Decay of even-even super heavy $^{288\text{-}318}118$ isotopes

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Introduction

The radioactive decay of nuclei emitting particles heavier than alpha particle, termed as cluster radioactivity, was first predicted by Sandulescu et al. [1] in 1980 on the basis of quantum mechanical fragmentation theory. This rare, cold (neutronless) process is intermediate between alpha decay and spontaneous fission. Experimentally Rose and Jones [2] first observed such decay in 1984 in the radioactive decay of ^{223}Ra by the emission of ^{14}C. At present about twenty parent nuclei from ^{221}Fr to ^{242} Cm emitting clusters ranging from ^{14}C to ^{34}S are confirmed.

The exploration of cluster radioactivity in the super heavy island did not receive much attention because of the instability of nuclei in this region. The half-lives of different radioactive modes such as alpha decay, cluster radioactivity and fission are important to identify the decay chains of super heavy elements, which are the experimental signatures of the formation of super heavy elements by fusion reaction.

In the present work an attempt is made to examine the possibility of cluster emission from nuclei in the super heavy region with an aim to find the next neutron and proton shell closure in this region.

In the 1960's a number of theoretical predictions were made that pointed towards the existence of an island of long- lived super heavy elements centred on Z=126, N=184. One of the fundamental factors in the study of super heavy elements is the prediction and/or production of doubly magic numbers next to Z=82, N=126 (^{208}Pb). The super heavy elements are produced by complete fusion between an incident ion and a target ion. Discovery of super heavy elements has been announced at the Lawrence Berkelely National Laboratory. One of the experiments done at Dubna [3] was designed to investigate the radioactive properties of the isotopes of element 116, the alpha decay daughters of Z=118 isotopes produced in the reaction ^{249} Cf + ^{48}Ca.

Within Coulomb and proximity potential model, we have studied the probable cluster emissions for all the even-even isotopes with mass number ranging from 288 to 318 of Z =118, this being accomplished by, prima facie, considering all the combinations of splitting up of each of these mass numbers. Cold valley plots that connect mass number of clusters and driving potentials involved are drawn for each isotope. We studied the cold valleys in connection with radioactive decay and computed half-life values, in relation to clusters ^{4}He, ^{10}Be, ^{14}C, ^{20}O and ^{22}O, of all the above isotopes (as part of an extensive study on the subject matter of synthesis and decay of super heavy elements).

The model

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

$$V = Z_1 Z_2 e^2 / r + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2}$$

for z >0

Here Z_1 and Z_2 are the atomic numbers of daughter and emitted cluster; 'r' is the distance between fragment centers, l the angular momentum, μ the reduced mass and Vp is the proximity potential. The barrier penetrably P is given as:

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

The turning points 'a' and 'b' are given by $V(a) = V(b) = Q$, where Q is the energy released. The half life time is given by $T_{1/2}$ = ln2/νP, where, ν = $2E_\nu/h$, represent the number of assaults on the barrier per second and $E_{\nu,}$ the empirical zero point vibration energy.

Results and discussion

We studied cluster radioactivity based on the potential barrier determined by two sphere approximation, which is the sum of coulomb and proximity potentials for the touching configuration. The possibility to have a cluster decay process is:

$$Q=M(A,Z) - M(A_1,Z_1) - M(A_2,Z_2) > 0$$

where $M(A,Z)$, $M(A_1,Z_1)$, $M(A_2,Z_2)$ are the atomic masses of the parent ,daughter and cluster respectively.

The concept of cold valley was introduced in relation to the minima in the driving potential which is defined as the difference between the interaction potential and the decay energy (termed as Q value) of reaction. Q values are computed mostly using experimental binding energies of Audi and Wapstra [4] whereas some values are taken from finite-range droplet model. The driving potential of the compound nucleus is calculated for all cluster–daughter combinations for touching configuration of the fragments. In the touching configuration the distance between the fragments $r = C_1+C_2$, where $C_1$and C_2 are the siissmann central radii. Cold valley plots that connect mass number of clusters and driving potentials are drawn for each isotope and the plot of ^{294}118 is displayed in Fig 1. ^{294}118 is the only member among Z=118 isotopes which has been synthesized. In connection with cold valley plots, inclusion of the proximity potential does not change the position of the minima but makes it deeper. This result had been shown by Saroha et al. [5] earlier. The minima in potential energy curve represent the most probable decay. Thus ^{4}He, ^{8,10}Be, ^{14}C, ^{20,22}O, ^{24}Mg etc are possible candidates for emission from these parents. There are two deep valleys centered on ^{48}Ca and ^{208}Pb which shows the role of doubly magic nuclei in cluster emission.

Figiure 2 represents the plot for the computed half life times for ^{4}He, ^{10}Be, ^{14}C and ^{20,22}O versus neutron number of the daughter nuclei. In the present work calculations are done assuming zero angular momentum transfers. This has been done because the angular momentum l carried away in the alpha and cluster decay process, is found to be very small (5ħ) and its contribution to half life times are also shown to be small which is again decided by the spin parity conservation. The N = 184 neutron shell closure of the daughters is evident as a dip in the half life time plots. A dip is obtained at N = 172 neutron shell closure for the ^{14}C cluster emission. For the case of ^{20}O emission the highest value for the half life is obtained at ^{302}118 parent which again stresses the neutron shell closure at N = 184.

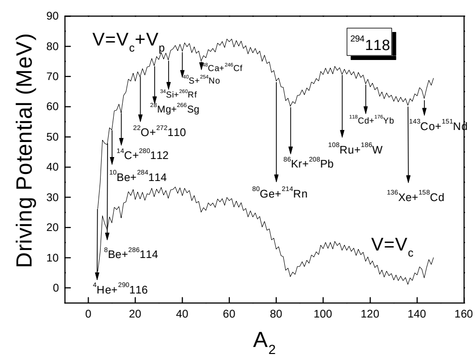

Fig 1. The plot of driving potential versus A_2, mass of one fragment for ^{294}118 with and without including proximity potential

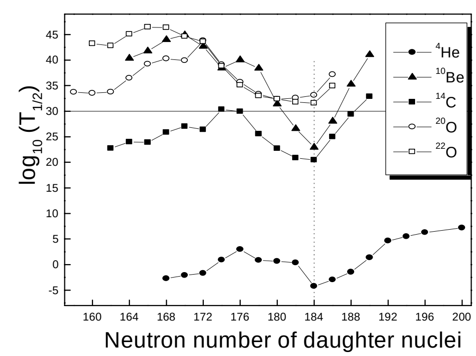

Fig 2. Plot for the computed half life times versus neutron number of the daughter nuclei

References

[1] A Sandulescu, D Poenaru and W Greiner, Sov. J. Part. Nucl. II 528 (1980)

[2] H J Rose and G A Jones, Nature (London) 307 (1984) 245

[3] Yu Ts Oganessian, et al., Phys. Rev. C 69 (2004) 054607

[4] G. Audi et al, Nucl. Phys. A 729 (2003) 337

[5] D R Saroha et al., J. Phys. G: Nucl. Part. Phys. 11 (1985) L27