A simplistic approach to ^{8}Be and ^{14}C cluster radioactivity

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Introduction

A simplistic approach to alpha decay of superheavy elements was presented recently [1].The present work is an extension of the simplistic approach to cluster emission which includes ^{8}Be and ^{14}C [2][3]. Gamow's theory which is suitable for alpha decay of super heavy elements as well as actinides, is not sufficient for cluster radioactivity because of the change in the form of potential.

Present Work

The present work is a theoretical evaluation of half lives for cluster emitters, without taking into account the different forms of potentials used by different authors[4][5][6][7][8]. Quantum mechanical tunneling of cluster is considered as usual, but instead of solving the barrier penetration integral, the area of the barrier is taken into account. The penetration integral involves momentum and displacement of cluster. 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.

As the 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 cluster, $V(r_t)$ is the corresponding Coulomb potential and Q is the kinetic energy of emerging cluster. When the cluster has emerged quite far 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,

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

By straight line fitting, it is found that

$$\log T_{\frac{1}{2}} = 0.3245\times[V(r_t)-Q]^{1/2}\ (r_a-r_t)-9.3614 \quad (3)$$

$$\log T_{\frac{1}{2}} = 0.1554\times[V(r_t)-Q]^{1/2}\ (r_a-r_t)-2.9841 \quad (4)$$

where $T_{\frac{1}{2}}$ is the half life of cluster emission in seconds. Equation (3) represents half life of ^{14}C, it has slope 0.3245 and intercept -9.3614. Equation (4) represents half life of ^{8}Be, it has slope 0.1554 and intercept -2.9841.

$$V(r_t) = \frac{Z_1 Z_2 \times 1.44}{r_t} \quad (5)$$

where Z_1 corresponds to that of cluster and Z_2 corresponds to daughter nucleus and r_t is the touching distance of daughter and cluster being emitted with radius constant 1.26 fm, $V(r_t)$ being in MeV.

$$r_a = \frac{Z_1 Z_2 \times 1.44}{Q} \quad (6)$$

Here, r_a corresponds to the outer turning point where potential is zero with Q in MeV. Equations (3) and (4) represents a straight line, can readily be used for evaluation of decay rates of cluster emitters.

Conclusion

The calculated half lives of cluster radioactive 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[2][3].

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TABLE I: Half life predictions of ^{8}Be and ^{14}C emissions from cluster radioactive nuclides.

Parent nuclei		cluster	Q(MeV)	$\log T_{1/2}(T_{1/2}$in sec)	
Z	A			Calculated	Experimental
87	221	^{14}C	31.28	14.143	14.52[2]
88	221		32.39	13.080	13.39[2]
88	222		33.05	12.030	11.01[2]
88	223		31.85	13.975	15.04[2]
88	224		30.54	16.295	15.68[2]
88	225		30.48	17.262	17.16[2]
56	112	^{8}Be	10.72	11.881	11.20[3]
56	114		7.520	22.064	23.61[3]
56	116		5.500	35.891	37.19[3]
56	118		5.350	36.912	38.23[3]
56	120		2.920	78.054	76.96[3]

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