Study of Decay properties of $^{269-271}$Hs* nucleus formed via Different incoming Channels by using GSkI Skyrme Force

Aman Deep[1], Niyti[1],* Rajesh Kharab[1], Sahila Chopra[2], and Raj K. Gupta[2]
[1]*Department of Physics, Kurukshetra University, Kurukshetra - 136119, INDIA and*
[2]*Department of Physics, Panjab University, Chandigarh - 160014, INDIA*

Introduction

The occurrence of superheavy nuclei is due to the quantum shell effect that overcomes the strong Coulomb repulsion between the large numbers of protons and stabilized them against spontaneous fission. In the present work, we extend our earlier [1] study of the excitation functions (EFs) of ^{274}Hs*, formed in fusion reactions ^{26}Mg+^{248}Cm, ^{48}Ca+^{226}Ra and ^{36}S+^{238}U, based on Dynamical Cluster-decay Model (DCM) [2], to the use of other nuclear interaction potential derived from Skyrme energy density formalism (SEDF) based on semiclassical extended Thomas Fermi (ETF) approach. The Skyrme force used is the new GSkI force [3] for our calculation for cross section and comparison with the experimental data taken from [4–7]. Here, only the EFs for the production of $^{269-271}$Hs isotope via 3n-5n decay channel from the ^{274}Hs* compound nucleus are studied at $E^* = 40$ to 51 MeV for three incoming channel, including quadrupole deformations β_{2i} and "hot-optimum" orientations θ_i. The calculations are made within the DCM where the neck-length ΔR is the only parameter representing the relative separation distance between two fragments and/or clusters A_i(i=1,2) which assimilates the neck formation effects.

Methodology

The nucleus-nucleus interaction potential in SEDF, based on ETF method, is defined as

$$V_N(R) = E(R) - E(\infty) = \int H(\vec{r})d\vec{r} - \left[\int H_1(\vec{r})d\vec{r} + \int H_2(\vec{r})d\vec{r}\right] \quad (1)$$

*Electronic address: sharmaniyti@gmail.com

where H is the Skyrme Hamiltonian density, a function of nucler, kinetic-energy, and spin-orbit densities, the later two themselves being the functions of the nucleon/ nuclear density, written in terms of, so-called, the Skyrme force parameters, obtained by fitting to ground-state properties of various nuclei. There are many such forces, both old and new, and we have chosen new GSkI Skyrme [3] force for our calculation. The radius vectors for axially symmetric deformed nuclei are

$$R_i(\alpha_i, T) = R_{0i}(T)\big[1 + \sum_\lambda \beta_{\lambda i} Y_\lambda^{(0)}(\alpha_i)\big], \quad (2)$$

with T-dependent equivalent spherical nuclear radii $R_{0i}(T) = R_{0i}(T = 0)(1 + 0.0007T^2)$ [8] for the nuclear proximity pocket formula, and $R_{0i}(T) = R_{0i}(T = 0)(1 + 0.0005T^2)$ [9] for SEDF, where $R_{0i}(T = 0) = [1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3}]$.

Finally, the compound nucleus temperature T (in MeV) is given by

$$E^* = E_{c.m.} + Q_{in} = (A/10)\, T^2 - T. \quad (3)$$

Adding to V_N, the Coulomb and angular momentum ℓ-dependent potentials V_C and V_ℓ, we get the total interaction potential $V(R, \ell)$, characterized by barrier height V_B^ℓ, position R_B^ℓ and curvatur $\hbar\omega_\ell$, each being ℓ-dependent.

The compound nucleus decay/ fragment formation cross sections are calculated within the DCM, given as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; \qquad k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (4)$$

where P_0 is preformation probability referring to mass asymmetry $\eta\, [= (A_1 - A_2)/(A_1 + A_2)]$

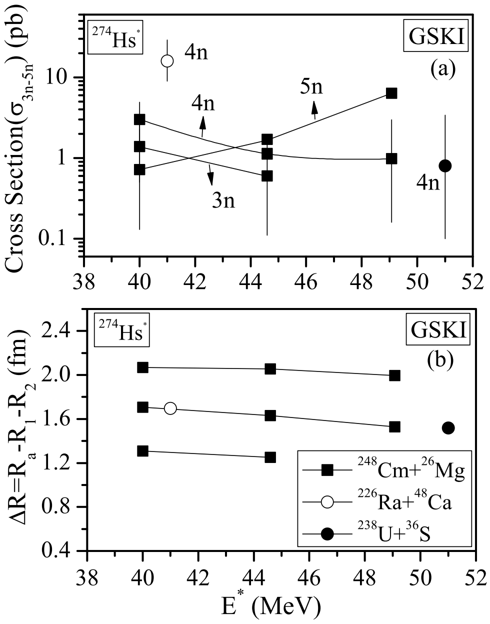

FIG. 1: (a) A comparison of experimental 3n-5n evaporation channel cross section(σ_{3n-5n}) (lines denotes theoretical results and symbol denotes experimental results) for the fusion reactions ^{248}Cm(^{26}Mg,5n-3n)$^{269-274}$Hs, ^{226}Ra(^{48}Ca,4n)^{274}Hs and ^{238}U(^{36}S,4n)^{274}Hs with the calculations made for the included DCM GSkI Skyrme force. (b) The best fitted ΔR values obtained for 3n to 5n evaporation cross section from CN ^{274}Hs as a function of energy.

motion and P, the penetrability, to R motion. For further details, refer to [2, 10].

Calculations and Results

Fig.1 (a) shows the comparison of experimental 3n to 5n evaporation channel cross section with the calculations made by using the GSkI Skyrme Force. Fig.1 (b) shows the best fitted neck-length parameter ΔR as a function of E^* for 3n to 5n evaporation channel cross section of ^{274}Hs*. The calculations are made for the best fit to each and every data point, and the curves are the results of graphical fit functions for the guide of eyes. Apparently, the GSKI Skyrme force included DCM reproduces the data nicely with in one parameter fitting(ΔR). An interesting result from Fig.1(b) is that ΔR for a given decay channel, say, 3n, 4n, or 5n, is independent of the entrance-channel (t,p) combination. Specifically, we notice that, though cross sections for the 4n decay channel in three reactions (^{26}Mg+^{248}Cm, ^{48}Ca+^{226}Ra and ^{36}S+^{238}U) are quite different (respectively, 3, 0.8 and 16 pb; ΔR is nearly the same, the small change of (± 0.2fm) being due to the spread in E* from 40 to 51 MeV. In other words, the decay process at a fixed E* occurs at the same relative separation, independent of incoming channel, irrespective of their producing strongly varying cross sections as observed in one earlier work [1] as well.

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