Parity Assignments based on β-decay log ft values

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While enumerating the ‘Bases for spin & parity J’ 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:
\[ \Delta J=0 \text{ or } 1, \Delta \pi=\text{no} (\text{no change in parity}) \]

This ‘strong rule’ with a sharp lower limit of log ft=5.9 for parity-changing first-forbidden (1f) β-transitions (\(\Delta J=0 \text{ or } 1, \Delta \pi=\text{yes}\)) is widely invoked by experimentalists for parity assignments. For instance, while analysing \(^{150}\)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 (\(\Delta \pi=\text{no}\)) and 264 cases for 1f (\(\Delta \pi=\text{yes}\)) transitions, as compared to 36 (\(\Delta \pi=\text{no}\)) and 32 (\(\Delta \pi=\text{yes}\)) 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 \(\Delta \pi=\text{yes}\), having log ft ≤ 5.9, in violation of above mentioned strong rule. Our analysis [7] of \(^{150}\)Pm decay data provides a striking instance of such violation. β-decay of \(^{150}\)Pm(2.68m) [8] populates 11 levels in \(^{150}\)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 \(^{150}\)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 \(J^\pi\) of constituent odd-A isotopes, we identify the underlying transformation as \((s_{31/2})_h \rightarrow (p_{3/2})_l\), 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 \((p_{11/2})_h \rightarrow (s_{11/2})_l\). In the case of A=208 decay, parent \(^{208}\)Tl(5\(^+\)) configuration is \([s_{3/2}]_h (g_{9/2})_l\) while the daughter states in \(^{208}\)Pb states have mixed \([p_{11/2}]_l (g_{9/2})_l\), \([s_{11/2}]_h (h_{9/2})_l\) and a few other configurations. Thus here we have both \((p_{11/2})_h \rightarrow (s_{11/2})_l\) and \((g_{9/2})_h \rightarrow (h_{9/2})_l\) 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 β±/EC decays having a Pb (Z=82) isotope as either a parent or a daughter. Spin-parity Jπ for all e-e parents is 0+; for odd-A and odd-odd parents, Jπ is as follows. 197Pb(3/2+), 206,211,213Pb(9/2+), 207,209Ti(1/2+), 206Ti(0) and 208Ti(5/2). The listed data are from July 2013 version of ENSDF/XUNDL[3].

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<th>Jπ</th>
<th>log ft</th>
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<td>82PbN</td>
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<tr>
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<td>109</td>
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<td>1(-)</td>
</tr>
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<td>119</td>
<td>526</td>
<td>1-</td>
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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