Cluster radioactivity in Uranium isotopes

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Introduction

The emission of particles heavier than alpha and lighter than the lightest fission fragment is called cluster radioactivity [1, 2]. The emitted particles are termed as cluster. Ever since the experimental observation of this rare cold nuclear phenomenon, several theoretical as well as experimental studies were carried out. The present work aims in predicting the feasibility of the emission of various clusters from Uranium isotopes (Z=92), within the framework of Effective Liquid Drop Model (ELDM). The emission of ^{24,25,26}Ne and ^{28,30}Mg from certain U isotopes were experimentally confirmed.

Theoretical formalism

ELDM developed by Gonclaves et al. [3] has been adopted for the current study. The barrier penetrability is calculated using,

$$P = exp\{-\frac{2}{\hbar}\int_{\zeta_o}^{\zeta_c}\sqrt{2\mu(V-Q)}d\zeta\} \qquad (1)$$

The limits of integration corresponds to inner and outer turning points. Here the interacting potential (V) is the sum of Coulomb, surface and centrifugal potential. The Coulomb potential chosen is the analytical solution of the Poisson's equation. The centrifugal contribution is considered only after the scission part. Here, the angular momentum is taken as zero, as its contribution towards alpha and cluster decay is very small. Q-values are evaluated using the experimental mass table AME2020 [4].

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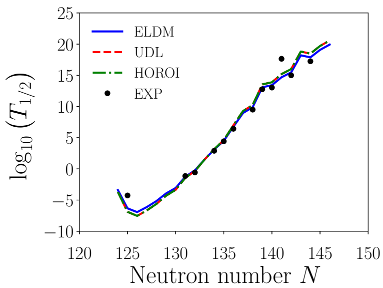

FIG. 1: α-decay half-lives.

decay mode	isotopes unstable
^{8}Be	218-229
^{12}C	218-230
^{16}O	218-229
^{20}Ne	218-230

TABLE I: Mass region unstable against various cluster decay.

The inertia coefficient μ is determined using Werner-Wheeler inertia coefficient[5]. The decay constant is calculated as

$$\lambda = \nu_o P \qquad (2)$$

where ν_o is the assault frequency and it is approximately equal to $10^{22}s^{-1}$ [6]. Finally half life for the decay is obtained as

$$T_{1/2} = \frac{\ln 2}{\lambda} \qquad (3)$$

Result and Discussion

We have selected Uranium isotopes in the mass range A=218 to 242. Alpha decay is the dominant decay mode in heavy nuclei. Here we tried to analyse the stability of U

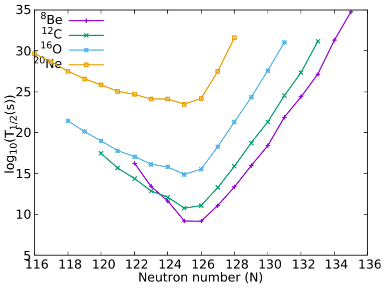

FIG. 2: Cluster decay half-lives.

isotopes against alpha decay. The half-lives are calculated using the ELDM and are plotted in fig (1). The results are compared with semi-empirical formulae, Universal Decay Law (UDL) [7] and scaling law of Horoi et al. [8]. Good agreement is obtained among the selected models and experimental values. A standard deviation of 0.947 is obtained for the ELDM values w.r.t experimental values. It is also observed that all the selected isotopes are unstable against this decay mode.

Further, we investigated whether these isotopes are unstable against the various cluster decay modes. Here, we tried to predict the emission of other clusters like ^{8}Be, ^{12}C, ^{16}O, ^{20}Ne and ^{24}Mg from U isotopes. The isotopes which are unstable against these decay modes are listed in table 1. Cluster decay half-lives are shown in fig (2). We can see that as the neutron number increases, the half-lives decreases and have a minimum value when the neutron number of daughter nuclei become 125 (near to magic N=126). On further increase of neutron number, the half-life starts increasing. The minimum half-life means, the probability of the emission of that particular cluster is maximum. This result shows the importance of shell closure in cluster decay process. Also this phenomena vanishes towards the neutron rich side.

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