Skyrme Forces and the Decay of $^{266}_{104}$Rf* nucleus formed via different incoming channels

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Introduction

In recent years, decay studies of nuclei located around Z =108 and N=162, such as $^{269-271}$Hs, ^{265,266}Sg, and ^{261,262}Rf, have attracted special interest to verify the existence of a shell closure predicted at Z =108 protons and N =162 neutrons. Among transactinide series, the study of Z=104 Rf isotopes has been of much interest since 1964. The first signature of the Rf nucleus was reported at the Joint Institute for Nuclear Research (JINR), Dubna (USSR) in ^{22}Ne-induced reactions with the ^{242}Pu actinide target. The second major reaction proposed for Rf production was ^{18}O+^{248}Cm, for which the unique identification of a spontaneously fissioning (SF) nuclide with a half-life of a few seconds was suggested. Recently, the same reaction was again investigated and the excitation functions of ^{260}Rf, ^{261}Rf, and ^{262}Rf were measured, using the gas-filled recoil ion separator (GARIS) at Rikagaku Kenkyusho (RIKEN) [1]. Earlier, Gorshkov *et al.* [2] produced ^{261}Rf by ^{22}Ne+^{244}Pu reaction at GSI.

In the present work, we study the excitation functions (EFs) of ^{266}Rf*, formed via different incoming channels ^{18}O+^{248}Cm and ^{22}Ne+^{244}Pu, which have been studied earlier on the basis of the Dynamical Cluster-decay Model (DCM) [3], using, respectively, the pocket formula for nuclear proximity potential and nuclear interaction potentials derived from Skyrme energy density formalism (SEDF) based on semiclassical extended Thomas Fermi (ETF) approach. The Skyrme forces used are the old forces SIII and SIV, and new forces GSkI and KDE0(v1) [4], with the experimental data taken from [1] for ^{18}O+^{248}Cm and from [2] for ^{22}Ne+^{244}Pu reaction. Here, only the EFs for the production of ^{261}Rf isotope via 5n decay channel from the ^{266}Rf* compound nucleus are studied at E_{lab}=88.2 to 115.888 MeV. The calculations are made within the DCM where neck-length ΔR is the only parameter representing the relative separation distance between two fragments and/or clusters A_i which assimilates the neck formation effects. All calculations are made for deformed and oriented co-planar nuclei, taking quadrupole deformations β_{2i} and "hot-optimum" orientations θ_i.

Methodology

The semiclassical Extended Thomas Fermi (ETF) model: The ETF defines the nucleus-nucleus interaction in SEDF, as

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

where H is the Skyrme Hamiltonian density, a function of nuclear, kinetic-energy, and spin-orbit densities, the later two themselves being the functions of the nucleon/ nuclear density, written in terms of the, so-called, Skyrme force parameters, obtained by fitting to ground-state properties of various nuclei. There are many such forces, both old and new, and we choose two old SIII, SIV and two new GSkI, KDEV(0) forces, the later having an additional tensor coupling term with spin and gradient, fitted also to isospin-rich nuclei. The nuclear density is the T-dependent, two-parameter Fermi density, and for the composite system, densities are added in frozen densities approximation (see [4] for detalis).

Adding to V_N, the Coulomb and angular

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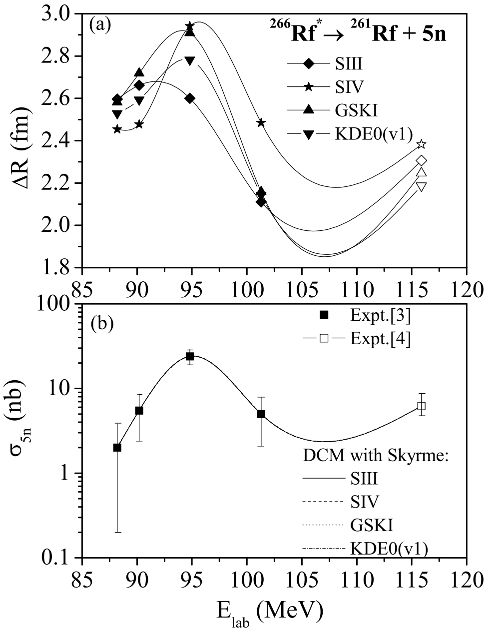

FIG. 1: (a) The best fitted ΔR values obtained for the four Skyrme forces. (b) A comparison of experimental 5n evaporation channel cross section σ_{5n} for the fusion reaction ^{18}O+^{248}Cm [1] and ^{22}Ne+^{244}Pu [2] with the calculations made for the four Skyrme Forces SIII, SIV, GSkI and KDE0(v1) potentials. Note that the solid symbols show ^{18}O+^{248}Cm reaction data and the hollow symbols that of ^{22}Ne+^{244}Pu reaction.

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, as

$$V(R,\ell) = V_C(R,Z_i,\beta_{\lambda i},\theta_i,T) + V_N(R,A_i,\beta_{\lambda i},\theta_i,T) + V_\ell(R,A_i,\beta_{\lambda i},\theta_i,T). \quad (2)$$

Calculations and Results

Fig. 1(a) shows the best fitted neck-length parameter ΔR as a function of E_{lab} for 5n evaporation channel cross section of ^{266}Rf* formed in fusion reactions ^{18}O+^{248}Cm and ^{22}Ne+^{244}Pu. Fig. 1(b) shows the comparison of experimental 5n evaporation channel cross section σ_{5n} [1] with the calculations made by using the chosen four Skyrme Forces SIII, SIV, GSkI and KDE0(v1). 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 DCM reproduces the data nicely with in one parameter fitting, independent of chosen Skyrme force nuclear interaction potentials used, and also independent of the incoming channels.

Concluding, in DCM, the EFs of 5n decay of ^{266}Rf* are independent of the choice of Skyrme force and entrance channel.

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