Competition of alpha and heavy cluster in superheavy element ^{294}Og

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Introduction

The possibility of emission of alpha and cluster decay from superheavy nuclei (SHN) has become a hot topic in nuclear physics. SHN up to Z=118 has been experimentally synthesized so far using cold and hot fusion evaporation techniques and attempt to study Z=120 have been reported. Several theoretical studies are proposed to study decay modes of SHN. Newly synthesized SHN are studied by observing its modes of decay and hence has become a prime concern.

In the present work, we aim to study the possibilities of SHN ^{294}Og to emit alpha and heavier cluster using Modified Generalized Liquid drop model (MGLDM) [1] with Q value dependent preformation factor [2] and also we calculate its decay modes by comparing alpha decay half-lives with spontaneous fission half-lives proposed by Bao et al., [3]

Theory

In MGLDM, for a deformed nucleus, the macroscopic energy is defined as,

$$E = E_V + E_S + E_C + E_R + E_P \qquad (1)$$

Here the terms E_V, E_S, E_C, E_R and E_P represents the volume, surface, Coulomb, rotational and proximity energy terms respectively.

The barrier penetrability P is calculated with the action integral

$$P = \exp\left\{ -\frac{2}{\hbar} \int_{R_{in}}^{R_{out}} \sqrt{2B(r)[E(r) - E(sphere)]}\, dr \right\}$$

Where $R_{in} = R_1 + R_2, B(r) = \mu$, the reduced mass and $R_{out} = e^2 Z_1 Z_2 / Q$. R_1, R_2 are the radius of the daughter nuclei and emitted cluster respectively, Q the released energy.

The partial half-life is related to the decay constant λ by

$$T_{1/2} = \left(\frac{\ln 2}{\lambda} \right) = \left(\frac{\ln 2}{\nu P_C P} \right) \qquad (2)$$

The assault frequency ν has been taken as 10^{20} s^{-1} and the preformation factor is given as

$$P_C = 10^{aQ + bQ^2 + c} \qquad (3)$$

With a = -0.25736, b = 6.37291 x 10^{-4}, c = 3.35106 and Q is the Q value.

Results and discussion

Half-lives and branching ratio of all splitting of SHN ^{294}Og are calculated. Half-lives are computed using MGLDM with Q value dependent preformation factor. We considered only those splitting of ^{294}Og which are within experimental half-life limit (less than 10^{30} s) and branching ratio limit (down to 10^{-19}). Among all cluster emission, ^{120}Cd with ^{174}Yb daughter nuclei and ^{121}In with ^{173}Tm daughter nuclei are found to be the most probable cluster decay of ^{294}Og with half-lives comparable with alpha decay half-lives. Half-lives of some important splitting of ^{294}Og are shown in table 1. Also in all the splitting, ^{138}Ba with ^{156}Sm daughter nuclei and ^{136}Xe cluster with ^{158}Gd daughter nuclei are the most stable heavy cluster reaction possible with minimum half-life. Both the cluster emitted have neutron number N= 82, which is a magic number, thereby proving the role of stability of neutron shell closure in cluster decay.

And the decay energy or the Q value of the reaction is given by the equation

$$Q = \Delta M_p - (\Delta M_d + \Delta M_c), \qquad (4)$$

Where ΔM_p, ΔM_d and ΔM_c are the mass excess of parent, daughter nuclei and cluster respectively. The mass excess values are added from the recent mass table of Wang et al., [4].

A graph with cluster size along X axis and logarithm of half-lives using Q dependent preformation factor of splitting of ^{294}Og along Y axis is plotted in figure 1. Only those half-life within experimental half-life limit and branching ratio limit are plotted. Straight line drawn in the graph corresponds to half-life of alpha decay. Half-life of clusters in the range of alpha decay half-life and those cluster emitted with minimum half-life is clearly understood from the figure.

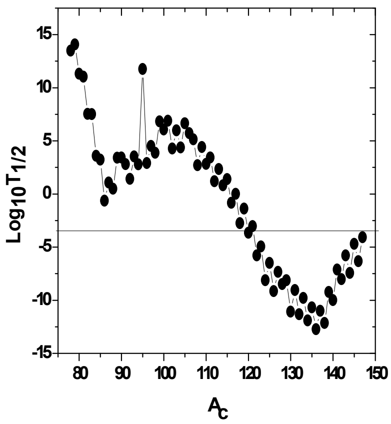

Fig. 1 Graph with cluster size vs logarithm of half-life of splitting of ^{294}Og.

Table 1 Splitting of ^{294}Og whose half-lives are comparable with alpha decay half-lives and those with minimum half-life are given.

Daughter Nuclei	Probable Cluster	Q Value (MeV)	$T_{1/2}$ (s)
^{290}Lv	^{4}He	11.84	0.0003957
^{120}Cd	^{174}Yb	340.36	0.00022
^{121}In	^{173}Tm	341.55	0.00093
^{138}Ba	^{156}Sm	357.08	7.12E-13
^{136}Xe	^{158}Gd	356.58	1.87E-13

We also calculated the decay modes of ^{294}Og by comparing alpha decay half-life with spontaneous fission half-lives and are listed in table 2. Alpha decay half-lives are calculated using MGLDM and Spontaneous fission half-lives are calculated using equation proposed by Bao et al., [3] and is given by

$$\log_{10}[T_{1/2}(yr)] = c_1 + c_2\left(\frac{z^2}{(1-kI^2)A}\right) + c_3\left(\frac{z^2}{(1-kI\,2)A}\right)^2 + c_4 E_{sh} + h_i$$

With c_1 = 1174.35341, c_2 = -47.666855, c_3 = 0.471307, c_4 = 3.378848, k = 2.6 and h_i is blocking effect given in [3].

From table it is clear that for first 3 decay, alpha decay half-life is less compared to spontaneous fission and in the fourth case, spontaneous fission half-life is minimum. Thus without any doubt, we can say that for superheavy element ^{294}Og, decays by 3 alpha chains followed by spontaneous fission.

Table 2 Compares alpha decay half-lives with spontaneous fission and decay modes of ^{294}Og.

Parent Nuclei	Q_α (MeV)	T_{SF} (s)	T_α (s)	Mode of decay
^{294}Og	11.84	19686.75	0.00039	α
^{290}Lv	11.01	3768.07	0.0107	α
^{286}Fl	10.37	13.59	0.1306	α
^{282}Cn	10.18	9.55E-05	0.1038	SF

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