Fayoum University
Faculty of Science
Physics Department

Prediction of α-Decay and Cluster Radioactivity of Heavy and Superheavy Nuclei

by

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A thesis submitted in partial fulfillment

Of

The requirements for the

Ph. D degree of Science

In

(Theoretical physics)

Physics Department

Faculty of Science

Fayoum University

(2024)

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ABSTRACT

The α-decay half-lives ($T_{1/2}$) for 16 isotopic chains of even-even and even-odd nuclei, from $_{52}$Te to $_{82}$Pb were investigated by employing the density dependent cluster model. The α-nucleus potential was calculated by the double-folding model (DFM) using the M3Y-Reid NN interaction with the zero-range exchange part assuming spherical and deformed density distributions of the daughter nuclei. In the framework of the WKB approximation, the half-lives of the α-emitters were calculated and compared using six analytic formulas: the universal curve (UNIV), the universal decay law (UDL), the scaling law of Horoi, the BKAG, the NRDX and the TM formulas. We found a clear similarity in the behavior of $log_{10}\ T_{1/2}$ versus the neutron daughter number (N_{d}) when the calculations performed using both DFM and these mentioned analytical formulas for each isotopic chain. In addition, the theoretical results of $log_{10}\ T_{1/2}$ obtained with the UDL and UNIV formulas slightly better agree with the DFM calculations than those calculated from the other analytical methods. The results pointed out some magic or semimagic neutron numbers of the daughter nuclei corresponding to dips in the behavior of $log_{10}\ T_{1/2}$ with variation in N_d. The interplay of these magic (semimagic) numbers is inspected as the total number of neutrons filling the upper neutron level in the parent nucleus. Starting from the number of neutrons needed for level closure and the available values of the confirmed spin of parent and daughter nuclei, we predicted the level schemes around the known magicities N = 50, 82, and 126. We found changes in the neutron levels for isotopes of the same element which become too large for heavy nuclei. An example for these changes is the repetition of the spin value $1/2^-$ for the three isotopes $^{195-199}$Hg, with their three odd mass numbers, and their daughters, we need five different neutron level arrangements with $3p_{1/2}$ level at the top.

Moreover, we systematically investigate the *α*-decay and spontaneous fission (SF) half-lives of SHN $Z = 124$ and 126 in the mass number range $292 \leq A \leq 314$. In this case, the *α*-decay half-lives have been calculated within the double folding model besides only three analytical formulas, the universal decay law, the scaling law of Horoi and the UNIV formula. To identify the mode of decay of these SHN, a competition between SF half-lives calculated by Xu *et al.* and *α*-decay half-lives has been performed. The study shows that the even mass number isotopes of $^{292-314}124$ and $^{292-314}126$ will survive fission, and *α*-chains can also be predicted from these SHN. The variation of $log_{10} T_{1/2}$ against parent nucleus mass numbers of *α*-decay chains of each SHN isotope is found to be governed by magic or semimagic nucleon numbers of the parent nucleus in the sense that $log_{10} T_{1/2}$ becomes maximum at or near these numbers. The probable heavy cluster radioactivity (CR) in the mass number range A_c =18-126 from $^{294-324}124$ and $^{294-312}126$ is also studied using the same four models of *α*-decay half-lives. Heavy clusters with charge numbers in the range $36 \leq Z_c \leq 46$ are dominant decay modes relative to *α*-decay. Clusters with small $log_{10} T_c$ values relative to *α*-decay are found to be the six clusters, Kr, Sr, Zr, Mo, Ru, and Pd. The most probable cluster emissions having the smallest $log_{10} T_c$ values relative to *α*-decay are $^{104-106}$Mo and $^{106-110}$Ru from $^{312}124$; from $^{296}126$ the clusters are $^{94-96}$Mo and $^{104-106}$Pd; from $^{298}126$ the clusters are ^{90}Zr and ^{96}Mo; and from the SHN isotope $^{300}126$ the most probable clusters are $^{100-102}$Ru. The most probable cluster emissions are for clusters with proton and neutron numbers (Z_c and N_c) near proton and neutron magic numbers,leaves the double magicity or semimagicity nucleus as a daughter.