Breakdown in N_pN_n Scheme- evidence and proposed solution

A K Varshney[1], M Singh[2], Y Singh[3] and D K Gupta[4]

1. *Govt. College, Palampur, HP University, Shimla, India.*
2. *Greater Noida Institute of Technology, Greater Noida (UP), India.*
3. *Govt. College, Dhaliara (HP University), Shimla, India.*
4. *SSLD Varshney Engineering College, Aligarh (UP), India.*

The correlation of the integrated valance p - n interaction with the onset of collectivity and deformation has been described phenomenological in terms of N_pN_n scheme. With the increase of the value of N_pN_n the $B(E2; 2_1^+ \rightarrow 0_1^+)$ value increases and the $E2_1^+$ value decreases. Grodzins observed that the product $E2_1^+.B(E2; 2_1^+ \rightarrow 0_1^+)$ is constant for large part of nuclear chart [1]. It has also been found that energy $E2_1^+$ increases with increasing Z at N = 88 and N = 86 isotones where $B(E2; 2_1^+ \rightarrow 0_1^+)$ values also increases. Thus, the product $E2_1^+.B(E2; 2_1^+ \rightarrow 0_1^+)$ do not remain constant at N = 88 isotones in Nd - Dy nuclei. This constancy of the product is due to charge independence of the nuclear force and the breakdown in this observation may be due to charge dependence of nuclear force [2].

There are cases viz. $^{144\text{-}146}$Sm where N_pN_n increases from 0 to 24 but the $B(E2; 2_1^+ \rightarrow 0_1^+)$ decreases from 0.26 to 0.24. We observe a number of cases in nuclear chart beginning from light nuclei Be to heavy nuclei Cf in the present work (Table1). In the first row ^{10}Be and ^{12}Be should have same $E2_1^+$ and $B(E2)$ as these nuclei have same N_pN_n but these are not only different in addition have similar increasing trend. In row two N_pN_n increases and also $E2_1^+$increases which is clear breakdown. Third and fourth row have same phenomena. Fifth, sixth and seventh row exhibit opposite trend of N_pN_n and $B(E)$ however, very heavy nuclei U, Pu and Cf exhibit similar trend of N_pN_n and $E2_1^+$. We keep in mind that $E2_1^+$ should decrease while $B(E2)$ increases with the increase of the value NpNn for obeying Grodzins law.

We find two categories which exhibits the breakdown in N_pN_n scheme. Firstly there are $^{10\text{-}12}Be_6$, $^{178\text{-}184}Os_{76}$ which are around midshell region where the interaction behavior becomes different due to sudden change of pairs ph (particle – hole), hh (hole – hole) and pp (particle – particle) in the shells. This phenomena of sudden change occurs in $^{144\text{-}146}$Sm also. Secondly in nuclei $^{80\text{-}82}$Se, $^{106\text{-}108}$Mo, $^{124\text{-}126}$Ce, $^{234\text{-}236}$ U, $^{240\text{-}242}$Pu and $^{250\text{-}252}$Cf the behavior of $E2_1^+$ values with N_pN_n is reserved. $B(E2; 2_1^+ \rightarrow 0_1^+)$ values increase with increase of N_pN_n and $E2_1^+$ also increase with N_pN_n and so the constancy of the product $E2_1^+.B(E2; 2_1^+ \rightarrow 0_1^+)$ is disturbed. We propose in the present work that the behavior of $E2_1^+$, whether increases or decreases depends upon the moment of inertia is I_o [3].

$$E(I) = \frac{\hbar^2 I(I+1)}{2I_0(1+\sigma I)} \qquad \ldots\ldots\ldots (1)$$

The moment of inertia depends on number of particles i.e. the mass and distribution of particles around axis of rotation or ultimately the radius of gyration geometrically. We propose that due to alignment of orbitals of protons and neutrons along with deformation axis employing shell model the radius of gyration is reduced. Therefore, the moment of inertia I_0 decreases and as such energy value E (I) increases according to equation (1). D. Bonatsos et al; has employed Pseudo Shell model recently and has shown that there is alignment of particles that changes the distribution of nucleons [4]. A K Varshney et al; has observed the breakdown behavior in Plutonium nuclei earlier [5].

Table-I

N_pN_n	Nucleus	$E2_1^+$ (KeV)	BE2 (e^2b^2) ↑	Reason Assigned
4 4	^{10}Be ^{12}Be	336.8 210.2	0.00467 0.00400	Interaction
112 ↓ 128 ↓	^{106}Mo ^{108}Mo	171 ↓ 192 ↓	1.29 1.70	Nucleons Distribution
24 ↓ 36 ↓	^{124}Ce ^{126}Ce	141 ↓ 169 ↓	3.50 3.65	Nucleons Distribution
24 ↑ 12 ↑	^{80}Se ^{82}Se	666 ↑ 654 ↑	0.25 ↑ 0.18 ↑	Nucleons Distribution
0 ↓ 24 ↓	^{144}Sm ^{146}Sm	1660 747	0.260 ↑ 0.240 ↑	Interaction
120 ↓ 132 ↓ 120 ↑ 108 ↑	^{178}Os ^{180}Os ^{182}Os ^{184}Os	132.2 132.1 126.9 119.8	4.07 3.9 ↑ 3.2 ↑ 3.0 ↑	Interaction
40 32	^{202}Rn ^{204}Rn	504 542	1.00 1.55	Interaction
160 ↓ 180 ↓	^{234}U ^{236}U	43.5 ↓ 45.2 ↓	10.2 10.9	Distribution of nucleons
240 ↓ 264 ↓	^{240}Pu ^{242}Pu	42.8 ↓ 44.5 ↓	1.31 1.40	Distribution of nucleons
416 ↓ 448 ↓	^{250}Cf ^{252}Cf	42.7 ↓ 45.7 ↓	16.0 16.7	Distribution of nucleons

***Arrows represent the increasing trend of values.**

References:

1. L Grodzins Phys Lett 2, 88 (1962)
2. J B Gupta : Symp Nucl Phys 59, 58 (2014)
3. P. Von Brentano, N. V. Zamfir, R. F. Casten, W. G. Rellergert and E. A. McCutchan; Phys. Rev. C 69, 044314 (2004).
4. D Bonatsos et al; Phys Rev C 88, 054309 (2013)
5. A K Varshney et al; Symp on Recent trends in Nucl. Phys.; (2015) held at AMU, Aligarh India.

Acknowledgement:

One of the authors namely M. Singh is thankful to the Chairman and Director GNIOT, Gr. Noida, for their kind co-operation and providing working facilities.