Parity Assignments based on β-decay log ft values

R. Gowrishankar* and P. C. Sood
Department of Physics, Sri Sathya Sai Institute of Higher Learning, Prasanthi Nilayam,(A.P.) 515134
** email: rgowrishankar@sssihl.edu.in*

While enumerating the 'Bases for spin & parity J^{π} assignments' in the Policy document of Nuclear Data Sheets (NDS), the following condition is listed [1] as the **'STRONG'** argument in β-transitions:

If log ft <5.9, the transition is allowed:
ΔJ=0 or 1, Δπ=no (no change in parity)

This 'strong rule' with a sharp lower limit of log ft~5.9 for parity-changing first-forbidden (1f) β-transitions (ΔJ=0 or 1, Δπ=yes) is widely invoked by experimentalists for parity assignments. For instance, while analysing ^{156}Pm β-decay data, Hellstrom *et al.* [2] ruled out positive parity for the parent state 'since 1515 keV $J^{\pi} = 5^-$ level is populated with log ft as low as 6.0'. We have undertaken a critical examination of available data [3] on log ft values across the periodic table to assess the applicability of this rule.

To start with, we examined the 1997 global compilation of log ft values by Singh *et al.* [4], to find that the data therein included over 40 cases of 1f transitions having log ft ≤ 5.9 in violation of the above strong rule.

Next an exhaustive survey was undertaken of log ft values for both the allowed and 1f transitions in heavy (A>228) region. Our survey [5] yielded 252 cases for allowed (Δπ=no) and 264 cases for 1f (Δπ=yes) transitions, as compared to 36 (Δπ=no) and 32 (Δπ=yes) cases listed in earlier [4] compilation. Detailed side-by-side examination (including histogram representation) of these data surprisingly revealed very similar distribution (almost identical mean and also standard deviation) of log ft values for both parity-nonchanging and parity-changing transitions. This analysis led us to conclude that log ft value, by itself, cannot be used to deduce parity, at least in actinide region.

Turning our attention to medium-weight nuclei, we find [6] that the 1997 compilation [4] includes as many as 14 cases, just in the limited 146≤A≤157 mass range, with confirmed Δπ=yes, having log ft ≤ 5.9, in violation of above mentioned strong rule. Our analysis [7] of ^{154}Pm decay data provides a striking instance of such violation. β-decay of ^{154}Pm(2.68m) [8] populates 11 levels in ^{154}Sm; 68% of β-intensity populates a 987 keV $J^{\pi}=3^-$ level with log ft=5.3 while each of the other 10 β-branches has log ft≥6.2. However, even though 'strong rule' mandates negative parity for the parent ^{154}Pm isomer, NDS evaluators [8] have not even tentatively considered such an assignment.

In a footnote to this rule, NDS [1] adds that *'in the mass region around Z=82, the upper limit of 5.9 could be 5.1'*. In an attempt to assess the extent of this exceptional region, we have compiled an exhaustive list, given in our table 1, of all β-transitions with log ft ≤ 5.9 having a Pb (Z=82) isotope as a parent or daughter state. We briefly comment on a few features thereof. In this discussion, we denote first forbidden β-transitions with log ft>5.9 as 1f; those with log ft=5.6(3) as 1f(fast), and the ones with log ft=5.2(1) as 1f(very fast).

All the 15 transitions in Table 1[A] linking highly n-deficient (N≤118) Pb to Tl isotopes fall in the category of 1f(fast) with log ft very similar to those observed in decays of deformed nuclei. Based on the experimental J^{π} of constituent odd-A isotopes, we identify the underlying transformation as $(s_{1/2})_{\pi} \rightarrow (p_{3/2})_{\nu}$ in all cases.

Barring A=208, the other 3 transitions in Table 1[B] can be categorized as 1f(very fast); the underlying transformation in these cases corresponds to $(p_{1/2})_{\nu} \rightarrow (s_{1/2})_{\pi}$. In the case of A=208 decay, parent ^{208}Tl(5^+) configuration is $[(s_{1/2})_{\pi}\ (g_{9/2})_{\nu}]$ while the daughter states in ^{208}Pb states have mixed $[(p_{1/2})_{\nu}\ (g_{9/2})_{\nu}]$, $[(s_{1/2})_{\pi}\ (h_{9/2})_{\pi}]$ and a few other configurations. Thus here we have both $(p_{1/2})_{\nu} \rightarrow (s_{1/2})_{\pi}$ and $(g_{9/2})_{\nu} \rightarrow (h_{9/2})_{\pi}$ transformation components.

All the 9 transitions for A>209 nuclei in Table 1[C] correspond to across-the-shells

Table 1: Experimental data on first-forbidden (1f) β-branches having log ft ≤ 5.9 in $\beta^{\pm}$/EC decays having a Pb (Z=82) isotope as either a parent or a daughter. Spin-parity J^{π} for all e-e parents is 0^+; for odd-A and odd-odd parents, J^{π} is as follows. ^{197}Pb($3/2^+$), ^{209,211,213}Pb($9/2^+$), ^{207,209}Tl($1/2^+$), ^{206}Tl(0^-) and ^{208}Tl(5^+). The listed data are from July 2013 version of ENSDF/XUNDL[3].

$^{A}_{Z}X_{N}$	E_x(keV)	J^{π}	log ft
[A] $^{A}_{82}Pb_{N}$ **ε/β⁺** → $^{A}_{81}Tl_{N+1}$			
$^{190}_{81}Tl_{109}$	376	(1)-	5.8
	598	(1)-	>5.4
$^{192}_{81}Tl_{111}$	168	1(-)	5.7
	776	(0-,1-)	5.3
$^{194}_{81}Tl_{113}$	786	(1)-	5.4
	1188	(0,1)-	5.9
$^{196}_{81}Tl_{115}$	755	(1-)	5.6
$^{197}_{81}Tl_{116}$	1647	3/2+,5/2+	5.7
	1675	3/2+,5/2+	5.7
	1854	(3/2+,5/2+)	5.7
	2346	(3/2+,5/2+)	5.5
$^{198}_{81}Tl_{117}$	656	0-,1-	5.8
	865	1-	5.8
	1141	0-,1-,2-	5.9
$^{200}_{81}Tl_{119}$	526	1-	5.9

$^{A}_{Z}X_{N}$	E_x(keV)	J^{π}	log ft
[B] $^{A}_{81}Tl_{N}$ **β⁻** → $^{A}_{82}Pb_{N-1}$			
$^{206}_{82}Pb_{124}$	0	0+	5.2
$^{207}_{82}Pb_{125}$	0	1/2-	5.1
$^{209}_{82}Pb_{127}$	2149	1/2-	5.2
$^{208}_{82}Pb_{126}$	3198	5-	5.6
	3475	4-	5.7
	3708	5-	5.4
[C] $^{A}_{82}Pb_{N}$ **β⁻** → $^{A}_{83}Bi_{N-1}$			
$^{209}_{83}Bi_{126}$	0	9/2-	5.5
$^{211}_{83}Bi_{128}$	832	9/2-	5.7
	1109	9/2-	5.6
$^{213}_{83}Bi_{130}$	978	(9/2-)	5.6
$^{210}_{83}Bi_{127}$	47	0-	5.4
$^{212}_{83}Bi_{129}$	239	0(-)	5.2
	415	1(-)	5.3
$^{214}_{83}Bi_{131}$	295	1-	5.2
	352	0-,1-	5.1

$(g_{9/2})_{\nu} \rightarrow (h_{9/2})_{\pi}$ transformation. However, as seen in Table 1[C], the odd-mass decays belong to 1f(fast) category, while the even-mass decays fall within 1f(very fast) domain. Further, in even-A decays, the 0^+ to 1^-_{gs} (and also the ^{211,213}Pb($9/2^+$) to ^{211,213}Bi($9/2^-$g.s)) decays have log ft >6.3, while those with 0^+ to 0^- and 0^+ to first excited 1^- transitions have log ft=5.2(1). These, and other similar, distinctive features are being critically examined.

Extensive evidence gathered to date leads us to the conclusion that *'β-decay log ft value, by itself, cannot yield firm parity assignments. Certainly a sharp cut-off at log ft=5.9 for parity changing β-transitions is inadmissible'*.

References

[1] "Summary of bases for J^{π} Assignments", **NDS 114** (2013) p. iv.

[2] M. Hellström *et al.*, Phys. Rev. **C41** (1990) 2325.

[3] ENSDF & XUNDL: continuously updated data files at NNDC/BNL (July 2013 version).

[4] B. Singh *et al.*, **NDS 84** (1998) 487.

[5] P. C. Sood *et al.*, Phys. Rev. **C69** (2004) 057303.

[6] P. C. Sood *et al.*, Phys. Rev. **C83** (2011) 027303.

[7] P.C. Sood *et al.*, J. Phy. **G39** (2012) 095107

[8] C. W. Reich, **NDS 110** (2009) 2057.