Study of decay of ^{270}Sg* formed in ^{22}Ne + ^{248}Cm fusion reaction using KDE0(v1) Skyrme Force

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Introduction

The existence of superheavy (Z>100) nuclei is possible only by compensating the coulombian repulsive force by shell stabilization. To establish the existence of enhanced nuclear stability near the predicted deformed shells at Z=108 and N=162, the isotopes ^{265,266}Sg were reported by Lazarev et al.[1] in the ^{248}Cm(^{22}Ne,xn)$^{270-x}$Sg reaction at the Dubna Gas Filled Recoil Separator (DGFRS). In 2009 Düllmann et al.[2] reevaluated the decay properties of ^{265}Sg and found the isomeric state in ^{265}Sg. They also reanalyzed the cross section of the reaction ^{248}Cm(^{22}Ne,5n)^{265}Sg and found order of cross section for 5n emission was few hundred pb, by assuming α decay is the only decay mode. Recently Haba et al. [3] refined the production cross sections for isomeric state ^{265}Sg^a and ^{265}Sg^b determined 180^{80}_{-60}pb and 200^{60}_{-50} pb at 117.8 MeV, respectively which give a total cross section of $\sigma(^{265}\text{Sg}^a+^{265}\text{Sg}^b)= 380^{90}_{-70}$ pb.

In the present work, we have studied the excitation functions (EFs) of ^{270}Sg*, formed in fusion reactions ^{22}Ne+^{248}Cm [3], based on Dynamical Cluster-decay Model (DCM) [4]. For the nuclear interaction potentials, we use the Skyrme energy density functional (SEDF) based on semi-classical extended Thomas Fermi (ETF) approach under frozen density approximation. The Skyrme force used is the KDE0(v1)[5] force for our calculation for cross section and comparison with the experimental data taken from [2, 3]. Here, only the EFs for the production of ^{270}Sg* isotope via 5n decay channel from the ^{270}Sg* compound nucleus are studied at $E^* = 44$ to 52 MeV, including quadrupole deformations β_{2i} and "hot-compact" 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

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

where H is the Skyrme Hamiltonian density, a function of nuclear, kinetic-energy, and spin-orbit densities, the latter 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 here we have chosen new KDE0(v1) Skyrme[5] 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 $R_{0i}(T) = R_{0i}(T=0)(1 + 0.0007T^2)$ [6] for the nuclear proximity pocket formula, and $R_{0i}(T) = R_{0i}(T=0)(1 + 0.0005T^2)$ [7] 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 curvature $\hbar\omega_\ell$, 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 $\eta\,[=(A_1-A_2)/(A_1+A_2)]$ motion and P, the penetrability, to R motion. For further details, refer to [4, 5, 8].

Calculations and Results

Fig.1 (a) shows the comparison of experimental 5n evaporation channel cross section with the calculations made by using the KDE0(v1) Skyrme Force. Fig.1 (b) shows the best fitted neck-length parameter ΔR as a function of E^* for 5n evaporation channel cross section of ^{270}Sg*. An interesting result from Fig.1(a) is that our model reproduced the 5n evaporation cross section successfully for the given compound nucleolus(CN), and the fig1(b) represent the neck length parameter (ΔR) at different given excitation energy for the CN ^{270}Sg*. In other words, the decay products for different E* have different reaction time.

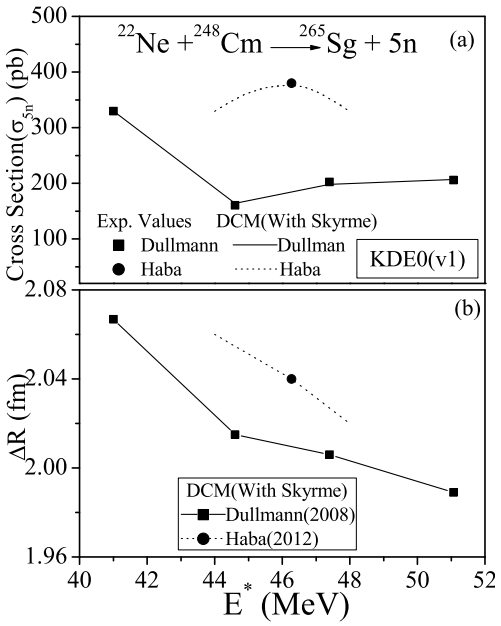

FIG. 1: (a) A comparison of experimental 5n evaporation channel cross section (σ_{5n}) for the fusion reactions ^{248}Cm(^{22}Ne,5n)^{270}Sg [2, 3], with the Skyrme included DCM. Fig1(b) The best fitted ΔR values obtained for 5n evaporation cross section from compound nucleus ^{270}Sg* as a function of excitation energy for KDE0(v1) Skyrme force.

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