Studies on the exotic decay possibilities of proton rich ^{10}C, $^{13, 14}$O from nuclides with Z in the range 103-118

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Introduction

Studies on exotic fragments lying on the edges of nuclear stability is one of the active current areas in nuclear Physics and many hundreds of studies have carried out since its discovery in the mid-1980s [1]. Exotic nuclei are characterized by large N/Z asymmetry and they differ remarkably from other stable and near stability elements through their short lifetime, large rms radii, low binding energy, small separation energies etc. Among different types of exotic nuclei in the nuclear landscape, our area of interest is limited to the proton rich nuclei beyond the proton drip line. The last few decades brought considerable progress in synthesizing and studying the properties of exotic nuclei [2]. The main experimental difficulty for most of the exotic nuclei is their very low production yield.

In the present work, we have studied the structure of the exotic nuclei ^{10}C, ^{13,14}O from the separation energy and driving potential calculations. Further, we have studied their decay possibilities from the superheavy parent nuclei within the range Z=103-114.

Exotic nuclei	S(1p)	S(2p)
^{10}C	4.007	3.821
^{13}O	1.512	2.112
^{14}O	4.627	6.570

Table 1. 1p and 2p separation energies of various exotic nuclei.

The model

1p and 2p separation energy for any nuclei in terms of mass excess can be calculated as

$S(p) = - \Delta M (A, Z) + \Delta M (A-1, Z-1) + \Delta M_H$

$S(2p) = - \Delta M (A, Z) + \Delta M (A-2, Z-2) + 2\Delta M_H$

$\Delta M (A, Z)$, ΔM_H, $\Delta M (A-1, Z-1)$, $\Delta M (A-2, Z-2)$ are the mass excess of the parent nuclei, mass excess of proton, mass excess of daughter nuclei produced in the 1p and 2p radioactivity respectively.

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:

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

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

Results and Discussions

In this section we present the numerical results obtained from the separation energy, potential energy and half-life calculations. Separation energies of the selected nuclei are included in the table 1. It is clear from the table that ^{13,14}O show low S (1p) than S (2p), whereas ^{10}C show S(1p)>S(2p).

Further, we have calculated the driving potential using CPPM [3], to identify the most probable cluster- core configurations. Driving potential is the difference between the interaction potential and the decay energy of the reaction (for touching configuration, z=0), for each nuclei with its all possible cluster core configurations.

The configuration formed with minimum driving potential has the largest quantum mechanical probability. Fig. 1 and 2 show the variation of driving potential for the exotic nuclei ^{10}C, $^{13,14}O$ with its all cluster-core configurations as a function of fragment mass A_2 for different angular momentum. It is clear from the figures that as the angular momentum increases the driving potential for each fragment also increases. But in many of the cases, slight deviations can be observed in the position of the minimum in the driving potential when move towards the higher angular momentum value, l=0 to l=3, which may be due to the mixed angular momentum and parity states of ground state configuration.

It is also obvious from fig. 1 that, deepest minimum is associated with 1p+core (2 body system) configuration. So this is the most probable configuration in the case of $^{13,14}O$. But for ^{10}C, in figure 2, 2p+core is the maximum probable configuration. So it is clear from our observations that the results of driving potential calculations are consistent with the separation energy findings.

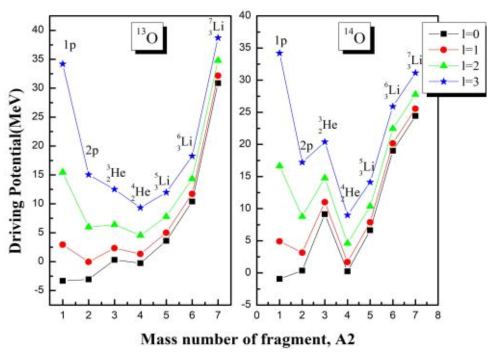

Fig. 1 The driving potential for ^{13}O and ^{14}O exotic nuclei as a function of mass number of the emitted fragment for angular momentum l=0,1,2 and 3.

Fig. 3 and 4 show the plot of half-life for the emission of selected exotic fragments from the SH parent nuclei. In these figures we can observe certain dips in the half lives for ^{13}O emission at neutron number of daughter nuclei N=156, 164, 168,172; for the ^{14}O emission at N~172; for the ^{10}C emission at N~164,170. This indicates the shell closure of daughter nuclei at or near to these neutron numbers. Also, it is obvious from these figures that many of the decays are well within the experimental limits (10^{30}s) of measurement and useful for the future experimental measurements.

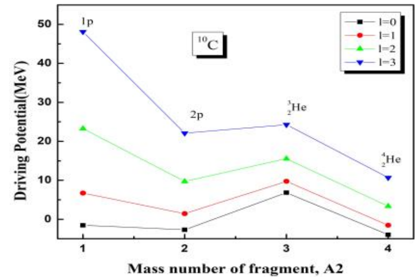

Fig. 2 The driving potential for ^{10}C exotic nucleus as a function of mass number of the emitted fragments for angular momentum l=0, 1, 2 and 3.

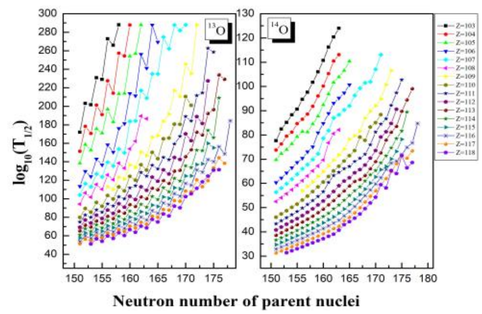

Fig. 3 Plot of $\log_{10}T_{1/2}$ versus neutron number of the parent nuclei from Z=103-118 for the decay of ^{13}O and ^{14}O .

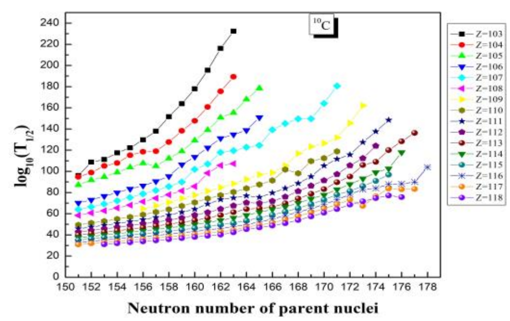

Fig. 4 Plot of $\log_{10}T_{1/2}$ versus neutron number of the parent nuclei from Z=103-118 for the decay of ^{10}C

References

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