Study of decay of $^{270}\text{Sg}^*$ formed in $^{22}\text{Ne} + ^{248}\text{Cm}$ 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 $^{265,266}\text{Sg}$ were reported by Lazarev et al.[1] in the $^{248}\text{Cm}(^{22}\text{Ne,xn})^{270-}\text{Sg}$ reaction at the Dubna Gas Filled Recoil Separator (DGFRS). In 2009 Dillmann et al.[2] reevaluated the decay properties of $^{265}\text{Sg}$ and found the isomeric state in $^{265}\text{Sg}$. They also reanalyzed the cross section of the reaction $^{248}\text{Cm}(^{22}\text{Ne,5n})^{265}\text{Sg}$ and found order of cross section for 5n emission was few hundred pb, by assuming a decay is the only decay mode. Recently Haba et al. [3] refined the production cross sections for isomeric state $^{265}\text{Sg}^b$ and $^{265}\text{Sg}^a$ determined 180$^{90}_{60}$ pb and 200$^{90}_{50}$ 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 $^{270}\text{Sg}^*$, formed in fusion reactions $^{22}\text{Ne} + ^{248}\text{Cm}$ [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 $^{270}\text{Sg}^*$ isotope via 5n decay channel from the $^{270}\text{Sg}^*$ compound nucleus are studied at $E^* = 44$ to 52 MeV, including quadrupole deformations $\beta_2$, and “hot-compact” orientations $\theta_i$. The calculations are made within the DCM where the neck-length $\Delta R$ 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

$$V_N(R) = E(R) - E(\infty)$$

$$= \int H(\vec{r})d\vec{r} - \left[ \int H_1(\vec{r})d\vec{r} + \int H_2(\vec{r})d\vec{r} \right]$$

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

$$R_i(\alpha_i, T) = R_{0i}(T)\left[1 + \sum_{\lambda} \beta_{\lambda} \mathcal{Y}_{\lambda}^{(0)}(\alpha_i)\right],$$

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 $R_{0i}(T = 0) = [1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3}]$.

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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 $\ell$-dependent potentials $V_C$ and $V_\ell$, we get the total interaction potential $V(R, \ell)$, characterized by barrier height $V_b$, position $R_b$ and curvature $\hbar \omega$, each being $\ell$-dependent.

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

$$\sigma = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{\text{max}}} (2\ell + 1) P_0 P; \quad k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (4)$$

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 $\Delta R$ as a function of $E^*$ for 5n evaporation channel cross section of $^{270}\text{Sg}^*$. An interesting result from Fig.1(a) is that our model reproduced the 5n evaporation cross section successfully for the given compound nucleus(CN), and the Fig1(b) represent the neck length parameter ($\Delta R$) at different given excitation energy for the CN $^{270}\text{Sg}^*$. In other words, the decay products for different $E^*$ have different reaction time.

**References**


