# Existence of neutron halo nuclei against cluster decay

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## Introduction

Cluster decay, also named heavy particle radioactivity, is a type of nuclear decay in which an atomic nucleus emits a small 'cluster' of neutrons and protons, heavier than an alpha particle, but lighter than a typical binary fission fragment. Cluster decay is now a well established phenomenon both from the experimental and the theoretical side. The rare nature of this process is due to the fact that cluster radioactivity is marked by several α emission. Cluster radioactivity was first predicted by Sandulescu et al in 1980 and such decay was first observed experimentally by Rose and Jones in 1984 in the radioactive decay of $^{223}$Ra by emission of $^{14}$C.

An atomic nucleus is called a halo nucleus (nuclear halo) when it has a core nucleus surrounded by a halo of orbiting protons or neutrons, which makes the radius of the nucleus appreciably larger than that predicted by the liquid drop model. Halo nuclei are very weakly bound exotic states of nuclear matter in which the outer one or two valence nucleons are spatially decoupled from a relatively tightly bound core, such that they spend more than half their time beyond the range of the binding nuclear potential. The first halo nucleus to be produced in the laboratory was $^{6}$He during 1936, using beam of neutrons on a $^{9}$Be [1] target just few years after the discovery of neutrons. The field of halo nuclei represents a paradigm shift in the study of nuclear structure and still regard as a hot topic almost twenty years after their discovery. Neutron halos are nuclear species consisting of a nucleus surrounded by halo of neutrons. The neutron halo has been found in single and double neutron forms. The two neutron form was identifiable due to instance of deuteron emission, since a double neutron halo cannot remains as a single halo after beta decay. $^{11}$Be is an example of single neutron halo and $^{11}$Li is an example of double neutron halo. The present works aims to study the possibility of emission of neutron halo nuclei such as $^{11-12}$Be, $^{8-11}$B and $^{16-20}$C from various even-even $^{278-300}$116, $^{278-300}$118, $^{278-306}$120 and $^{284-308}$122 isotopes using Coulomb and Proximity potential [2] as 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, $\mu$ 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, ν = 2Ev/h, represent the number of assaults on the barrier per second and $E_v$, the empirical zero point vibration energy.

### Results discussion and conclusion

In the present work interacting potential for the post scission region is taken as the sum of coulomb and proximity potential and for the overlap region we use simple power law interpolation. Using this model we have computed the characteristics such as half life, penetrability and Q values for the emission of different neutron halo nuclei like $^{11-12}$Be, $^{8-11}$B and $^{16-20}$C from different even-even $^{278-300}$116, $^{278-300}$118, $^{278-306}$120 and $^{284-308}$122 isotopes. The computation of half-life time helps to find the stability of parent nuclei against cluster emission. It is found that most of the decays has half life time values less than or equal to $10^{30}$ sec and is probable for emission. The Q-values are computed using experimental binding energies of Audi et al [3] and remaining values are taken from the tables of KTUY [4].

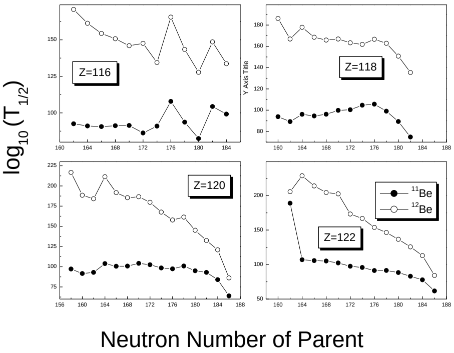

**Fig. 1** Computed half life time versus neutron number of parent nuclei for $^{11-12}$Be emissions from different even-even parents with Z ranging from 116 to 122.

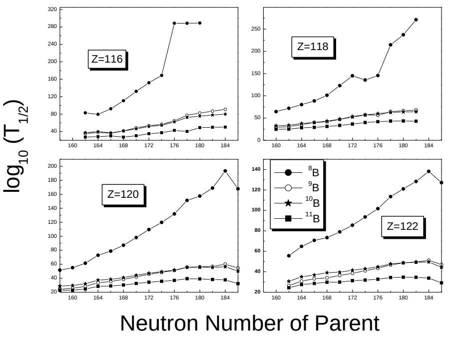

**Fig. 2** Computed half life time versus neutron number of parent nuclei for $^{8-11}$B emissions from different even-even parents with Z ranging from 116 to 122.

Figures 1 to 3 represent the plot connecting computed half life time for the neutron halo nuclides such as $^{11-12}$Be, $^{8-11}$B and $^{16-20}$C from different even-even $^{278-300}$116, $^{278-300}$118, $^{278-306}$120 and $^{284-308}$122 parents against neutron number of parent. The peaks in the half life value indicate the shell closure effect in the parent nuclei and a dip in half life represents the shell closure effect in the daughter nuclei. It is clear from the plots that there is a peak at N= 162, 168, 172 and 184 which represent the neutron shell closure of the parent nuclei at N= 162, 168, 172 and 184. We would like to point out that from the works of RMF [5] formalism, neutron number N = 162 has been predicted to exhibit shell closure. Gambler et al showed that the isotopes Z = 116 turn to be spherical or nearly spherical in the neighbourhood of neutron number at N=172. This fact supports the conclusion that spherical shell closure occurs at neutron number 172. It is also found that $^{11}$B from $^{284}$116 has the lowest half-life value [$\log_{10}(T_{1/2})$ = 27.335], which is due to the presence of doubly magic daughter with N=162, Z≈114. That is shell structure effect is evident in these plots in terms of largest barrier penetrability value.

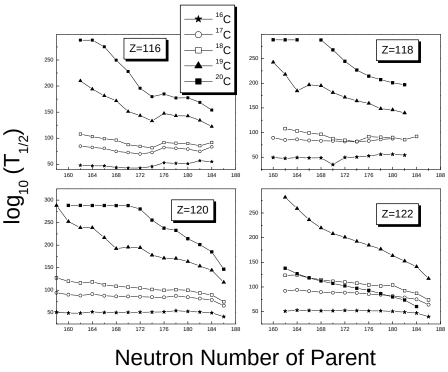

**Fig.3** Computed half life time versus neutron number of parent nuclei for $^{16-20}$C emissions from different even-even parents with Z ranging from 116 to 122

## References

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