Calculation of Q values and Half lives of α-decay for A = 152-181 using S-Matrix method

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Introduction

The success in the description of half lives and Q-values of Super heavy elements (SHE) using the microscopic alpha daughter nucleus potential and S-Matrix method (SM) [1] prompted us to extend the analysis to the nuclei in the rare earth regions with A=152-181. We have reported in 2010 [2], the results of the half lives and Q-values for the nuclei A=152-181 using WKB method. In this paper we report the results obtained using the more accurate S-Matrix method. The microscopic alpha nucleus potential is generated in the double folding model (tρρ-approximation) using relativistic mean field (RMF) densities along with density dependent M3Ynucleon-nucleon interaction. This potential is then used in the SM method to calculate both Q-values and decay half lives.

Calculations, Results and Discussions

In the S-Matrix approach one starts with time independent Schrodinger wave equation. Since the α-decay is likely to occur when the daughter nucleus and α-system are in s (l = 0) state, we confine our discussion to '*s*' state. Its generalization to higher partial waves, if needed, is fairly straight forward. For s(l = 0) state the equation reads

$$\frac{d^2u}{dr^2} + (k^2 - V(r))u = 0$$

k^2 and V (r) denote energy and well behaved short range potential, respectively.

Let $k_p = k_r - ik_i$, with k_r > k_i > 0 denote a resonance pole position. Then one can write

$$k_p^2 = k_r^2 - k_i^2 - 2ik_r k_i = \frac{2\mu}{\hbar^2}(E_R - i\frac{\Gamma_R}{2})$$

Here, E_R denotes the resonance energy and in the α-decay problem it signifies the Q-value, Γ_R is the width, which is related mean (half) life $\tau(\tau_{1/2})$ and decay constant λ¸ through the relation

$$\Gamma_R = \frac{\hbar}{\tau} = \frac{\hbar \ln 2}{\tau_{1/2}} = | 4k_r k_i | = \hbar\lambda$$

In order to get a reasonable fit, RMF generated potential needs to be fine tuned by multiplying with an overall factor 'f' which is the ratio of the actual depth of the potential 'V_o' to the adjusted value of the depth. The value of 'f' varies between 0.91 to 0.94.

Here in Table 1 [3], the SM results for both Q-values and half lives of the nuclei together with the experimental results are given. We have used the coulomb radius parameter r_c=1.2 fm.

Table 1

Sl.No	A	Z	Q(ex)(MeV)	Q(SM)(MeV)	$T_{1/2}$(exp)	$T_{1/2}$(SM)
1	153	69	5.248	5.841	0.48s	0.023s
2	155	70	5.337	5.852	1.739s	0.062s
3	158	74	6.613	6.816	1.25ms	1.22ms
4	158	73	6.208	6.262	55ms	41.13ms
5	159	74	6.443	6.795	7.3ms	1.33ms
6	161	75	6.439	7.095	0.37ms	0.36ms
7	162	75	6.240	6.798	10.5ms	3.3ms
8	166	77	6.724	7.262	0.62ms	0.60ms
9	167	76	5.980	6.256	0.815s	0.726s
10	168	78	6.991	7.224	2ms	2.03ms
11	170	78	6.704	6.987	13.8ms	12.4ms
12	171	78	6.610	6.816	45.5ms	45.45ms
13	174	80	7.235	7.4605	2.1ms	2.03ms
14	175	79	6.562	7.308	1.5ms	1.61ms
15	177	80	6.738	6.9053	127.3ms	126.19ms
16	181	82	7.210	7.227	45ms	51.18ms

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References

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