Possible combinations for the production of the isotopes of Z=126 via cluster radioactivity

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Introduction

Super heavy element research is currently a trending area in the field of theoretical nuclear physics. In that field. Synthesize of super heavy elements is a pioneering research area that is going on. Till now, researchers were able to synthesize SHE up to Z=118. In our work, we are trying to analyze the possibility of producing the isotopes of Z=126 by computing their half-lives with the help of the Coulomb Proximity Potential Model(CPPM). The decay mode that we consider in our evaluation is cluster radioactivity, which was proposed by Sandulescu in early 1980[1].

Cluster radioactivity is regarded as a mode of nuclear decay in which an unstable parent decays into a stable one with the emission of cluster. This cluster is regarded as a particle heavier than alpha particle (^{4}He). Cluster radioactivity is experimentally proved by Rose and Jones. Normally an unstable nucleus becomes stable by particle emission or nuclear fission. Nuclear fission liberates higher energy as compared to particle emission. Previously, classical theory was not able to explain the alpha decay process. But in 1992, George Gamow resolved this problem by treating it with the help of tunneling theory. Quantum mechanical treatment was used by Gamow to explain this. The current possible experimental limit of half-life to measure is $\leq 10^{30}$s.

Model

The interaction potential barrier for a parent nucleus exhibiting exotic decay is given by

$V = \frac{Z_1 Z_2 e^2}{r} + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2}$, for Z>0 (1)

Here Z_1 and Z_2 are the atomic numbers of daughter and cluster nuclei. r is the distance between fragment centers. l is the angular momentum, μ is the reduced mass and V_p is the proximity potential.

Where N, Z and A represents neutron, proton and mass number of the parent nucleus.

Barrier penetrability,

$$P=\exp\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)dz}\ \} \quad (2)$$

The turning points a and b are determined from the equation V(a)=V(b)=Q.

The above integral can be evaluated numerically or analytically and the half life is given by ,

$$T_{\frac{1}{2}} = (\frac{\ln 2}{\lambda})=(\frac{\ln 2}{\nu P}) \quad (3)$$

Results, Discussion and Conclusion

The radioactive decays are possible only if the Q value of the reaction is greater than or equal to zero. The Q values are computed from the relation

$$Q = M(A,Z) - M(A_1,Z_1) - M(A_2,Z_2) \quad (4)$$

Where M(A,Z), $M(A_1,Z_1)$ and $M(A_2,Z_2)$ represent the mass excess of the parent, daughter and cluster respectively. The Q-values are taken from mass excess tables such as Audi et al [2] and the remaining masses are from the table of KTUY [3].

Figures 1,2 represent the cold valley plots for the ^{308,312}126 isotopes. The interaction potential that we consider is the Coulomb and Proximity potential. It is obvious from the figure that, when proximity potential is included, the minimum in driving potential becomes deeper, but there was no change in the position of the minima. The minimum in the driving potential corresponds to the maximum probable emission. The ^{8,10}Be, ^{12,14}C, ^{18,20}O, ^{22,24}Ne, $^{26,28\&30}$Mg, ^{32,34}Si, ^{36,38,40}S, ^{42,44}Ar, ^{46,48}Ca and ^{54}Ti shows the minimum in driving potential, that means these decays are more probable. Table 1 shows the computed Q values, half-life time and other possible combinations for the production of $^{308, 310, 312}126$ isotopes. It is obvious from the that the $^{280}Fl + ^{28}Mg$, $^{276}Cn+ ^{32}Si$, $^{260}Sg+ ^{48}Ca$ and $^{254}Rf + ^{54}Ti$ are the most probable combinations for the isotope $^{308}126$.

It is found from the figure 2 that minimum in driving potential at ^{8}Be,$^{12,14}C$,^{18}O,^{24}Ne,^{28}Mg, $^{32,34}Si$, ^{44}Ar and $^{48,50}Ca$ cluster. But $^{288}Lv+ ^{24}Ne$, $^{284}Fl + ^{28}Mg$, $^{280}Cn+ ^{32}Si$, $^{278}Cn+ ^{34}Si$, $^{268}Hs + ^{42,44}Ar$, $^{264}Sg+ ^{48}Ca$, $^{262}Sg+ ^{50}Ca$ are the most probable combinations for the isotope $^{312}126$ and is given in the table. We have also analysed all the possible combinations of $^{310}126$ isotopes and is found that $^{286}Lv+ ^{24}Ne$, $^{278}Cn+ ^{32}Si$, $^{262}Sg+ ^{48}Ca$ and $^{260}Sg+ ^{50}Ca$ are the most probable combinations. Therefore, we presume that these combinations are more possible for the production of $^{308,310,312}126$ isotopes and is a guide through future experiments.

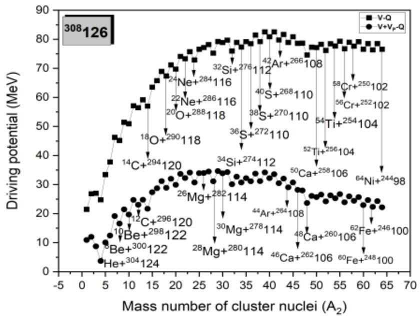

Fig 1. Plot of driving potential versus mass number of cluster nuclei for $^{308}126$ isotopes

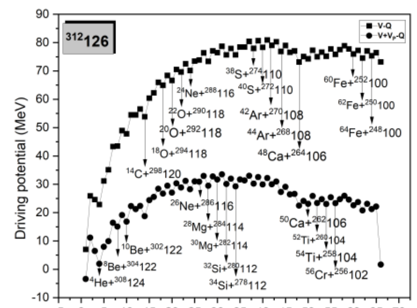

Fig 2. Plot of driving potential versus mass number of cluster nuclei for $^{312}126$ isotopes

The computed half-lives versus neutron number of daughter nuclei for $^{308,310,312}126$ isotopes are shown in figure 3. The minimum in the plot of half-life indicates most probable decay. It is obvious from the plot that there is a dip in half life time at N= 154, 166, 172, 176 and 184. It indicates the neutron shell closure of daughter nuclei at N= 154, 166, 172, 176 and 184.

Parent	Possible combinations	QValue (MeV)	$\log_{10}(T_{1/2})$ (sec)
$^{308}126$	$^{280}Fl + ^{28}Mg$	108.84	29.36
	$^{276}Cn+ ^{32}Si$	132.31	28.55
	$^{260}Sg+ ^{48}Ca$	196.26	28.04
	$^{254}Rf + ^{54}Ti$	211.45	34.95
$^{310}126$	$^{286}Lv+ ^{24}Ne$	85.43	30.94
	$^{278}Cn+ ^{32}Si$	131.06	30.10
	$^{262}Sg+ ^{48}Ca$	195.46	28.85
	$^{260}Sg+ ^{50}Ca$	192.67	31.49
$^{312}126$	$^{288}Lv+ ^{24}Ne$	87.68	27.75
	$^{284}Fl + ^{28}Mg$	110.01	28.89
	$^{280}Cn+ ^{32}Si$	131.84	29.54
	$^{278}Cn+ ^{34}Si$	130.66	30.16
	$^{268}Hs + ^{44}Ar$	172.61	31.49
	$^{264}Sg+ ^{48}Ca$	196.71	25.99
	$^{262}Sg+ ^{50}Ca$	194.54	27.40

Table 1. Possible cluster daughter combinations, Computed Q values and half-lives for the production of $^{308,310,312}126$ parent isotopes.

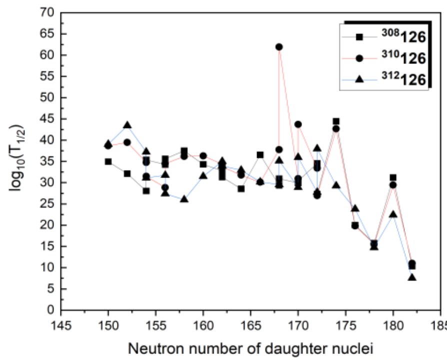

Fig 3. Plot of computed half-lives versus neutron number of daughter nuclei for $^{308,310,312}126$ isotopes.

References

[1] A. Sandulescu et al, Sov. J. Part. Nucl. II, 528 (1980)
[2] G. Audi et al, Nucl. Phys, A 729, 337 (2003)
[3] H. Koura et al, Prog. Theor. Phys., 113, 305 (2005)