in calculations. The results thus obtained have shown that; the nuclei with magic neutron number such as $_{58}Ce^{140}$ and $_{60}Nd^{142}$ have minimum value for $|M(E2)|^2_{w.u.}\downarrow$. The reduced transition probabilities B(E2) are also calculated and compared with the experimental data and other theoretical models.

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Keywords:- Electromagnetic transition, lifetime and transition probability, multiple mixing ration

دراسة أنتقال رباعي القطب الكهربائي للنوى $_{58}$Ce و $_{60}$Nd

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الخلاصة

تم حساب قوى الانتقال $|M(E2)|^2_{w.u.}\downarrow$ لانتقالات أشعة كاما من المستوي المتهيج الأول 2_1^+ إلى المستوي الأرضي والناتج عن إشعاع رباعي قطب كهربائي نقي للنويات الزوجية– زوجية لكل من $_{60}$Nd, $_{58}$Ce كدالة إلى العدد النيوتروني. حيث حسبت قوى الانتقال $|M(E2)|^2_{w.u.}\downarrow$ بالاعتماد على معدل العمر للمستوي المتهيج الأول 2_1^+ والشدة النسبية لأشعة كاما المنبعثة من ذالك المستوي المحفز إلى المستوي الأرضي. أوضحت النتائج الحالية بأن اصغر قيمة لـ $|M(E2)|^2_{w.u.}\downarrow$ تكون للنويات $^{140}_{58}Ce,\ ^{142}_{60}Nd$ والتي لها العدد النيوتروني السحري ٨٢ . حسبت احتمالية الانتقال المختزلة $B(E2)e^2b^2\uparrow$ لتلك الانتقالات ثم قورنت مع المعطيات العملية ونتائج نظرية أخرى.

Introduction

The study of electromagnetic transition strengths in nuclei provides available information on the ability of nuclear models to describe details of nuclear structure and transition properties. A good deal of works has been carried out on studying the electromagnetic transitions in nuclei. It is sufficient to indicate the several groups that have devoted their works

to study the properties of some (even-even) nuclei [1,2].
The nuclear resonance florescence in ^{142}Nd isotope have been studied by Metzger (1978) [1] for proton energies up to 5MeV. The radiative with for 13 levels were estimated. The E1 strength was compared with that measured in other even –even N=82 nuclei.
Lobianco et al.(1989)[2] measured the ratio of the B(E2) values for $2_1^+ \rightarrow 0_1^+$ transitions in ^{138}Ce and ^{142}Ce nuclei by coulomb excitation with α-particales from the known value of the transition probability in ^{142}Ce the B(E2, ^{138}Ce, $2_1^+ \rightarrow 0_1^+) = 0.45 \pm 0.03\, e^2b^2$.Lifetime measurements of the $3_1^-, 5_1^- and 1_1^-$ states in ^{144}Nd show that the E2 and E3 transition rates from the $5_1^- and 1_1^-$ states are consistent with their structure being formed by coupling of the lowest quadrupole 2_1^+ and octupole 3_1^- excitations. This study was carried out by Robinson et al.(1994)[3].
The recent data on the ground state band and excited states based on the 0_2^+ level in ^{150}Nd and ^{152}Sm, especially the measurement B(E2) values had been well described by clark et al.(2003)[4] by including $\Delta k = 0$ coupling between rotational bands.
Yazar and Uluer (2007)[5] carried out an analysis for even-even ^{122,128}Te core nucleus the band on IBM-2.The energy levels and the electric quadrupole transition probability B (E2) and $\gamma - ray\,(E2/M1)$ mixing rations had been calculated. Their results were in a good agreement with the existing experimental data.
In the present work, the calculations concentrate on the transition strengths $|M(E2)|^2$ for γ-transition from first excited 2_1^+ state to the 0^+ ground state for even-even nuclei of ${}_{58}^{A}Ce\,(124 \le A \le 145)$ and ${}_{60}^{A}Nd\,(128 \le A \le 150)$.

Theory

The WeissKoph single-particle transition probability B(EL,ML) is defined by as the ratio of the single-particle half-life time to the experimental half-life time for gamma transition[6],

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

Where L is the multipolarities L=1,2,3,……… L≠ 0

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) [7],

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

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
The mean life time T of initial level is given by:

$$T = \frac{\tau_{1/2}}{\ln 2} \text{ …………………………………....(5)}$$

$\hbar = \frac{h}{2\pi} =$ 0.65822x 10^{-15} eV.s h is Plank constant.
From eqs. 2, 3 and equ. 4 one can be concluded
$B(EL,ML)_{W.u}\downarrow = [M(EL,ML)]^2_{W.u}$ ………...(6)
Specific expression for $B(EL,ML)_{W.u}$ suggested by Martin [8] is :

$$B(EL,ML)_{W.u}\downarrow = \frac{B(EL,ML)_{\exp}}{B(El,Ml)_{s.p.}} \text{ ………..(7)}$$

If the transition is of mixed multi polarity M1 and E2 then [8],

$$\delta^2 = \frac{\Gamma(E2)}{\Gamma(M1)} \text{ ………………………..….(8)}$$

Where δ is the mixing ratio
and $\Gamma_\gamma = \Gamma(M1) + \Gamma(E2)$ ………………….....(9)
For 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 equ . 2 and 7

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

On the basis of an extreme single particle model the value for the $\Gamma(E2)_{W.u}$ in e .V.is given by [4]

$$\Gamma(E2)_{W.u} = 4.7907\text{X } 10^{-23}\, A^{4/3} E_\gamma^5 \text{ …………(12)}$$

Where E γ in KeV for nuclear of mass number A and the corresponding reduced transition probability is :

$$B_{W.u.}(E2) = 0.05940\, A^{4/3}\, e^2\, (fm)^4 \text{ ………..(13)}$$

The relation between B(E2) ↓ =B(E2 ;2→1) and B(E2) ↑=B(E2;1→2) is given by [8]:

$$B(E2)\uparrow = \frac{2J_f+1}{2J_i+1} B(E2)\downarrow \ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

Results of Calculations

The electric quadrupole transition strengths $|M(E2)|^2_{w.u.}\downarrow$ for the $2^+ \rightarrow 0^+_{g.s.}$ transition have been calculated as a function of neutron number (N) using eq. 11 with the aid of the experimental data reported in ref. [6] for even – even isotopes. The results of calculations are presented in table 1 for $_{58}$Ce nuclei , and in table 2 for $_{60}$Nd nuclei. 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. 11 and then eq.14, the present B (E2) e^2 $b^2\uparrow$values for; $_{58}$Ce (124≤A≤148) and $_{60}$Nd (128≤A≤152) which have only one transition for γ is γ_0 with intensity (100%)E2.

The results are compared with the experimental values as well as with other of various theoretical models. These comparison are presented in tables 3 and 4 and shown in Figuers 3 and 4 respectively

Table 1: Transition strengths $[M(E2)]^2_{W.u.}\downarrow$ of γ_0 - rays from the transition $2^+_1 \rightarrow 0^+_1$ in $_{58}$Ce nuclei with the partial gamma widths in W.u., total gamma widths ,mean life times for first excited states, The experimental data of ref.[6]are used in the present work

A	N	E_i(keV)	$E\gamma_0$ (keV)	$t_{1/2}$ (Ps)	τ_m (Ps)	Γ_{tot} (× 10^{-6})$_{eV}$	$\Gamma_{w.u.}(E2)$ (× 10^{-6}) eV	$[M(E2)]^2_{W.u.}\downarrow$
124	66	124	142	880± 190	1269.84 (274.17)	0.518 (0.111)	0.00171	303.0726±65.4361
126	68	169.59	169.59	658 ± 36	949.4949 (51.9481)	0.693(0.037)	0.00424	163.2973±8.93419
128	70	207.3	207.3	296 ± 3	427.12849(4.3290)	1.541(0.015)	0.01183	130.2562±1.32017
130	72	253.99	253.9	143 ± 7	206.3492(10.1010)	3.1897(0.1561)	0.03334	95.6511±4.6822
132	74	325.54	325.5	41 ±3	59.16306(4.32900)	11.1253 (0.8140)	0.11772	94.5067±6.9151
134	76	409.1	409.1	23 ± 2	33.18903(2.88600)	19.83221(1.72450)	0.37652	52.6719±4.5802
138	80	788.74	788.74	2.00 ± 0.15	2.886003(.216450)	228.07045(17.105 00)	10.4292	21.8684±1.6401
140	82	1596.227	1596.21	.0078 ±0.011	0.11255(0.01587)	5848.854 (824.6890)	360.272	16.6306±2.4071
142	84	641.286	641.285	5.56 ± 0.12	8.023088(0.173160)	82.0397 (1.7706)	3.8492	21.3132±0.4599
146	88	258.46	258.42	250 ± 30	360.7504(43.2900)	1.8245 (0.2189)	0.04247	42.9526±5.1543
148	90	158.468	158.468	1010 ±60	1457.431(86.580)	0.45162 (0.02680)	0.00374	120.5004±7.1584

Table 2: Transition strengths $[M(E2)]^2$ W.u.↓ of γ_0 - rays from the transition $2_1^+ \rightarrow 0_1^+$ in $_{60}$Nd nuclei with the partial gamma widths in W.u., total gamma widths ,mean life times for first excited states, the experimental data of ref.[6]are used in the present work

A	N	E_i(keV)	$E\gamma_0$ (keV)	$t_{½}$ (Ps)	τ_m (Ps)	Γ_{tot} $(\times 10^{-6})$ eV	$\Gamma_{w.u.}$(E $(\times 10^{-6})$ eV	$[M(E2)]^2$ W.u.↓
132	72	212.62	212.5	216 ± 17	311.6883(24.5310)	2.1118 (0.1662)	0.01399	150.94±11.8793
134	74	294.3	294.2	64 ± 4	92.35209(5.77201)	7.1272 (0.4450)	0.0725	98.272±6.1419
142	82	1573.83	1573.85	0.11 ± 0.002	015873(0.00289)	4146.735 (75.4)	342.1364	12.024±0.2186
144	84	696.513	696.51	4.51 ± 0.24	6.507937(0.346320)	101.1340 ± (5.38)	5.9273	17.063±0.908
146	86	453.77	453.88	21.6 ± 1.3	31.16883(1.87590)	21.118 (1.271)	0.7085	29.803±1.7937
148	88	301.702	301.702	78 ± 1.2	112.5541(1.7316)	5.848 (0.090)	0.0937	62.378±0.9597
150	90	130.21	130.23	1492 ± 15	2152.958(21.645)	0.3057 (0.0031)	0.00142	213.92±2.1507

Table 3:The calculated reduced transition probabilities B (E2) e^2b^2 ↑ values are compared with that of experimental [10], Global best fit and, theoretical predications for$_{58}$Ce nuclei.

A	N	E_{γ_0} (keV)	B(E2; $2_1^+ \rightarrow 0_1^+$) $e^2 b^2$				
			Experimental of Ref.[10]	Present work	Global Best fit of Ref.[10]	Theoretical Ref.[10]	
						SSANM	FRDM
124	66	142	3.7 ± 0.9	5.576 ± 1.204	2.44±0.43	2.355	2.866
126	68	169	2.68 ± 0.48	3.069 ± 0.160	2.02 ± 0.35	2.318	2.626
128	70	207	2.28 ± 0.22	2.50± 0.025	1.64 ± 0.29	2.279	2.256
130	72	253	1.74 ± 0.10	1.874 ± 0.092	1.23 ± 0.23	2.057	1.82
132	74	325	1.87 ± 0.17	1.890 ± 0.138	1.02 ± 0.18	1.753	1.177
134	76	409	1.04 ± 0.09	1.074± 0.093	0.81 ± 0.14	1.466	0.077
136	78	552	0.81 ± 0.09	-	0.59 ± 0.10	1.205	0.0337
138	80	788	0.450 ±0.030	0.464 ± 0.035	0.41 ± 0.07	0.973	< 0.001
140	82	1596	0.298 ± 0.009	0.359 ± 0.052	0.201 ±0.035	0.707	< 0.001
142	84	641	0.480 ±0.006	0.469 ± 0.010	0.49 ± 0.09	1.245	< 0.001
144	86	397	0.83 ± 0.09	-	0.79 ±0.14	1.661	0.0788
146	88	258	1.14 ± 0.12	0.983 ± 0.118	1.20 ± 0.21	2.104	1.349
148	90	158	1.96 ± 0.18	2.807± 0.167	1.95 ± 0.34	2.398	2.096
150	92	97	3.3 ± 0.8	-	3.1 ± 0.6	2.663	3.061

Table 4:The calculated reduced transition probabilities B (E2) e^2b^2 ↑ values are compared with that of experimental [10], Global best fit and, theoretical predications for $_{60}$Nd nuclei.

A	N	E_{γ_0} (keV)	B(E2; $2_1^+ \to 0_1^+$) e^2 b^2				
			Experimental of Ref .[10]	Present work	Global Best fit of Ref. [10]	Theoretical Ref. [10] SSANM	Theoretical Ref. [10] FRDM
128	68	133	-	-	2.72±0.47	2.797	3.607
130	70	158	4.1 ± 1.8	-	2.28 ± 0.40	2.754	3.363
132	72	212	3.5 ± 0.6	3.019± 0.238	1.68 ± 0.29	2.504	2.99
134	74	294	1.83 ± 0.37	2.005± 0.125	1.20 ± 0. 21	2.16	1.549
136	76	373	-	-	0.93 ± 0 16	1.832	0.931
138	78	520	-	-	0.66 ± 0.12	1.533	0.487
140	80	773	-	-	0.44 ± 0.08	1.263	< 0.001
142	82	1575	0.265 ± 0.006	0.265 ± 0.005	0.215 ± 0.038	0.951	< 0.001
144	84	696	0.491 ± 0.005	0.383 ± 0.020	0.48 ± 0.08	1.579	< 0.001
146	86	453	0.760 ± 0.025	0.682 ± 0.041	0.73 ± 0. 13	2.056	1.089
148	88	301	1.35 ± 0.05	1.453± 0.022	1.09 ± 0.19	2.56	1.92
150	90	130	2.760 ± 0.040	5.073± 0.051	2.51 ± 0.44	2.891	2.915

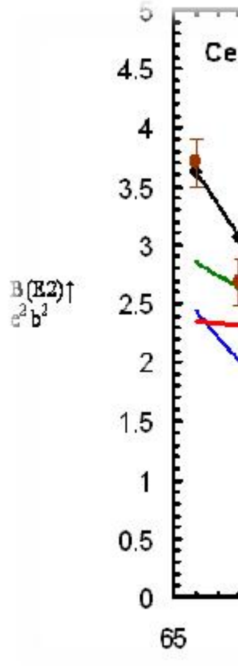

Fig.1:Comp

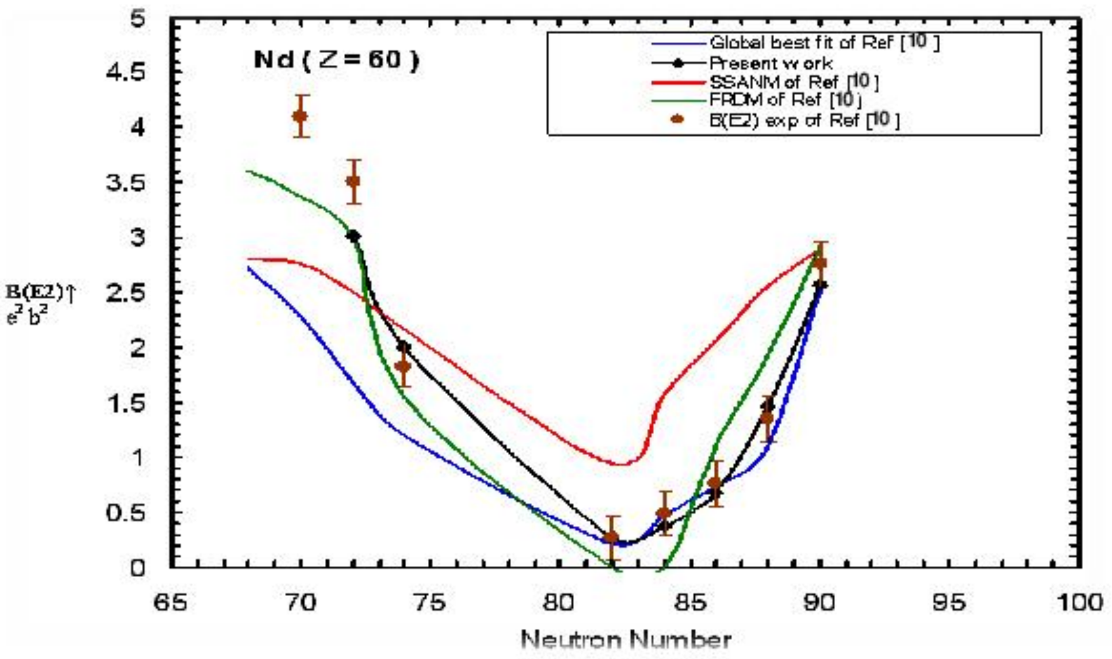

Fig.2: Comparison between the B (E2) ↑ values of the present work for $_{60}$Nd nuclei with Global experimental and other theoretical results.

Discussion and Conclusions

In view of tables1and 2 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, so that the calculated $|M(E2)|^2_{w.u.}\downarrow$ which are limited to the even – even nuclei and shown in table 1 and table 2 reproduce the diffraction minimum at the magic neutron number N= 82 which is included in $_{58}$Ce and $_{60}$Nd nuclei. The reduced transition probabilities B(E2) values of γ_0 -transitions for the following nuclei ; $^{136}_{58}Ce, ^{144}_{58}Ce$, in table 3 and for $^{136}_{60}Nd, ^{138}_{60}Nd, ^{140}_{60}Nd$ in table 4 are not presented because the experimental data such as half life time $t_{1/2}$ for 2^+ excited states and the intensities of γ_0-transitions are not available.

Figures 1, 2 show the comparison of the present values of B(E2) with those reported in ref.[10] of ; experimental, Global best fit, SSANM and 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.[10] are departal by some amount.The FRDM results of ref. [10] are deviated for Nd at 80 < N< 84 but for Ce fall down at 76 < N< 84 nuclei. The observed diffraction minimum at N=82 are very well reproduced by the present work as well as by other models except for FRDM results [10]. The present results together with the Global best fits are in a good agreement with the experimental data[10].

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