Neutron magicity for $Z = 120$ using mass models

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Introduction

Superheavy elements (SHE), a term that often refers to the transactinide elements with Z>103, has become one of the interesting fields in nuclear physics. Since its discovery in 1950 by John Wheeler who examined theoretically the limits of nuclear stability, experimental advancement in producing SHN, through either hot or cold fusion nuclear reactions [1] and upto Z = 118(Og) have been synthesized. Studies suggests that new experiments are presently running at GSI, Darmstadt to produce Z = 120 [2]. Because of its low probability of formation, very short life and low reaction cross section, synthesizing it experimentaly has become a major task [3, 4]. Much of the impetus for SHE research derives from theories of nuclear structure and in particular from predictions based on the shell model developed in late 1940s. The ground state properties of nuclei such as binding energy, nuclear masses etc., are important quantities to study the stability of a nucleus. Different approaches are been made to give good estimates about these properties. In the present work, we did a comparative study with different mass models such as Weizsacker-Skyrme model(WS4) [5], Finite-range droplet model(FRDM) [6] and Dirac-Hatree-Bogoliubov calculation for spherical nuclei(DIRHBS) [7].

Methodology

To define the decay process of a parent nucleus, different approaches have been available in literature and the cubic plus proximity potential, the most followed model, is considered in this work. To start with, spherical nuclei are subjected to the interaction between the nuclear potentials and to define this , the proximity - 77 formalism is adopted. In this model, we slightly deviate from SK model that the post-scission region potential is taken as

$$V_{ext}(r) = V_n(r) + V_c(r) + V_l(r) \tag{1}$$

and the pre-scission region potential ie., the overlapping region, the barrier is approximated to the third-order polynomial in terms of the distance of mass centers of fragments, as described in [8] and the required parameters are referred from ref [8-9]. The imperative part of cluster decay, the tunneling process, the probability is obtained through the recently implemented improved transfer matrix method in nuclear decay, by us [10, 11]

$$P = |A_{N+1}|^2 . \tag{2}$$

The DIRHBS code based on the relativistic self-consistent mean field frame work is used here which solves the stationary relativistic Hartree-Bogoliubov equations and the ground state properties of Z=120 are obtained through DD-PC1 effective interaction.

Result and Discussion

This work is focused on the prediction of magic/sub-magic numbers using different mass models such as WS4, FRDM and DIRHBS for the nucleus Z=120 with neutron number N=160-250 and to compare their predictive powers on the basis of cluster decay, Q-value and half-life period. The Q-values calculated using the said mass models are plotted in fig. 1. The dips obtained in these plots w.r.t the neutron numbers are taken care off for

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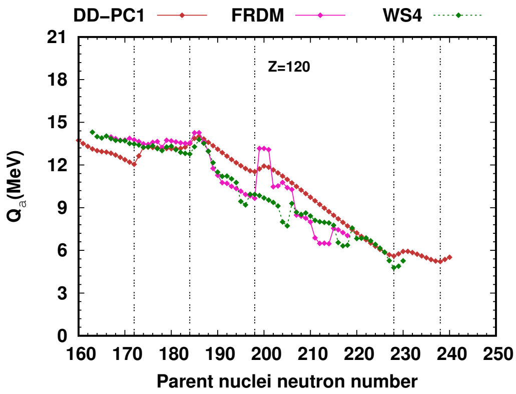

FIG. 1: Comparison of alpha decay Q-values for Z = 120 by DD-PC1 parametrization, and FRDM & WS4 mass models.

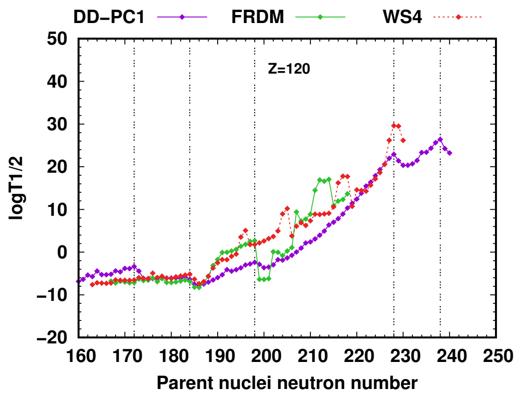

FIG. 2: $logT_{1/2}$ values for Z = 120 by DD-PC1 parametrization, and FRDM & WS4 mass models.

predicting the neutron magic numbers. The well known expected neutron magic number at N=184 is observed as a dip obtained in the Q-value by all the mass formulas. But WS4 and DIRHBS predicts N=228 as neutron magic number, while FRDM & WS4 at N=178. DIRHBS predicted neutron magic number even at low neutron numbers since the dip is obtained at N=172. Beyond N=184, N=196 & 198 may be the neutron magic numbers, where the dips are also obtained in WS4 and DIRHBS & FRDM Q-value respectively. When neutron number increases to N>200, the fall in Q-value is obtained at N=202, 208 & 212 in FRDM calculations, N=204, 218 & 228 in WS4 calculations and N=228 & 238 by DIRHBS. These dips correspond to either the magic/sub-magic numbers particularly for Z=120. The half-life ($logT_{1/2}$) of α -decay plotted in fig. 2 shows longer half lives at N = 172, 184, 198, 228 and 238 for DIRHBS; N = 178, 184, 196, 204 or 206, 218 & 228 for WS4 and at N = 178, 184, 198, 202, 208 & 212 for FRDM which correspond to the dips obtained in Q-value. From the plots of Q-value and $logT_{1/2}$ (fig. 1 & fig. 2) the fluctuation in the plots of WS4 and FRDM shows the less predictive power compared to the smooth DIRHBS plot.

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