A simplistic approach to alpha decay of superheavy nuclides

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Introduction

In recent years, experimental physicists have reported half lives of alpha decay for superheavy elements [1][2][3]. The authors, G M Carmel Vigila Bai and J Umai Parvathiy [4], Yu Ts Oganessian and V K Utyonkov [5] have employed different forms of nuclear potential for evaluation of theoretical rates of decay. One expects the good old Gamow theory to be suitable for superheavy alpha emitters as well, with suitable selection of radius constant.

Present Work

The present work is a theoretical evaluation of half lives of newly reported alpha emitters, with a simplistic approach taking Coulomb potential for the outer region as employed by Gamow. Quantum mechanical tunneling of alpha clusters is considered as usual, but instead of solving the barrier penetration integral, the area of the barrier in one dimension is taken into account. The penetration integral involves momentum and displacement of alpha clusters. The present approach is based on the assumption that the area of the momentum and displacement curve needs to be approximately equivalent to the penetration integral, Gamow factor.

As the alpha cluster emerges out of the daughter nucleus, the momentum will be proportional to $[V(r_t) - Q]^{1/2}$ where r_t is the touching distance of daughter and alpha cluster and $V(r_t)$ is the corresponding Coulomb potential and Q is the kinetic energy of emerging alpha particle. When the alpha particle has emerged quite away from the daughter , the potential becomes zero at the distance r_a. Here $(r_a - r_t)$ is the width of the barrier. Thus,

$$\text{Penetration integral} \propto \sqrt{V(r_t) - Q}\ (r_a - r_t) \quad (1)$$

Using an approach similar to that of Gamow theory,

$$\log T_{\frac{1}{2}} \propto [V(r_t) - Q]^{1/2}\ (r_a - r_t) \quad (2)$$

By straight line fitting using the known data, it is found that

$$\log T_{\frac{1}{2}} = 0.1775 \times [V(r_t) - Q]^{1/2}\ (r_a - r_t) - 17.8 \quad (3)$$

where $T_{\frac{1}{2}}$ is the half life of alpha emission in seconds.

$$V(r_t) = \frac{2Z \times 1.44}{r_t} \quad (4)$$

where Z corresponds to that of daughter nucleus and r_t is the touching distance of daughter and alpha cluster with radius constant 1.26 fm, $V(r_t)$ being in MeV.

$$r_a = \frac{2Z \times 1.44}{Q} \quad (5)$$

Here, r_a corresponds to the outer turning point where potential is zero with Q in MeV. Equation (3) representing a straight line can be readily used for evaluation of decay rate of superheavy alpha emitters. The same equation is found to be suitable for alpha emitters in the Actinides region with a change in the value of intercept, the slope remaining the same. The intercept is different because the width of the potential well for Actinides is small compared to that of superheavy elements and hence the frequency of collision is expected to be different.

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TABLE I: Alpha decay half lives of superheavy elements.

Parent nuclei		Q(MeV)	$\log T_{1/2}$(sec)	
Z	A		Calculated	Experimental
106	271	8.67	2.0381	2.0513 [1]
107	266	9.26	0.4941	0.3926 [3]
107	272	9.15	0.7362	0.9912 [1]
109	276	9.85	-0.8512	-0.1427 [1]
110	279	9.84	-0.5041	-0.6989 [1]
112	283	9.67	0.6042	0.5797 [1]
112	285	9.29	1.8692	1.5321 [2]
113	283	10.26	-0.8213	-1.0000 [1]
113	284	10.15	-0.4924	-0.3212 [1]
114	286	10.33	-0.7072	-0.8860 [1]
114	287	10.16	-0.2533	-0.3213 [1]
114	288	10.09	-0.0379	-0.0969 [2]
114	289	9.96	0.3254	0.4313 [2]
115	287	10.74	-1.5421	-1.4922 [1]
115	288	10.61	-1.1990	-1.0604 [1]
116	291	10.89	-1.6815	-1.7447 [1]
116	292	10.80	-1.5275	-1.7447 [2]
116	293	10.67	-1.1373	-1.2757 [2]
118	294	11.81	-3.3821	-3.0506 [1]

Conclusion

The calculated half lives of superheavy alpha emitters are listed in the table and it is convincing to observe that these are in good agreement with the experimental half lives reported in[1][2][3].

References

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