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

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Introduction

The production of superheavy nuclei is only possible due to the quantum shell effect that overcomes the strong Coulomb repulsion between the large numbers of protons and stabilized them against spontaneous fission. The method being used successfully for the synthesis of superheavy elements is that of complete fusion reactions, which are classified as Pb- or Bi-based cold fusion and ^{48}Ca based hot fusion reactions. In the present work, we extend our earlier [1] study of the excitation functions (EFs) of ^{274}Hs*, formed in hot fusion ($E^*>$ 25MeV) reactions ^{26}Mg+^{248}Cm [2], ^{48}Ca+^{226}Ra [3] and ^{36}S+^{238}U [4], based on Dynamical Cluster-decay Model (DCM) [5], 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 old SIII force [6] for our calculation for cross section and compared with experimental data taken from [2–4]. 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.

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Methodology

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

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

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 SIII Skyrme [6] 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 $R_{0i}(T)=R_{0i}(T=0)(1+0.0007T^2)$ [7] for the nuclear proximity pocket formula, and $R_{0i}(T)=R_{0i}(T=0)(1+0.0005T^2)$ [8] 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.

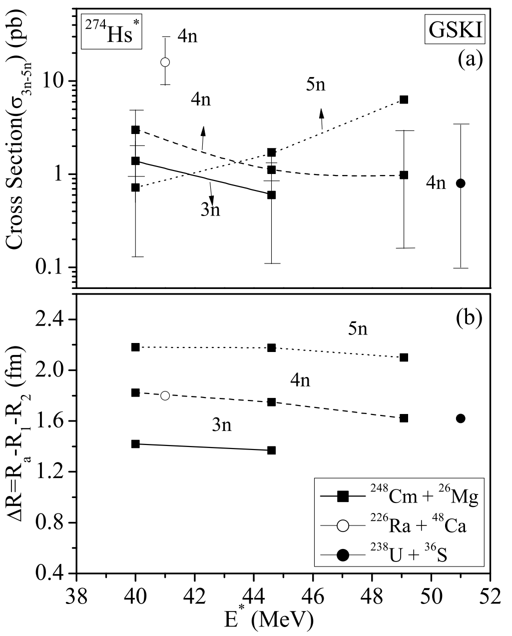

FIG. 1: (a) A comparison of experimental 3n-5n evaporation channel cross section (σ_{3n-5n}) for the fusion reactions ^{248}Cm(^{26}Mg,5n-3n)$^{269-274}$Hs, ^{226}Ra(^{48}Ca,4n)^{274}Hs and ^{238}U(^{36}S,4n)^{274}Hs with the calculations made for the included DCM SIII Skyrme force. (b) The best fitted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

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

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

where P_0 is preformation probability referring to mass asymmetry η [$=(A_1-A_2)/(A_1+A_2)$] motion and P, the penetrability, to R motion. For further details, refer to [5, 9].

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 SIII 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*. Apparently, the SIII 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. This result strongly agrees with experiment and supports our previous findings [1].

Acknowledgments

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