Landmark role of Z =101/100 nuclides in the transuranic region

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None of the transuranic (Z>92) species occur in nature; they are all produced in the laboratory through nuclear reactions. However, while the 93≤Z≤101 nuclides can be reached in α (or lighter) particle induced reactions, exploration of the still higher Z domain is a highly challenging, albeit competitive, task.

Considering this fact, International Union of Pure and Applied Chemistry (IUPAC) and that of Physics (IUPAP) had constituted [1] a joint Transfermium Working Group (TWG) for authentication of discovery of Z>100 elements. A factual summary of experiments on the first identification, and the ones confirming the same, for each nuclide in the Z>100 isotopic sequences has since been presented by Thoennssen [2]. Exhaustive information across all nuclear regions is available in various nuclear data bases [3-5]. Spurred by findings in some of our recent reports [6,7], herein we examine the occurrence of a LANDMARK around Z=100/101 in the vast nuclear landscape. To start this exercise, we first look at some basic properties and processes.

A survey [3-5] of the half-lives ($t_{1/2}$) of Z>92 nuclides reveals that such data for the Longest-Lived Isotope (LLI) in each sequence fall in 3 zones: for Z<100 species, LLI is in years, for Z=100/101, it is 100/51 days and for Z>101, it progressively appears in h/s/ms. This observation clearly indicates a landmark at Z=100/101 along this trajectory.

Another evidence for such an occurrence is provided by consideration of their production procedures. It is seen that while the Z≤101 species are produced in 'stepping' process wherein n/d/α incident on a newly synthesized high Z material produces the next high Z species, the Z>101 species need Heavy-Ion accelerators for their production.

Next we turn our attention to the higher end of the periodic table. In our 2011 report [6], we had traced the trajectory starting from each of the 4 Naturally Occurring Radioactive Series (NORS) across the Z=100/101 domain right upto Z=113 isotopes synthesized in Cold Fusion (CF).

Our recent (2017) study of ^{254}Md level structures [7] provides evidence for a landmark role of Z=101/100 [^{254}Md (ε) ^{254}Fm] locale in the decay path of (4n+2) SHE, as shown in Fig. 1.

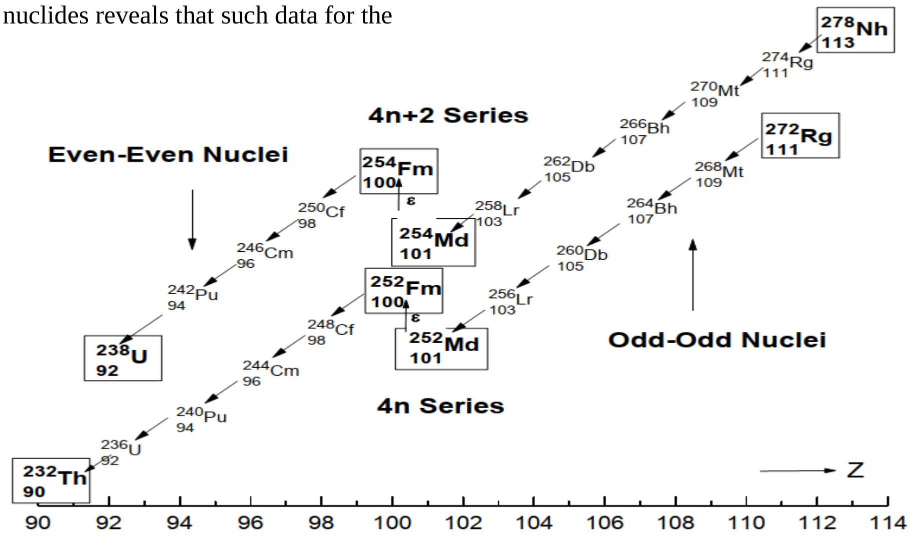

Fig. 1: Sequential α-decays from SHE to NORS Head with marked discontinuities at Md (ε) Fm for (4n) & (4n+2) series.

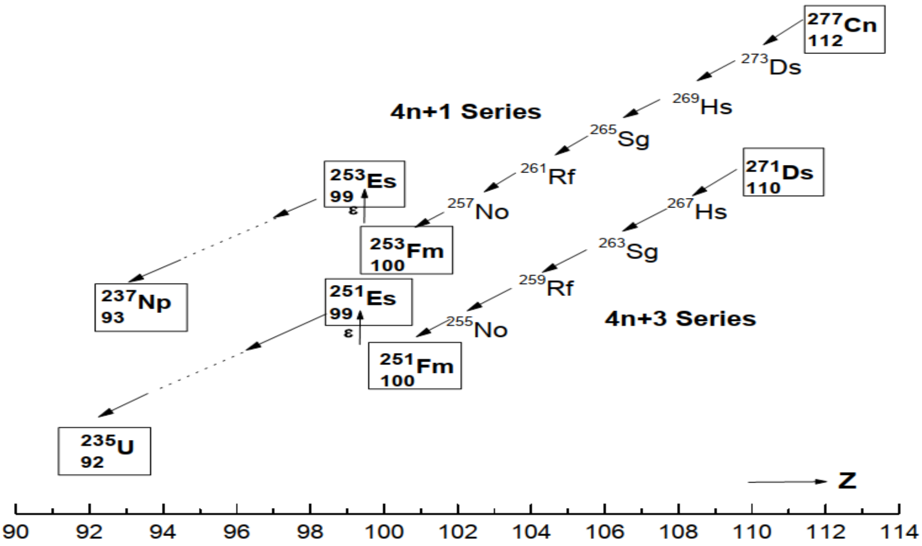

Fig. 2: Sequential α-decays from SHE to NORS Head with marked discontinuities at Md (ε) Fm for 4n+1 and 4n+3 series

In the analysis therein [7], we expressedly took note of the fact that decay of each CF–produced SHE proceeds via a genetically correlated sequential α–chain. This process is depicted in the ^{278}Nh (6α) ^{254}Md segment in our plot of Fig. 1. This plot, further on, shows an α-discontinuity at the ^{254}Md (ε) ^{254}Fm transition point, and then proceeds via ^{254}Fm (4α) ^{238}U to the sequential ^{238}U → ^{208}Pb (4n+2) NORS. The Landmark feature at Z=101/100 across the transuranic region is thus unmistakably established through the following process:

^{278}Nh (6α) ^{254}Md (ε) ^{254}Fm (4α) ^{238}U

Another new feature, highlighting the Landmark at Z=100/101, brought out in our earlier study [7] was that all the Z≥101 nuclides in this chain are odd-odd whereas all the Z<101 nuclides are even-even.

The third distinctive feature from SHE decay is that α and SF are dominant decay modes for all Z>101 nuclei, whereas SF is usually minor/insignificant decay channel for Z≤101 members thereof. It is of interest to add that, a collateral decay path of another 4n+2 SHE can be traced as ^{266}Mt (4α) ^{250}Md (ε) ^{250}Fm, again with a discontinuity at Z=101/100.

Results from similar analysis for each of the 4n, 4n+1 and 4n+3 SHE decay chain, are plotted in Fig.s 1 & 2. The decay chain for 4n SHE, as shown in Fig. 1 corresponding to

^{272}Rg (5α) ^{252}Md (ε) ^{252}Fm (5α) ^{232}Th

replicates all the above discussed three features of 4n+2 chain, and thus confirms the Landmark role for the Z=101/100 in the 4n series as well.

The odd-A (4n+1) and (4n+3) SHE, namely ^{277}Cn and ^{271}Ds respectively, decay chains shown in Fig. 2 again clearly depict the discontinuity at Z=100. This feature results from the fact that CF produces only n-deficient SHE and the odd-A nuclides are predominantly even Z / odd N assemblies, and hence the sequential 6/5 α-decays terminate at an ε-decaying Z=100 isotope.

In summary, our analysis identifies five observed factors namely $t_{1/2}$, production process, SHE α-chains terminations, odd-odd/ even-even transitions, and % SF branching. These factors, individually and collectively, establish the Landmark role for the respective Z=101/100 isotope in the transuranic domain.

References

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