Synthesis of Super Heavy Elements

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Introduction

An era of study and synthesis of superheavy elements began with the prediction of the existence of an island of stability of long lived superheavy elements in the vicinity Z=126,N=184 by Myers and Swiatecki in 1966.Within coulomb and proximity potential model [1], we have studied cluster emission from all even-even nuclei from $^{270}118$ to $^{318}118$. Fission decay half lives for these isotopes are calculated by the model proposed by Ren et al. The range of isotopes in which α-decay shall occur for the element Z=118 is found out using the difference in α-decay half life and fission decay half life as a criterion. This range is also the one in which isotopes can exist without getting spontaneously fissioned . Making use of the concepts of quantum mechanical fragmentation theory and the information that is gathered from our work, about the range of isotopes where synthesis of Z=118 is probable, sets of reactions, according to order of possibility, for the production of all isotopes in the range have been elucidated. Along with that the involved fusion barrier and ground state Q-value also are shown.

Model

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

$$V = \frac{z_1 z_2}{r} e^2 + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2}, \qquad \text{for } z>0 .$$

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

The α-decay half-lives are calculated using the equation $T_{1/2}=\ln 2/\lambda=\ln 2/\nu P$. Spontaneous fission half lives are calculated by the formula proposed by Ren at al[2].

Driving potential (V-Q)of the compound nucleus is calculated as a function of mass and charge asymmetries $\eta_A = \frac{A_1-A_2}{A_2+A_2}$ and $\eta_Z = \frac{Z_1-Z_2}{Z_1+Z_2}$ for the touching configuration of the fragments. For a fixed η_A and r the charges of the fragments are fixed by minimizing the driving potential. In the process a set of driving potential minima is evolved. The set of driving potential minima has got various local regions each having its own minimum. .

The production of the element Z=118 has been reported from Dubna, Russia, in the reaction ^{249}Cf(^{48}Ca,3n)^{294}118 [3].

Results and discussion

The region of isotopic chain, the “window”, where production of elements shall be comparatively easy has been found out for the element Z=118. It is from $^{282}118$ to $^{294}118$.

Based on most low driving potential minimum of various local regions for a given isotope, we suggest reactions for the production of various isotopes of Z=118. The reactions are given in order of preference. Preference is decided according to the leastness of driving potential minima. The least of all driving potential minima is associated to the first reaction. In the case of production of $^{294}118$, we suggest the following six reactions.

(1) $^{136}Xe+^{(158+x)}Gd \rightarrow ^{294}118+xn$

(2) $^{126}Sn+^{(168+x)}Er \rightarrow ^{294}118+xn$

(3) $^{86}Kr+^{(208+x)}Pb \rightarrow ^{294}118+xn$

(4) $^{68}Ni+^{(226+x)}Th \rightarrow ^{294}118+xn$

(5) $^{48}Ca+^{(246+x)}Cf \rightarrow ^{294}118+xn$

(6) $^{34}Si+^{(260+x)}Rf \rightarrow ^{294}118+xn$

In the above reactions, x=0,1,2,3,4 etc. In the case of analyzing $^{294}118$, the reactions of the type $^{136}Xe+^{158}Gd \rightarrow ^{294}118$ {reaction(1)} is obtained. However, in the actual situations, due to the dynamical nature of bombardment, few neutrons shall be stripped off. In order to take that into account neutron number of the target is increased by x.

The coulomb barrier and ground state Q-value for x=0 in each case in units of MeV is, respectively, as follows:(1) 416.10,355.63; (2) 410.10,347.53; (3) 363.65, 303.52; (4) 316.24, 238.77; (5) 253.78,178.63;(6) 149.01,119.38

Of these six reactions, the reaction(1) which belongs to the category "cold fusion" has got the most probability to occur. But to realize that reaction, one shall have to overcome a huge coulomb barrier and this shall pose a large technical challenge. Reactions(2) and (3) also belongs to the "cold fusion" category. Reaction(4) belongs to "hot fusion" category. Reaction(5) also belongs to "hot fusion" category. Reaction (5) is the reaction of the reported production of Z=118 [3] with x=3, the reaction used being $^{48}Ca+^{(246+3)}Cf \rightarrow ^{294}118+3n$. Reaction (6) belongs to "hot fusion" category and might be mentioned "more hot" in the sense that the compound nuclide (CN) shall be more excited than in the previous case.

It is notable that from theoretical consideration alone, we could develop a reaction which, essentially, is the reaction used for the reported production of $^{294}118$. Yet, it shall be more appropriate to consider the reaction $^{136}Xe+^{(158+x)}Gd \rightarrow ^{294}118+xn$ for the production of $^{294}118$. Reactions (2) and (3) also may be considered ,in order, for the production of $^{294}118$. These reactions may be considered as to belonging to "more cold" category.

Originally, reactions which may be mentioned as "more hot" was used for the production of SHE's. Due to stagnation, thereafter, cold fusion and hot fusion were depended upon. Hence, to produce even more heavy elements that are produced by "hot fusion", it shall be quite necessary to depend upon reactions like the ones suggested above, which may be mentioned as "more cold" .

In the case of $^{292}118$ to $^{282}118$ similar sets of reactions are obtained and the most preferred ones in each case are shown. $^{292}118$: $^{136}Xe+^{(156+x)}Gd \rightarrow ^{292}118+xn$; $^{290}118$: $^{143}Ce+^{(147+x)}Nd \rightarrow ^{290}118$; $^{288}118$: $^{143}Ce+^{(145+x)}Nd \rightarrow ^{288}118+xn$; $^{286}118$: $^{143}Ce+^{(143+x)}Nd \rightarrow ^{286}118+xn$; $^{284}118$: $^{140}Ce+^{(144+x)}Nd \rightarrow ^{284}118+xn$; $^{282}118$: $^{40}Ce+^{(142+x)}Nd \rightarrow ^{282}118+xn$

For the production of superheavy elements which are not produced yet, reactions with nearly equal constituents ("more-cold fusion") is to be attempted. The method put forward here can be used to elucidate reactions for the production of other even heavier SHEs. All the category of reactions are considered to be alike but with varying degree of hotness of compound nucleus.

We expect that these new sets of reactions would tempt experimentalists to create newer isotopes of presently created superheavy elements as well as new superheavy elements.

References

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