Two-particle configuration states in the odd-odd nucleus ^{156}Pm

M. Sainath[1,2],* B. Singh[3], and P.C. Sood[1]
[1]*Department of Physics, Sri Sathya Sai University, Prasanthinilayam (A.P)- 515134, INDIA.*
[2]*Department of Physics, Methodist College of Engineering & Technology, Abids, Hyderabad – 500001, INDIA.*
[3]*Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, CANADA*
* *email: msainath@stanley.edu.in, sai1968@gmail.com*

The latest Nuclear Data Sheets (NDS) for A = 156 [1] lists only one level with $t_{1/2}$ = 26.7s and a possible $I^{\pi} = 4^{-}$, but with unidentified energy and unacceptable two-quaisparticle (2qp) configuration for the odd-odd nucleus ^{156}Pm (Z=61). This critical evaluation [1] was based on the ^{156}Pm $\rightarrow$ ^{156}Sm decay study by Hellstrom et.al. [2] who had concluded I_{gs} (^{156}Pm) to be at least four units. Further, consideration of the deduced assignments for ^{156}Sm levels in their study [2] suggests 4^- (p_1,n_0), vide our notation in table 1, as ^{156}Pm ground state (gs) configuration. However this assignment, requiring a lower lying 1^- GM triplet state, was found unacceptable by NDS evaluators [1] who mentioned that only available 2qp configuration making 4^- as gs would involve p_0 coupling to a (much higher lying) 3/2[651] n-orbital. A recent study of ^{156}Nd decay [3] listed 30 low-energy (upto 320 keV) gammas, while placing only 3 of them in a proposed 4-level ^{156}Pm level scheme. More importantly, the authors firmly established a low-spin isomer connected to the 26.7s gs by an 150.3 keV M3 transition and characterized these two interconnected levels as (4^-,1^-) GM pair with NDS preferred alternative 2qp configuration. We have evaluated level energies for low-lying 2qp structures in ^{156}Pm using the well-tested two-particle-rotor-model [4] which explicitly includes residual n-p interaction contribution. Using these results as guidelines taken together with the experimental gamma energies [3] as inputs, we construct a 14-level ^{156}Pm level scheme with E_x upto 450 keV and $I \leq 2$, consistent with presently known information as described below.

A simple phenomenological model [4] is employed to evaluate the low-lying bandhead energies in ^{156}Pm. With the aim of constructing a decay scheme to fit the experimentally observed gammas [3], we limit the consideration of the neutron and proton single particle states to only those with $E_p + E_n \cong 500$ keV only. The model used a simple formula given by:

$$E(K:\Omega_p,\Omega_n) = E_K^0 + E_p(\Omega_p) + E_n(\Omega_n) + E_{(rot)} - \left(\frac{1}{2} - \delta_{(\Sigma,0)}\right)\Delta E_{GM} + \delta_{K,0}(-)^I E_N \quad ...(1)$$

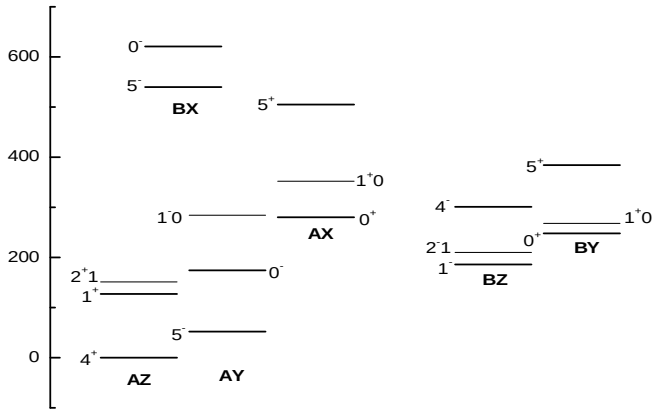
The input for the single particle energies in Eqn. (1) are taken from the respective neighbouring odd-particle nuclei which are ^{157}Sm (N=95) and ^{155}Pm (Z=61). The relevant data is presented in Table 1 below.

Using the data in Table 1 as input in our model, we evaluate the low-lying bandhead energies. The results are presented in Figure 1. Our analysis yields 4^+ (p_o,n_0) as the only acceptable assignment for the ^{156}Pm gs, with its 1^+ GM singlet member identified with the 150.3 keV isomer. The 4^- (p_1,n_0) gs configuration is ruled out following GM rule since now the low-spin isomer has been identified as lying higher. The alternate NDS suggested configuration for 4^- is unacceptable since 3/2[651] n-orbital is experimentally seen to lie at $E_x \geq 600$ keV in all the N = 95 isotones.

Table 1: Expected low-lying 2qp bands in ^{156}Pm arising from single particle orbitals with (E_p + E_n) $\cong$ 500 keV. The GM splitting energy for each doublet is from ^{156}Eu and in ^{158}Tb, if data is not available in the former.

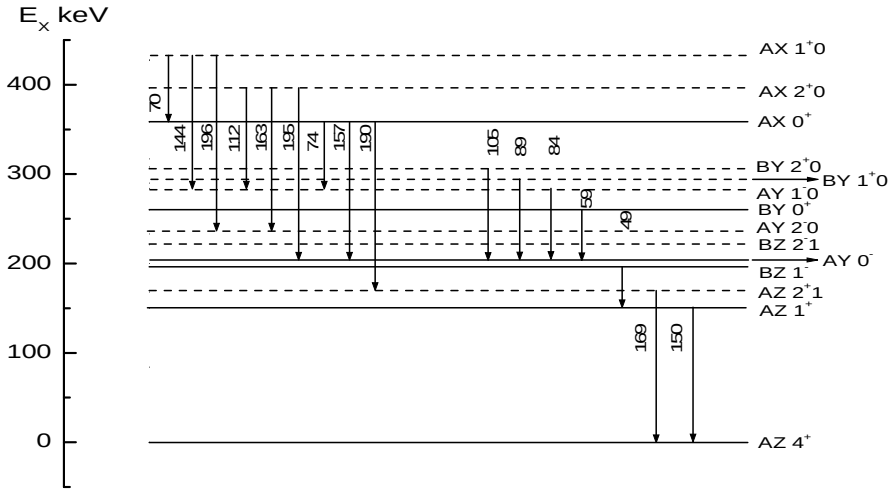
$n_j \rightarrow$ $p_j \downarrow$	n_0 = 0 3/2[521] **Z**	n_1 = 160 $5/2^+$[642] **Y**	n_3 = 350 $5/2^+$[523] **X**
p_0 = 0 $5/2^-$[532] **A**	4+ 1+ E_{GM}=145	5- 0- E_{GM}=201 E_N=-49	0+ 5+ E_{GM}=165 E_N=-30
p_1 = 180 $5/2^+$[413] **B**	1- 4- E_{GM}=97	0+ 5+ E_{GM}=102 E_N=-4	5- 0- E_{GM}=125 E_N=-14

Figure 1: Expected low-lying energy bands in ^{156}Pm.



In the recent experiments of Shibata et.al. [3] "many gamma rays following decay of ^{156}Nd were newly observed upto 1.5 MeV" whereas they have explicitly listed in their table 1 only 30 gammas in low energy region ($E_g \leq 325$ keV only). Further there is no coincidence data reported so far. Our proposed level scheme in Fig.2 includes 14 energy levels with specified spin-parities and two-particle configurations, wherein 16 observed gammas are placed. Further refinement and confirmation of this level scheme shall await more precise and detailed data, particularly from coincidence studies.

Figure 2: Proposed level scheme for ^{156}Pm based on the data in Fig.2 incorporating the isomers and gammas recently observed in ^{156}Nd beta decay studies [3].



References

[1] C.W. Reich; *Nuclear Data Sheets* **99** (2003) 753.

[2] M. Hellstrom et.al.; Phys. Rev. **C41** (1990) 2325.

[3] M. Shibata et.al.; *Eur. Phys. J.* **A31** (2007) 171.

[4] P.C. Sood, D.M. Headly, R.K. Sheline & R.W. Hoff; *At. Data & Nucl. Data Tables* **58** (1994) 107.