Unified description of Q values and half lives of α-decay for A = 152 – 181

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Introduction

The success of the microscopic α-daughter nucleus potential providing the unified description of both Q values and half lives of the α-decay chains of super-heavy elements (SHE) based on the WKB and S-matrix methods, prompted us to extend the analysis to the nuclei in the rare earth regions with A=152-181. The microscopic α-nucleus potential is generated in the double folding model (tρρ - approximation) using relativistic mean field (RMF) densities along with density dependent M3Y nucleon- nucleon interaction. This potential is then used in the WKB approximation to calculate both the Q values and decay half-lives. Here we report the WKB results both Q values and half lives for the nuclei with A=152 - 181.

Calculations, Results and Discussions

The total effective α -nucleus potential $U_{eff}(l,r)$ governing the WKB method is a sum of alpha-nucleus nuclear potential, α-nucleus electrostatic potential $U_c(r)$ and the kinematical centrifugal term $U_{cf}(r) = (l+1/2)^2/r^2$

$U_{eff}(l,r) = U_n(r) + U_c(r) + U_{cf}(r)$ (1)

The Q value is calculated using the WKB formula for eigenenergy given by

$$\int_{r_1}^{r_2} \left[k^2 - U_{eff}(l,r)\right]^{1/2} dr = \left(n + \frac{1}{2}\right)\pi$$

At decay energy Q this potential has three turning points r1<r2<r3. The range $r_1<r<r_2$ governs the generation of WKB quasi-bound state eigenvalue Q and the domain $r_2<r<r_3$ defines the barrier the tunneling alpha particle experiences. With the Q value so obtained, one uses the following WKB formula for the half width:

$$\Gamma_{1/2} = PA_f(kR)\exp\left[-2\int_{r_2}^{r_3}\left(U_{eff}(l,r) - E_R\right)^{1/2} dr\right]$$

Here P is the pre formation factor assumed to be unity and A_f is the assault frequency factor and

$$E_R = k_R^2 = (\mathrm{Re}(k_R))^2 - (\mathrm{Im}(k_R))^2$$

Using the doubly folded RMF based alpha-nucleus potentials we have calculated Q and $T_{1/2}$ for a set of nuclei in the mass range A=150-181. The Coulomb radius parameter r_c =1.2 f is used.

We found that in order to get reasonable fits RMF generated potentials need to be fine tuned (marginally adjusted) by multiplying an overall factor f. The value of f varies between 0.91 – 0.94 (close to unity) as shown in Fig. 1.

The calculated Q-values and half lives shown in Figures 2 and 3 respectively closely agree with the experiment.

References

[1] P. Prema, S. Mahadevan, C. S. Shastry, A. Bhagawat and Y. K. Gambhir, International Journal of Modrn Physics E, **17**, 611, 2008 and references cited therein.

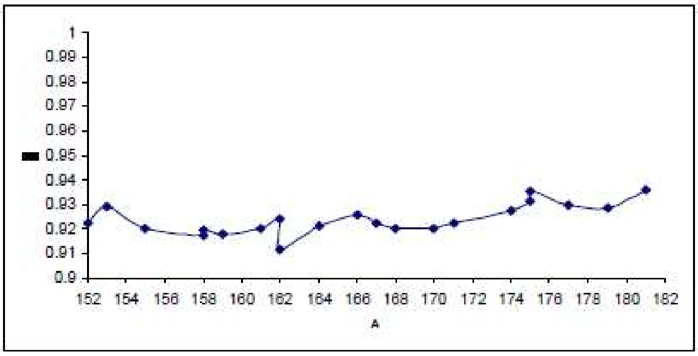

Fig 1: Variation of the norm factor *f* with Mass number of nuclide

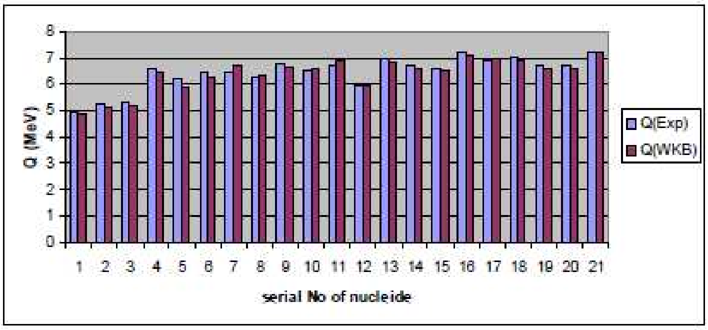

Fig 2: Variation of calculated Q-value (WKB) with Experimental Q-value for nuclides with A = 152 to A= 181 (see legend).

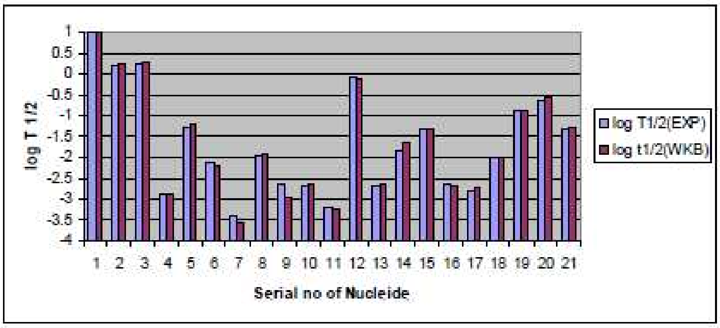

Fig 3: Variation of calculated log T 1/2(WKB) with Experimental log T1/2 for nuclides with A = 152 to A=- 181 (see legend).

Legend

Sl No	A	Z
1	152	68
2	153	69
3	155	70
4	158	74
5	158	73
6	159	74
7	161	75
8	162	75
9	162	76
10	164	76
11	166	77
12	167	76
13	168	78
14	170	78
15	171	78
16	174	80
17	175	79
18	175	80
19	177	80
20	179	81
21	181	82

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