Probable exotic decays in Tungsten isotopes

Deepthy Maria Joseph[1],* Antony Joseph[1], and Nithu Ashok[1]
[1]*Department of Physics, University of Calicut, Kerala - 673635, INDIA*

Introduction

Cluster radioactivity or exotic decay is the emission of an entity as a cluster of nucleons with mass number heavier than that of an alpha particle and lighter than that of the lightest fission fragment, without being accompanied by neutron emission. The purpose of the present work is to investigate the probable cluster decays of different proton-rich and neutron-rich isotopes of Tungsten (Z=74) using a fission model approach [1]. We have used the effective liquid drop model (ELDM) for the study. The half lives for cluster decays of different W isotopes are calculated considering the interacting potential as the effective liquid drop one. We have considered all possible combinations of parent and cluster for which the Q value is positive.

The Model

In the effective liquid drop model, the barrier potential V is the effective liquid drop one [2] which is the sum of Coulomb and surface potentials plus the centrifugal potential.

$$V = \frac{8\pi a^5 \epsilon(x_1, x_2)\rho_c}{9} + 4\pi(R^2 - R_1^2 - R_2^2)\sigma_{eff} + \frac{\hbar^2}{2\mu\zeta^2} l(l+1) \tag{1}$$

where ρ_c is the charge density, a is the neck radius of the decaying system and $\epsilon(x_1, x_2)$ is a function of angular variables. R is the radius of the parent nucleus and σ_{eff} is the effective surface tension. The emitted fragment and the daughter nucleus have radius R_1 and R_2 respectively. The geometrical centres of the fragments are separated by a distance represented by ζ [3]. The barrier penetrability factor is calculated as:

$$P = exp\left\{-\frac{2}{\hbar}\int_{\zeta_1}^{\zeta_2} \sqrt{2\mu(V-Q)}d\zeta\right\} \tag{2}$$

where μ is the inertia coefficient and Q is the Q value of the decay. Now the decay constant is given by the expression,

$$\lambda = \nu P \tag{3}$$

where ν is the assault frequency. The decay half-life is calculated by the expression,

$$T_{1/2} = \frac{0.693}{\lambda} \tag{4}$$

Results and Discussion

The decay half lives calculated using ELDM model for ^{8}Be, ^{12}C, and ^{16}O cluster emissions are found to be well within the measurable range ($T_{1/2} < 10^{30}s$) and hence they are predicted to be the probable exotic decay modes in neutron-deficient Tungsten isotopes. The probability of cluster emission is observed to decrease with the rise in neutron number and consequently, no cluster radioactivity is identified in the case of neutron-rich isotopes. Table 1 shows the mass ranges of W isotopes exhibiting various cluster decays with half-lives in the measurable range.

TABLE I: Mass ranges of W isotopes exhibiting various cluster emissions with half lives in the measurable range.

Decays with $T_{1/2} < 10^{30}s$	Mass range (A)
^{8}Be decay	158-165
^{12}C decay	157-168
^{16}O decay	158-167

*Electronic address: `deepthy13@gmail.com`

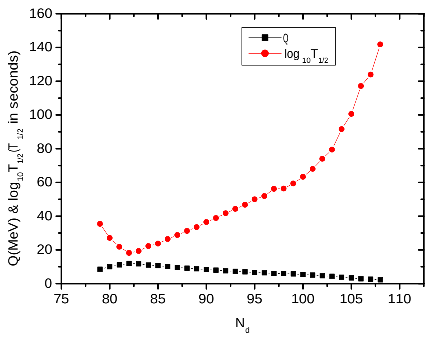

FIG. 1: Half-life and Q against N_d for ^{8}Be decay.

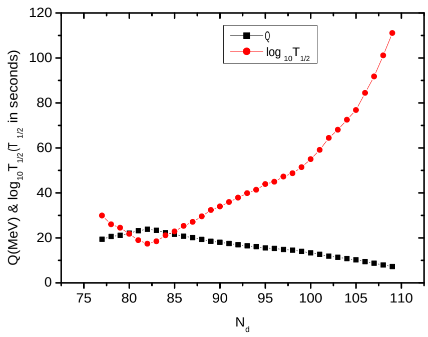

FIG. 2: Half-life and Q against N_d for ^{12}C decay.

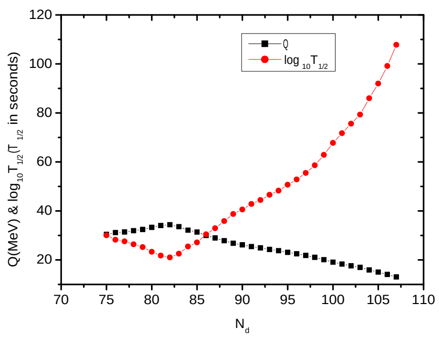

FIG. 3: Half-life and Q against N_d for ^{16}O decay.

Fig. 1, fig. 2 and fig. 3 show the profiles of N_d (neutron number of daughter nucleus) against decay half-life and Q value for ^{8}Be, ^{12}C, and ^{16}O cluster decays respectively. These plots appear almost similar and look like mirror reflected images. The plots show a decrease in the Q value corresponding to an increase in half-life with the rise in N_d. Since barrier penetrability factor is inversely proportional to decay half-life, the probability of decay decreases with the rise in half-life value. Therefore, the probability of cluster emissions decreases with the increase in neutron number of daughter. Also, in these plots, we can see a dip in the half-life at $N_d = 82$, which is a magic number. At this point, the probability of cluster emissions will be high, which in turn points to the significant role played by neutron magicity in cluster radioactivity.

Conclusion

Fission model calculations with the effective liquid drop potential predict that the most probable exotic decay modes in neutron-deficient Tungsten isotopes are ^{8}Be, ^{12}C, and ^{16}O cluster decays. It is found that the probability of cluster emissions decreases with the increase in neutron number. The study also points out the crucial role played by neutron magicity in cluster radioactivity.

Acknowledgment

One of the authors (Deepthy Maria Joseph) acknowledges with gratitude, the receipt of BSR research fellowship from UGC, Govt. of India.

References

[1] D. N. Poenaru, M. Ivascu, A. Sandulescu and W. Greiner, *Phys. Rev.* **C32**, 572 (1985).
[2] M. Goncalves and S. B. Duarte, *Phys. Rev.* **C48**, 2409 (1993).
[3] S. B. Duarte, O. A. P. Tavares, F. Guzman, and A. Dimarco, *Atomic Data and Nuclear Data Tables* **80**, 235 (2002).