Ternary shape parametrization

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Introduction

A nucleus approaches the saddle point shapes with a single neck (double neck) before it undergoes binary (ternary) fission, respectively. Trentalange *et al.,* [1] studied the ternary and quaternary saddle point shapes using the axially symmetric Legendre polynomials expansion method. They found that the saddle point energies for the ternary and quaternary shapes has higher energies compared with binary. Frankfurt group [2] studied the ternary fission dynamical effects of the superheavy nucleus $^{298}114$ using the five dimensional three-center shell model parametrization. The constant two body viscosity μ was considered to solve the classical equations of motion. The effect of the initial conditions like deformation of fragments, initial kinetic energy and the μ on the dynamical trajectories were reported.

Shape parametrization

In the present study, the Funny-Hills [3] parametrization (c,h,α) is used to characterize the ternary fission shapes. This parametrization was successfully applied for the fission studies by numerous authors. Here, the elongation c, the neck thickness h and the axially symmetric ($\alpha = 0$) shapes are considered. The variation of the neck thickness h without changing the length in the units of R_0 is considered. The nuclear surface in the cylindrical coordinates is given as,

$$\rho_s^2(z) = \left(1 - \frac{z^2}{c^2}\right)\left(a\,c^2 + b\,z^2\right) \qquad (1)$$

where the z coordinate represents the symmetry axis and the nuclear radius is denoted by ρ_s. a and b defined in terms of c and h.

$$a = \frac{1}{c^3} - \frac{b}{5}; \quad b = \frac{c-1}{2} + 2h \qquad (2)$$

In Eq. (1), ternary fission shape arises for magnitude of the negative b values higher than the a values $|-b| \geq a$, without introducing any additional parameters. In the present study, the shapes of ^{240}Pu for the $c = 1.6$ to 2.0 and the $h = 0$ to 1 values are considered. The negative values of h are neglected to avoid physically unacceptable diamond like shapes and the heavy fragment in the middle which are energetically unfavoured.

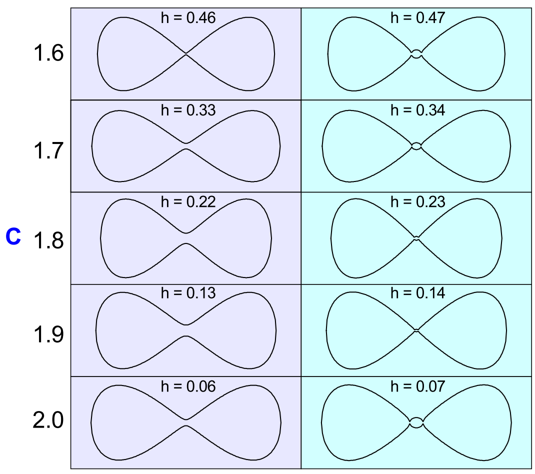

FIG. 1: Evolution of binary to ternary shapes for different c and h values

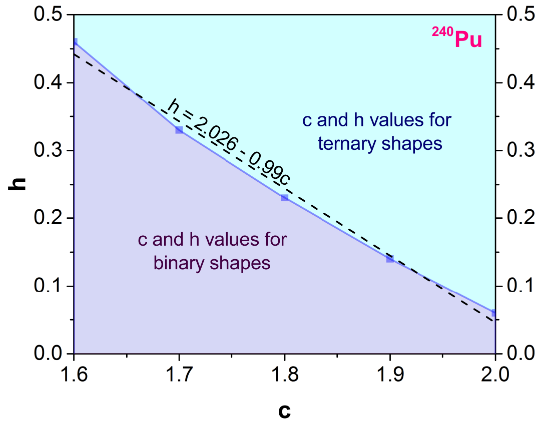

FIG. 2: Condition for binary to ternary for the h values as a function of c.

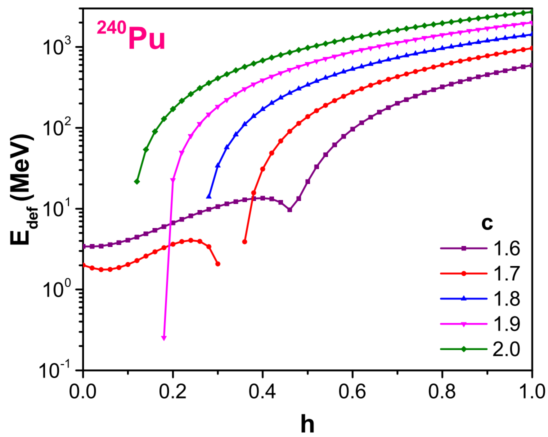

FIG. 3: E_{def} as a function of h for the different c values.

Results and discussions

In Fig. 1, the evolution of the binary to ternary shape for different c values are shown. In ternary shape, the size of the middle fragment increases with the value of h which is not shown here. The region of c and h values for the binary (violet) and ternary (cyan) shapes are shown in Fig. 2. The condition for binary to ternary shapes is obtained by linear fitting as $h = 2.026 - 0.99c$. The potential energy $E(c, h)$ for the different shapes are calculated using the folded Yukawa plus exponential energy and the Coulomb energy. The deformation energy is calculated as $E_{def} = E(c, h) - E_0$, where E_0 is the potential energy of the spherical shape. The deformation energies as function of h for the different c values are shown in Fig. 3. Here, E_{def} are plotted in log scale. The negative values of E_{def} for $c = 1.7 - 2.0$ are not shown due to log scale. The deformation energies increases exponentially upto $h = 0.5$ except transition region where E_{def} decreases. Further, E_{def} increases linearly beyond $h = 0.5$ and reaches a saturation. For ternary fission shapes the deformation energies are lower if the particle are at the middle is small. If it is large, the E_{def} is higher, indicating that, the light charged particle accompanied fission has larger probability than the heavy fragment accompanied fission. This parametrization explains successfully the following experimental facts:

i The light third particle forms between the two fission fragments.

ii The probability of the ternary fission decreases with the size of the third particle due to increase in the value of E_{def} with the size of the third particle.

To summarize, without introducing any additional parameters, the ternary fission shapes are obtained within the Funny-Hills parametrization. The binary to ternary shape evolution condition is obtained using the linear fitting. The deformation energies for these shapes are calculated.

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References

[1] S. Trentalange *et al.*, Phys. Rev. C **22**, 1159 (1980).

[2] Xi-zhen Wu *et al.*, Il Nuovo Cimento A **87**, 3 (1985).

[3] M. Brack *et al.*, Rev. Mod. Phys. **44**, 320 (1972).