Cluster Emission from ^{296}120

A. Jain[1,2,*] P. K. Sharma[3], S. K. Jain[1], and G. Saxena[2]
[1]Department of Physics, School of Basic Sciences,
Manipal University Jaipur, Jaipur - 303007, INDIA
[2]Department of Physics (H&S), Govt. Women Engineering College, Ajmer - 305002, INDIA and
[3]Govt. Polytechnic College, Rajsamand - 313324, INDIA

Cluster decay is an exotic decay in which a heavy nucleus decays into light daughter nucleus and emits a fragment. This fragment is called 'Cluster', which usually has its mass between the α-particle and the daughter nucleus. Historically, it was first studied by Sandulescu *et al.* in 1980 [1]. Thereafter in 1984, Rose and Jones experimentally observed [2] that in cluster emission process a parent nucleus ^{223}Ra decays into a large fragment ^{209}Pb and a lighter cluster ^{14}C. Many theoretical models predicted the cluster emission from superheavy nuclei, out of which few heavy clusters are speculated to emit from unknown superheavy nucleus ^{296}120 [3–5].

In the present work, we have studied cluster decay from superheavy nucleus ^{296}120 by picking up the emission of all possible even-even isotopes from He to Mo (Z = 2−42). We have calculated logarithmic half-lives of these clusters, as mentioned, by using Horoi [6], RenA [7], NRDX [8], UDL [9], and UNIV [10] formulas and predicted that there is a reasonable probability of emission of heavy massive clusters while compare with half-lives of α-decay.

The present study on α-decay and cluster decay is done by using above mentioned formulas. These formulas are represented as,

$$\begin{aligned} log_{10}T_{1/2}^{Horoi} &= (a_1\sqrt{\mu}+b_1)[(Z_cZ_d)^yQ^{-1/2} \\ &\quad -7]+(a_2\sqrt{\mu}+b_2) \end{aligned} \qquad (1)$$

$$\begin{aligned} log_{10}T_{1/2}^{RenA} &= aZ_cZ_dQ^{-1/2}+cZ_cZ_d+d \\ &\quad +h \end{aligned} \qquad (2)$$

$$\begin{aligned} log_{10}T_{1/2}^{NRDX} &= aZ_cZ_d\sqrt{\frac{\mu}{Q}} \\ &\quad +b\sqrt{\mu Z_cZ_d}+c \end{aligned} \qquad (3)$$

$$\begin{aligned} log_{10}T_{1/2}^{UDL} &= aZ_cZ_d\sqrt{\frac{\mu}{Q}}+b[\mu Z_cZ_d(A_c{}^{1/3} \\ &\quad +A_d{}^{1/3})]^{1/2}+c \end{aligned} \qquad (4)$$

$$\begin{aligned} log_{10}T_{1/2}^{UNIV} &= 0.22873\sqrt{\mu Z_cZ_dR_b} \\ &\quad [arccos\sqrt{r}-\sqrt{r(1-r)}] \\ &\quad -log_{10}S-22.1692 \end{aligned} \qquad (5)$$

where, $r = R_a/R_b$ with, $R_a = 1.2249(A_c{}^{1/3} + A_d{}^{1/3})$, $R_b = 1.43998Z_dZ_c/Q$. $log_{10}S = -0.598(A_c-1)$.

In these formulas all the half-lives are in second. A_c and A_d represent the mass numbers of the emitted cluster and daughter nucleus, respectively. Z_c and Z_d denote the charge numbers of the emitted cluster and daughter nucleus, respectively. $\mu = A_dA_c/(A_d + A_c)$ is the reduced mass. Q is disintegration energy in MeV. The constants $(a, b, c, d, h, y,\ a_1,\ a_2,\ b_1$, and $b_2)$ may be found in Refs. [6–10].

The half-lives of α-decay and cluster decay are sensitive to the disintegration energy (Q−value), which is given by:

$$Q = B.E.(d) + B.E.(c) - B.E.(p) \qquad (6)$$

Where B.E.(p), B.E.(d) and B.E.(c) are the binding energies of the parent nucleus, daughter nucleus, and emitted cluster, respectively. In this work, we use Q−values from WS4 mass model [11], which are found to be more precise than other widely used theories, as shows in our previous work [12].

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[*] Electronic address: `jainakshay311@gmail.com`

To describe the competition between α-decay and cluster emission, we use branching ratio b_c of cluster emission relative to the corresponding α-decay as:

$$log_{10} b_c = log_{10}(\lambda_c/\lambda_\alpha) = log_{10}(T_\alpha/T_c) \quad (7)$$

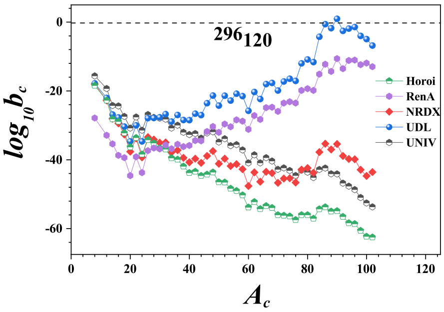

FIG. 1: Variation of decimal logarithm of b_c with the mass number of emitted cluster using Horoi [6], RenA [7], NRDX [8], UDL [9], and UNIV [10] formulas for $^{296}120$.

Where λ_c and λ_α are the decay constants of cluster emission and α-decay, respectively. If $log_{10} b_c$ is positive then one can speculate the dominancy of cluster decay over α-decay.

Decimal logarithm of b_c for the most probable emitted clusters versus the mass number of clusters using various formulas as mentioned, are shown in Fig. 1. We find that values of $log_{10} b_c$ are mostly negative for the lighter massive clusters, which means α-decay half-lives are much shorter than corresponding cluster emission. It indicates that α-decay is the dominant decay mode and the emission of lighter massive cluster from $^{296}120$ is very unlikely. As the mass number of cluster increases, the probability of cluster emission also increases using UDL and RenA formulas. The clusters having $log_{10} b_c$ near to zero or positive values have the probability of emission. It should be noted that we have included most probable cluster emission from each mass number of cluster.

Therefore, from Fig. 1, the most probable cluster is ^{90}Sr from the nucleus $^{296}120$. Some of the clusters viz. ^{86}Kr, ^{88}Kr, ^{94}Zr, and ^{96}Zr from $^{296}120$ are also found at marginal line. Our predictions of these heavy masses clusters are in agreement with recently studied cluster emission from $^{296}120$ by Bai *et al.* [3] in which ^{88}Sr is found as a possible emitted cluster using Wentzel-Kramers-Brillouin (WKB) method. In addition, Santhosh *et al.* [4] and Zhang *et al.* [5] also described the probable emission of ^{88}Sr and ^{90}Sr respectively, from $^{296}120$. In conclusion, the probability of heavy clusters (Z>30) from superheavy nuclei is evident theoretically which requires more efforts from experimental fronts. It is also noticeable that the cluster emission half-lives and $log_{10} b_c$ using UDL and RenA formulas show different results as compared to the NRDX, Horoi and UNIV formulas, which points towards the model dependency of these half-lives and needs separate detailed investigation.

The support provided by SERB (DST), Govt. of India under CRG/2019/001851 grant is acknowledged.

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