Possibility for the existence of $^{16-22}N$ neutron halo isotopes via cluster decay

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Introduction

Neutron halo is one of the most important exotic structures that have been observed in nuclei near to the drip line. It is a nuclear state in which one or two valance nucleons, especially neutrons, are decoupled from the tightly bound core through quantum mechanical tunneling and remain most of the time beyond the interaction potential of the nucleus. This occurs when the separation energy of last one or two nucleon becomes extremely small, typically less than 1 MeV. One of the important criteria for a halo nucleus to exist is that the valance nucleon must be in the lowest orbital angular momentum state relative to the nucleus. This is because, a large angular momentum will give rise to a centrifugal potential that would tend to confine the nucleon. The existence of halo can be easily identified by a large nuclear radius than the usual one. Neutron halo was first observed in weakly bound ^{11}Li nucleus and their existence was confirmed in many nuclei such as ^{6}He, ^{11}Be, ^{14}Be, ^{14}C, ^{19}C etc.

The recent development of radioactive nuclear beams is very helpful in studying the detailed structure of nuclei far from the stability line. The neutron halos have been observed in nuclei near the neutron dripline by reaction measurements with intermediate- and high-energy radioactive nuclear beams [1]. These nuclei are of great interest to study the shell structures near the dripline and new excitation modes associated with the excess neutron on the nuclear surface. In the present work we have made an attempt to study the possibility of existence of $^{16-22}N$ neutron halo nuclei from even-even isotopes such as $^{270-310}116$, $^{272-314}118$ and $^{280-318}120$ in super heavy region through cluster radioactivity. Even though nuclei in this region are highly unstable, study of half-lives of various nuclear decay processes such as alpha decay, cluster decay, nuclear fission etc. are important in the prediction of the formation of super heavy elements by nuclear fusion. In the present work we have used the Coulomb and Proximity potential [2] as the interacting barrier.

The model

The interacting potential barrier for 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, 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

We have studied the cluster radioactivity of various isotopes in super heavy region based on the potential barrier determined by two sphere approximation [3], as the sum of coulomb and nuclear proximity potentials for the touching and separated configuration (z>0). Here z is the distance between near surface of the fragments. In the post scission region, the interaction potential is taken as the sum of Coulomb and Proximity potentials. For the overlap region a simple power law interpolation is used. The Q-values of the reactions are computed using the experimental binding energy data of Audi and Wapstra [4] and the tables of KTUY [5]. Cluster radioactivity is energetically possible only when the Q-value of the reaction is greater than zero. Using this model, we have computed the half-life time, disintegration constant and barrier penetrability for the emission of $^{16\text{-}22}$N from even-even isotopes; $^{270\text{-}310}$116, $^{272\text{-}314}$118 and $^{280\text{-}318}$120 in super heavy regions.

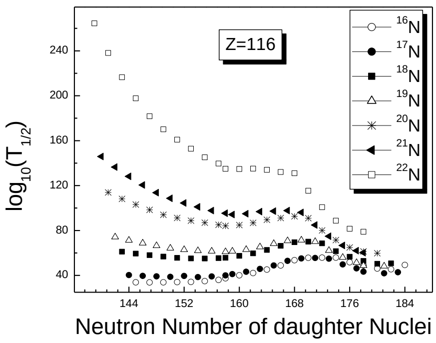

Fig. 1 Computed half life time versus neutron number of daughter nuclei for $^{16\text{-}22}$N isotopes emissions from different Z=116 parents.

Figures 1 to 3 represent the plot of neutron number of daughter nuclei verses the computed half-life time for the emission of $^{16\text{-}22}$N from even-even isotopes; $^{270\text{-}310}$116, $^{272\text{-}314}$118 and $^{280\text{-}318}$120. Radioactive decays with small half life time value or greater barrier penetrability indicate the neutron shell closure of the daughter nuclei [6]. It is found from the plots that there is a valley at N = 184, which represents the neutron shell closure of the daughter nuclei at this neutron number. It is also found from these plots that there is a minima in half life time occurs at N = 154, 162 which indicates the neutron shell closure of the daughter nuclei at N =154 and 162. From the computed half lives, we would like to point out that the isotopes, ^{16}N from $^{270\text{-}286}$116, $^{272\text{-}290}$118 and $^{280\text{-}294}$120 and ^{17}N isotope from isotopes $^{270\text{-}286}$116, $^{272\text{-}286}$118 and $^{280\text{-}288}$120 are possible for cluster emission. These isotopes of nitrogen fall under the category of neutron halo nuclei with a nucleus surrounded by a halo of neutrons.

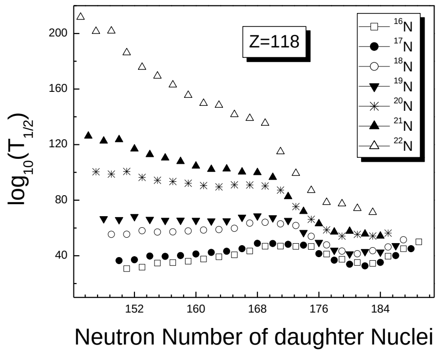

Fig. 2 Computed half life time versus neutron number of daughter nuclei for $^{16\text{-}22}$N isotopes emissions from different Z=118 parents.

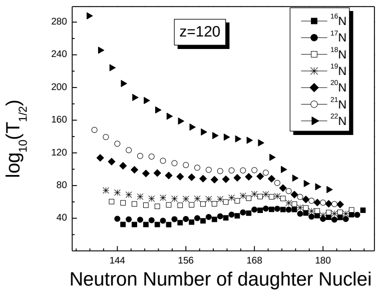

Fig. 3 Computed half life time versus neutron number of daughter nuclei for $^{16\text{-}22}$N isotopes emissions from different Z=120 parents.

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