Systematics in p-n interaction vs deformation

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The correlation of integrated valance p-n interaction in the onset of collectivity and deformation has been described phenomenologically in terms of N_pN_n scheme. L. Esser et al. presented the graphs between N_pN_n and deformation β and γ for some heavy nuclei [1]. Later E. A. McCutchan et al. pointed out that the deformation produced by same values of N_pN_n may by different [2].

The magic numbers 20, 28, 50, 82, 126 defines the major shell gap in the sequences of shell model single particle energies.

Table – 1
Nuclei of Quadrant I having pp pair

S. No.	Nucleus	N_pN_n	γ (deg.)	β
1	^{140}Ba	12	24.4	0.134
2	^{142}Ba	24	19.4	0.157
3	^{144}Ba	36	15.3	0.190
4	^{146}Ba	48	15.8	0.218
5	^{142}Ce	16	25.0	0.124
6	^{144}Ce	32	16.1	0.179
7	^{146}Ce	48	16.8	0.178
8	^{148}Ce	64	15.7	0.255
9	^{144}Nd	20	26.1	0.125
10	^{146}Nd	40	21.4	0.151
11	^{148}Nd	60	19.0	0.200
12	^{150}Nd	80	13.8	0.285
13	^{146}Sm	24	26.4	0.083
14	^{148}Sm	48	23.7	0.142
15	^{150}Sm	72	20.4	0.193
16	^{152}Sm	96	13.2	0.306
17	^{154}Sm	120	9.5	0.340

The major shell space Z = 50 – 82, N = 82 – 126 is divided into four subspaces or quadrants. The nuclei lies in quadrant I and III having particle – particle (pp) and hole – hole (hh) bosons respectively. In quadrant II and IV, those nuclei belongs which have particle – hole (ph) pair of bosons. The kind of valance pairs matter along with the numerical value of the product N_pN_n to produce the deformation in the nucleus.

Table – 2

Nuclei of Quadrant III having hh pair

S. No.	Nucleus	N_pN_n	γ (deg.)	β
1	^{178}Hf	200	11.0	0.278
2	^{180}Hf	180	11.0	0.273
3	^{180}W	160	12.1	0.251
4	^{182}W	144	11.4	0.248
5	^{184}W	128	13.8	0.234
6	^{186}W	112	16.0	0.226
7	^{182}Os	120	14.8	0.235
8	^{184}Os	108	14.1	0.212
9	^{186}Os	96	16.5	0.205
10	^{188}Os	84	19.2	0.184
11	^{190}Os	72	22.3	0.177
12	^{192}Os	60	25.2	0.164
13	^{184}Pt	80	19.4	0.224
14	^{186}Pt	72	21.6	0.200
15	^{188}Pt	64	25.9	0.183
16	^{190}Pt	56	31.1	0.154
17	^{192}Pt	48	31.6	0.156
181	^{194}Pt	40	31.3	0.142
9	^{196}Pt	32	30.0	0.131

Presently we consider the nuclei possessing 50< Z < 66 and 82 < N < 104 so that the pair of nucleons remain pp (quadrant I of nuclear chart) listed in table -1 and secondly the nuclei possessing 66< Z < 82 and 104 < N < 126 belonging to hh pairs (quadrant III of nuclear chart) listed in table – 2. The asymmetric deformation γ is evaluated from energy ratio $R\left[\frac{E2_2^+}{E2_1^+}\right]$ and quadrupole deformation β fron E2 transition rate $B(E2; 2_1^+ \rightarrow 0_1^+)$. The value of γ and β for various nuclei are listed in table 1 and 2.

The different values of asymmetric parameter γ belonging to pp and hh pair for the same value of N_pN_n from table 1 and 2 are listed in table 3. The table 3 exhibits a large difference in β and γ values for pp and hh pairs possessing same value of N_pN_n. Therefore, it will be wise and meaningful to plot the graph in N_pN_n vs β and γ for these different pairs separately (fig 1). It is inferred from figure 1 that β and γ follow smoother trajectories against N_pN_n if considered quadrant wise separately. Thus, there is a possibility of obtaining one parameter description of nuclear shapes relating one to the other quadrant wise.

Table – 3

List of Nuclei having different asymmetric parameter (γ) for the same value of N_pN_n

NpNn	Asymmetry parameter (γ)	
	pp pairs From table – 1	hh pairs From table – 2
32	16.1	30.0
40	21.4	31.3
48	15.8, 16.8, 23.7	31.6
60	19.0	25.2
64	15.7	25.9
72	20.4	22.3
80	13.8	19.4
96	13.2	16.5
120	9.5	14.8

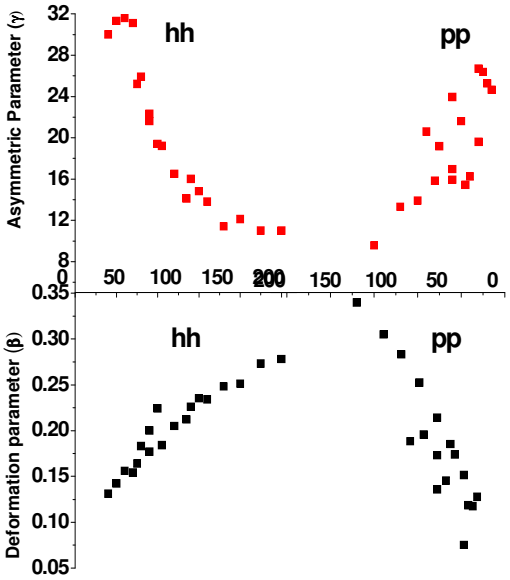

Figure – 1

Plots for asymmetric and deformation parameters against N_pN_n having pp and hh pairs separately for some even – even nuclei.

References:

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