Possibility for the existence of various $^{6-9}$B, $^{16-19}$Ne, $^{8-11}$ C, $^{23-30}$P and $^{26-32}$S proton halo nuclei via cluster decay process

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Introduction

Proton rich or neutron rich light nuclei that lie near the proton or neutron drip lines form halo nuclei and the study of such nuclei will help to understand their structure and behavior. The drip line determines the basic limit of stability. Nuclei beyond the proton or neutron drip lines have a negative proton and neutron separation energy respectively so that they naturally emit protons or neutrons, or have the tendency to transform protons into neutrons due to the large beta decay energy. Those nuclei near the drip lines are characterized by one or two loosely bound protons or neutrons which form a halo structure [1]. Nucleons in nuclei are not always arranged within a well-defined boundary; they move beyond the boundary and form a misty cloud. Such nuclei are called halo nuclei, which behave differently from other nuclei. These nuclei are larger than normal nuclei because they have a core nucleus surrounded by a halo of orbiting protons or neutrons and they are easy to break apart. In halo nuclei, one or two valence nucleons are weakly bounded to the inert core, so their lifetime is very small and are not stable. ^{6}He was the first halo nucleus produced in the laboratory by bombarding a beam of neutrons on a ^{9}Be target in 1936[2].

Most of the halo nuclei are said to be neutron halos [3], because the presence of repulsive Coulomb interaction holds the valence nucleons closer to the core and hinders the formation of proton halos [4]. There are one proton halo and two proton halo structures. The 1p-halo structures are identified for ^{8}B, ^{11,12}N, ^{17}F, ^{23}Al, ^{26,27,28}P, and 2p halos for ^{9}C, ^{17,18}Ne, ^{20}Mg, ^{27,28,29}S. The present work aims to study the probability for the existence of various proton halo nuclei $^{6-9}$B, $^{16-19}$Ne, $^{8-11}$C, $^{23-30}$P, $^{26-32}$S from even-even isotopes $^{272-334}$118, $^{264-338}$116 using Coulomb and Proximity Potential Model as the interacting barrier.

The model

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

$$V = Z_1 Z_2 e^2 / r + V_P(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2} \quad \text{for } Z > 0 \qquad (1)$$

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:

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

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

$$T_{1/2} = \ln 2/\nu P. \qquad (3)$$

Where, $\nu = 2E_v/h$, represent the number of assaults on the barrier per second and E_v, the empirical zero point vibration energy.

Results discussion and conclusion

The calculations are done by using Coulomb and Proximity Potential Model as the interacting barrier for various $^{6-9}$B, $^{16-19}$Ne, $^{8-11}$C, $^{23-30}$P, $^{26-32}$S proton halo nuclei from even-even super heavy isotopes $^{272-334}$118, $^{264-338}$116 as parent. The decay is possible when the Q-value of the reaction is greater than zero. Q-value for the reactions are computed using mass table of Audi et al [5] and the remaining masses are taken from the table of KTUY[6].

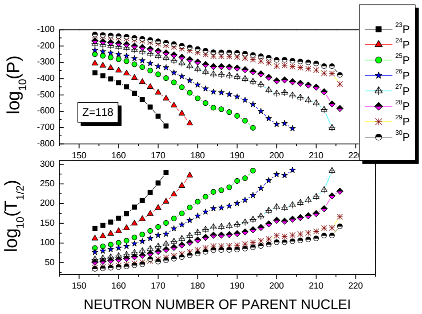

Fig. 1 Plot of logarithm of half- life and barrier penetrability versus neutron number of the parents for the decay of $^{23\text{-}30}P$ from $^{272\text{-}334}118$.

Figures 1-4 represent the plot of computed values of half lives and barrier penetrability versus neutron number of the parent for the emission of proton halo $^{16\text{-}19}Ne$, $^{23\text{-}30}P$, $^{26\text{-}32}S$ from even-even super heavy isotopes $^{272\text{-}334}118$, $^{264\text{-}338}116$. It is obvious that the plot of half life versus neutron number of the parent is always mirror reflection of the plot of barrier penetrability versus neutron number. That is a peak in the half life corresponds to a dip in the barrier penetrability and vice versa.

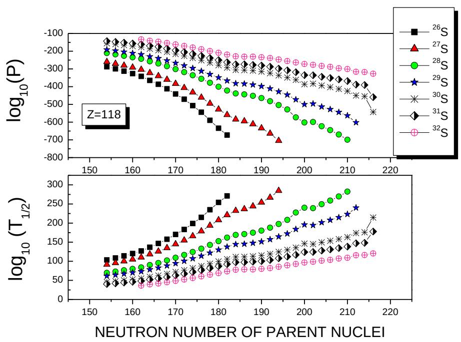

Fig. 2 Plot of logarithm of half- life and barrier penetrability versus neutron number of the parents for the decay of $^{26\text{-}32}S$ from $^{272\text{-}334}118$.

It is obvious from the calculations that half lives of most of the proton halo emissions are less than or equal to 10^{30}s, the experimental limit. A common behavior in all the plots is that there is a prominent peak at N=162, 178, 184, and 212 to it. This shows that shell closure occurs at or near to these neutron numbers. Also, the dip in the graph of half-life indicates the shell closure effects in the daughter nuclei. From these figures, it is noticeable that $^{300}116$, $^{316}116$, are the most stable parent isotopes in the emission of $^{16\text{-}19}Ne$, $^{27\text{-}32}S$ clusters, and $^{302}118$, $^{318}118$ parent isotopes are more stable in the emission of $^{25\text{-}30}P$, $^{27\text{-}32}S$. We can also notice that half life time of the same parent for the emission of different clusters decreases as the mass number of the cluster increases.

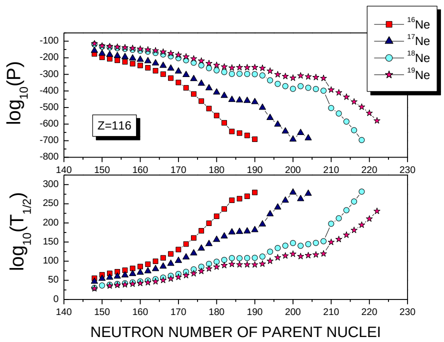

Fig. 3 Plot of logarithm of half- life and barrier penetrability versus neutron number of the parents for the decay of $^{16\text{-}19}Ne$ from $^{264\text{-}338}116$

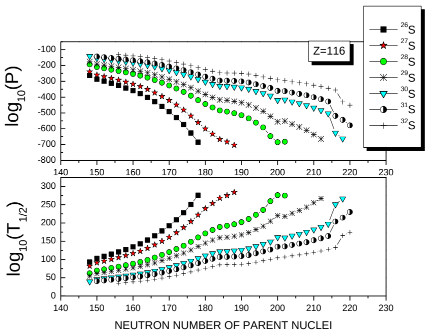

Fig. 4 Plot of logarithm of half- life and barrier penetrability versus neutron number of the parents for the decay of $^{26\text{-}32}S$ from $^{264\text{-}338}116$

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