Features of radioactive series originating from superheavy nuclei

*K.Vijay Sai, B. Shankaranand, R. Gowrishankar and P. C. Sood

Department of Physics, Sri Sathya Sai Institute of Higher Learning, Prasanthinilayam - 515134, A.P., INDIA

* email: kvijaysai@sssihl.edu.in

In an earlier report [1] we had discussed the extension of the naturally occurring radioactive series up to heavier actinides. Widening the scope of these investigations, we now consider radioactive series originating from the superheavy (SHE) region which connect all the way down to stable Pb–Bi nuclei. As an illustration, we list in Table 1 the parent nucleus ${}^{A}_{Z}X$, its half-life $t_{1/2}$ and Q_α value [2] in the main sequence for each of the series with A corresponding to 4n, (4n+1), (4n+2) and (4n+3) respectively; herein only the dominant α or β/ε branch is shown, with the isobaric β/ε decaying nuclides underlined. Some significant features of our analysis are outlined in the following.

Sood *et al*. [3] had recently brought into focus the unusual longevity of odd-N transplutonium nuclei relative to their even-even (e-e) neighbours. This feature is found to be more pronounced in the transactinide region. For instance, the longest-lived α-decaying nuclide in the 107≤Z≤118 region is the odd-A, odd-N ${}^{285}_{112}Cn$ ($t_{1/2}$ ~ 34 s) [4]. The only e-e nucleus with $t_{1/2}$ >1 sec in this region is the doubly magic deformed nucleus ${}^{270}_{108}Hs$ (3.8 s); for all other e-e nuclei $t_{1/2}$ is in ms range. This may be understood by noting [5,6] that all nuclides beyond Z > 106 solely exist due to shell stabilization effect arising, in present case, from the double deformed shell closure at Z=108 & N=162.

Another feature, which again is more pronounced in SHE, is the occurrence of relatively much longer collateral series. For instance, we have a collateral (4n+1) series originating from ${}^{269}_{110}Ds$, running parallel to the main series listed in Table 1, till merging with it at ${}^{249}_{98}Cf$, with no mid-way interconnections. This may be due to the absence of β/ε decay branches in the SHE region.

A unique feature of these series in the SHE region is the absence of any long chain involving e-e nuclei. Both the 4n and the (4n+2) even mass series in Table 1 are seen to have only odd-odd members in the transfermium (Z > 100) region, below which the series has primarily e-e constituents. This may arise from the fact that e-e nuclei in SHE region are more liable to undergo SF in competition with other decay modes.

Another unique feature witnessed herein is that, only even-Z members appear in both the (4n+1) and (4n+3) series in Table 1 in the Z>100 domain. Absence of odd-Z odd-A chains may be understood by noting that all these superheavy nuclei, synthesized in 'cold fusion' reactions [5], are neutron deficient; odd-Z species would lie still farther from β-stability domain.

Hot fusion reactions [6,7] have so far identified 45 new nuclides with Z=104-118 and A=266-294. Herein all heavier SHE species undergo sequential α (≤6) decays terminating at Z≥104 SF nuclide. The 'stand-alone' miniseries have essentially the same features as outlined above. For instance all even-A series have only odd-odd members and odd-A series predominantly include even-Z members.

Detailed analyses of these and other similar features of SHE region are being pursued.

References:

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Table 1: The $t_{1/2}$ and Q_α values [2] of α- decaying nuclei in the specified Radioactive series. The underlined nuclei correspond to β- / ε- decaying parents.

4n + 3	**$t_{½}$ Q_α(MeV)**	**4n**	**$t_{½}$ Q_α(MeV)**	**4n + 1**	**$t_{½}$ Q_α(MeV)**	**4n + 2**	**$t_{½}$ Q_α(MeV)**
-	-	-	-	**$^{277}_{112}$Cn**	0.69 ms 11.62	**$^{278}_{113}$**	0.24 ms 11.85
$^{271}_{110}$Ds	1.63 ms 10.9	**$^{272}_{111}$Rg**	3.8 ms 11.44	$^{273}_{110}$Ds	0.17 ms 11.37	$^{274}_{111}$Rg	6.4 ms 11.6
$^{267}_{108}$Hs	52 ms 10.1	$^{268}_{109}$Mt	21 ms 10.73	$^{269}_{108}$Hs	9.7 s 9.63	$^{270}_{109}$Mt	5 ms 10.4
$^{263}_{106}$Sg	1 s 9.39	$^{264}_{107}$Bh	0.44 s 9.97	$^{265}_{106}$Sg	8 s 9.08	$^{266}_{107}$Bh	1.7 s 9.55
$^{259}_{104}$Rf	3.2 s 9.12	$^{260}_{105}$Db	1.52 s 9.38	$^{261}_{104}$Rf	65 s 8.65	$^{262}_{105}$Db	35 s 9.01
$^{255}_{102}$No	3.1 m 8.44	$^{256}_{103}$Lr	27 s 8.82	$^{257}_{102}$No	25 s 8.47	$^{258}_{103}$Lr	4.1 s 8.90
251Fm-251Es $^{251}_{98}$Cf	898 y 6.18	252Md $^{252}_{100}$Fm	25.39 h 7.15	253Fm $^{253}_{99}$Es	20.47 d 6.74	254Md $^{254}_{100}$Fm	3.24 h 7.31
$^{247}_{96}$Cm	1.5 x10^7y 5.35	$^{248}_{98}$Cf	333.5 d 6.36	249Bk $^{249}_{98}$Cf	351 y 6.30	$^{250}_{98}$Cf	13.08 y 6.13
243Pu $^{243}_{95}$Am	7370 y 5.44	$^{244}_{96}$Cm	18.1 y 5.90	$^{245}_{96}$Cm	8500 y 5.62	$^{246}_{96}$Cm	4760 y 5.48
239Np $^{239}_{94}$Pu	24110 y 5.24	$^{240}_{94}$Pu	6561 y 5.26	241Pu $^{241}_{95}$Am	432.6 y 5.64	$^{242}_{94}$Pu	3.7x10^5 y 4.98
$^{235}_{92}$U	7.0 x10^8y 4.68	$^{236}_{92}$U	2.3 x10^7y 4.57	**$^{237}_{93}$Np**	2.1 x10^6y 4.96	**$^{238}_{92}$U**	4.5 x10^9y 4.27
231Th $^{231}_{91}$Pa	3.28x10^4y 5.15	**$^{232}_{90}$Th**	1.4x10^{10}y 4.082	233Pa $^{233}_{92}$U	1.59x10^5y 4.91	234Th - 234Pa $^{234}_{92}$U	2.45x10^5y 4.86
227Ac $^{227}_{90}$Th	18.68 d 6.15	228Ra 228Ac $^{228}_{90}$Th	1.912 y 5.52	$^{229}_{90}$Th	7880 y 5.17	$^{230}_{90}$Th	7.54x10^4y 4.77
$^{223}_{88}$Ra	11.43 d 5.98	$^{224}_{88}$Ra	3.632 d 5.79	225Ra $^{225}_{89}$Ac	10 d 5.94	$^{226}_{88}$Ra	1600 y 4.87
$^{219}_{86}$Rn	3.96 s 6.95	$^{220}_{86}$Rn	55.6 s 6.40	$^{221}_{87}$Fr	4.9 m 6.46	$^{222}_{86}$Rn	3.82 d 5.59
$^{215}_{84}$Po	1.78 ms 7.53	$^{216}_{84}$Po	0.145 s 6.91	$^{217}_{85}$At	32.3 ms 7.2	$^{218}_{84}$Po	3.09 m 6.14
211Pb $^{211}_{83}$Bi	2.14 m 6.75	212Pb 212Bi $^{212}_{84}$Po	0.29 µs 8.95	213Bi $^{213}_{84}$Po	3.72 µs 8.54	214Pb - 214Bi $^{214}_{84}$Po	164.3 µs 7.83
207Tl **$^{207}_{82}$Pb**	**Stable**	**$^{208}_{82}$Pb**	**Stable**	209Pb **$^{209}_{83}$Bi**	**Stable**	210Pb - 210Bi $^{210}_{84}$Po **$^{206}_{82}$Pb**	138.4 d 5.41 **Stable**