Asymmetric deformation and N_pN_n scheme

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The deformation parameters β and γ of the collective model are basic descriptors of the nuclear equilibrium shape and structure. The evolution of nuclear structure with mass is preliminary a consequence of proton neutron interaction. It is reasonable to suppose that these are the respective number of valance protons and neutrons. There is no distinction between particle and holes and above mid shell N_P or N_n is counted to the next higher magic number. The use of the quantity N_pN_n as a variable to gauge the structure of a given nucleus and to track the evolution of structure is called the N_pN_n scheme. The N_pN_n scheme which has been extensively applied to even – even nuclei is found to be very good bench mark for odd – even, even – odd and doubly odd nuclei as well. In last three decades many researchers had studied the evolution of collective nuclear structure as a function of number of N_pN_n [1, 2]. The quadrupole deformation β and γ are the result of interaction between valance protons and neutrons in the nucleus. Sometimes back the study of even Xe, Ba and Ce nuclei yielded that both the deformation parameters β and γ have a smooth systematics with N_pN_n [3]. Heavy mass even nuclei viz. Hf, W, Os, Pt and Hg were studied later and the systematics of γ with NpNn were not found smooth. To make the correlation of γ and N_pN_n smooth, the γ values were calculated by two methods where these values of γ differ substantially and the values giving the smoother systematics were used [4]. Later another γ deformation related quantity J_0 were used in even nuclei of mass region A = 90 – 120 viz. Mo, Ru, Pd, Xe and Ba, the striking correlation were found [5].

The present study is being done to explore the general correlation between asymmetric deformation γ and N_pN_n. We shall focus on three basic relations which are used to evaluate γ. These relations consist of observable quantities such as $E2_1^+$, $E4_1^+/E2_1^+$, $B(E2;0_1^+\rightarrow 2_1^+)$, β, $E2_\beta^+$ & $E3_\gamma^+$. We shall examine whether these ratios and relations also scale smoothly as a function of N_pN_n in various mass regions. In the past the asymmetric parameter was determined by the ratio $E4_1^+/E2_1^+$ [6]. Later it was found that it does not include the entire asymmetric nuclei and hence the older method to evaluate γ from $E2_2^+/E2_1^+$ was followed [7]. Baker et al objected to use γ - band head to evaluate γ and doubted the value of γ thus obtained. Recently, a new procedure to evaluate γ from Grodzins product was suggested [8]. We shall study the systematics of three quantities $R\left(\frac{4}{2}\right)=\frac{E4_1^+}{E2_1^+}$, $R(\gamma)=\frac{E2_2^+}{E2_1^+}$ and $\frac{E2_1^+\times B(E2;0_1^+\rightarrow 2_1^+)}{Z^2}=G_c$ versus N_pN_n in different mass regions of nuclear chart. We have considered Ge (Z = 32), Xe (Z = 54), Nd (Z = 60) and Os (Z = 76) isotopic chains in present work.

Observations readily caught from Table I give clear indications that all the γ related quantities support the collective behavior. The two γ related quantities i.e. R (4/2) and R (γ) are inversely proportional to γ and as such for maximum value of N_pN_n, we observe that R (4/2) and R (γ) are also maximum and γ is minimum for maximum value of N_pN_n. The third quantity Gc is proportional to γ and as such Gc is minimum for maximum N_pN_n. This is the case with Os nuclei that comes in heavy mass region of nuclear chart.

In Nd nuclei for zero value of N_pN_n, the R (4/2) and R (γ) are minimum so that γ is maximum while Gc is maximum which gives maximum value of γ. Therefore, it follows the observations of heavy mass region.

In Xe nuclei for maximum value of N_pN_n R (4/2) and R (γ) are maximum therefore, γ is minimum while Gc is maximum which gives maximum value of γ. For zero value of N_pN_n, R (4/2) and R (γ) also minimum therefore, γ is maximum and Gc is also maximum hence γ is maximum. There is no controversy with heavy mass region.

In Ge, N_pN_n is maximum R (4/2) and R (γ) are minimum so γ is maximum and Gc is maximum so γ is maximum and such observations go opposite to the findings in heavy and medium mass region of nuclear chart.

We have also evaluated the $|\beta A^{2/3}|$ parameter of Ge nuclei to investigate either these nuclei are worth for considering stable asymmetry (Table – II). Surprisingly the $|\beta A^{2/3}|$ come to be less than 4 in first three nuclei pointing out these nuclei too be vibrational. The value of asymmetry is not definite in these nuclei and we suppose this may be the reason for the discrepancy observed in last chain of nuclei.

Table – I

A	N_PN_N	$E2_1^+$ (MeV)	R(4/2)	R(γ)	Gc
Z = 32, Ge – Isotopes					
66	24	0.957	2.27	1.77	6.10
68	32	1.016	2.23	1.75	9.65
70	40	1.039	2.07	1.64	12.50
72	40	0.634	2.07	1.76	12.50
74	32	0.596	2.45	2.02	12.90
76	24	0.503	2.50	1.97	11.20
Z = 54, Xe – Isotopes					
116	48	0.393	2.33	2.58	18.94
118	56	0.337	2.40	2.75	19.11
120	64	0.332	2.47	2.72	22.95
122	56	0.331	2.50	2.55	19.40
124	48	0.354	2.48	2.39	14.45
126	40	0.388	2.42	2.26	12.93
128	32	0.442	2.33	2.19	14.58
130	24	0.536	2.24	2.09	15.53
132	16	0.667	2.15	1.94	13.90
134	8	0.847	2.04	1.61	13.23
136	0	1.313	1.29	1.92	22.00
138	8	0.588	1.82	1.48	-
140	16	0.367	2.21	-	5.86
Z = 60, Nd – Isotopes					
136	60	0.374	2.61	2.31	-
138	40	0.521	2.40	1.95	-
140	20	0.774	2.33	3.22	-
142	0	1.576	1.33	1.51	16.47
144	20	0.696	2.33	2.25	13.68
146	40	0.454	2.30	-	13.99
148	60	0.302	2.52	4.14	16.74
150	80	0.130	2.93	8.17	14.97
152	100	0.072	3.17	-	12.86

Table – I continued……….

154	120	0.076	3.23	-	-
156	140	0.066	-	-	-
Z = 76, Os – Isotopes					
172	84	0.228	-	-	22.38
174	96	0.159	2.77	-	22.47
176	108	0.135	2.92	-	-
178	120	0.132	3.02	5.83	-
180	132	0.132	3.09	6.58	14.84
182	144	0.127	3.15	7.01	15.44
184	156	0.120	3.20	7.87	12.33
186	168	0.137	3.16	5.59	12.81
188	156	0.155	3.08	4.08	12.86
190	144	0.187	2.93	2.99	14.43
192	132	0.205	2.82	2.39	14.37
194	120	0.218	2.75	3.00	-

Table – II

A	**66**	**68**	**70**	**72**	**74**
$\boldsymbol{\beta A^{2/3}}$	2.89	3.43	3.80	4.18	5.00

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