Decay of ^{266}Rf* formed in the fusion reaction ^{18}O+^{248}Cm using Skyrme forces based interaction potentials

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Introduction

The first signature of the ^{104}Rf nucleus was reported at the Joint Institute for Nuclear Research (JINR), Dubna in ^{22}Ne-induced reactions with a ^{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].

In the present work, we extend our earlier study of the excitation functions (EFs) of ^{266}Rf*, formed in fusion reaction ^{18}O+^{248}Cm, based on Dynamical Cluster-decay Model (DCM) [2] using the pocket formula for nuclear proximity potential (Prox-77), to the use of other 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 force SIII, and new forces GSkI and KDE0(v1) [3], with the experimental data taken from [1]. Here, only the EFs for the production of ^{262}Rf isotope via 4n decay channel from the ^{266}Rf* compound nucleus are studied at E_{lab} = 88.2 to 94.8 MeV, 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 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

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

where H is the Skyrme Hamiltonian density, a function of 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 choose an old SIII and new GSkI and KDE0(v1) 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. For the angular momentum dependent potential V_ℓ, we use the sticking moment-of-inertia I_S. The radius vectors for axially symmetric deformed nuclei are

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

with T-dependent equivalent spherical nuclear radii $R_{0i}(T) = R_{0i}(T=0)(1 + 0.0007T^2)$ [4] for the nuclear proximity pocket formula, and $R_{0i}(T) = R_{0i}(T=0)(1 + 0.0005T^2)$ [5] 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

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

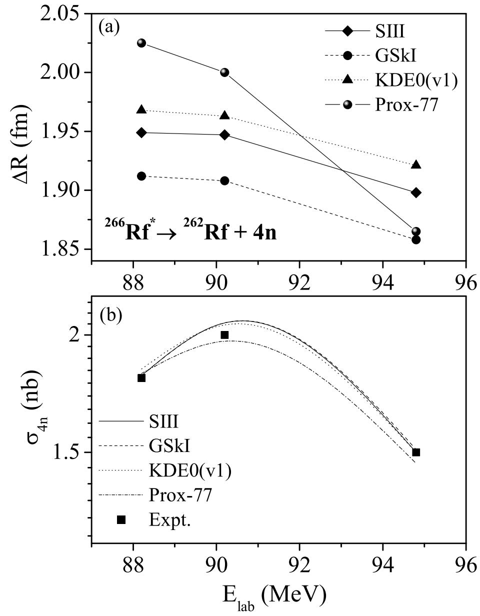

FIG. 1: (a) The best fitted ΔR values obtained for the three Skyrme forces, compared with those for nuclear proximity potential [2]. (b) A comparison of experimental 4n evaporation channel cross section σ_{4n} for the fusion reaction ^{18}O+^{248}Cm [1] with the calculations made for the three Skyrme Forces SIII, GSkI and KDE0(v1), and nuclear proximity potential [2].

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

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

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 [2, 3].

Calculations and Results

Fig.1 (a) shows the best fitted neck-length parameter ΔR as a function of E_{lab} for 4n evaporation channel cross section of ^{266}Rf* formed in the fusion reaction ^{18}O+^{248}Cm. Fig.1 (b) shows the comparison of experimental 4n evaporation channel cross section σ_{4n} [1] with the calculations made by using the three Skyrme Forces SIII, GSkI and KDE0(v1), and earlier used pocket formula for nuclear proximity potential [2]. 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 nuclear interaction potential used.

The interesting result of Fig. 1 (a) is that the ΔR for Skyrme forces, as well as the pocket formula for nuclear proximity potential, remain within the nuclear proximity limit of ∼2 fm. The accurate reproduction of the data within one parameter fitting using different nuclear interaction potentials emphasizes the credibility of the DCM.

The calculations of the excitation functions for the production of ^{260}Rf and ^{261}Rf isotopes via 6n- and 5n-decay channels of the ^{266}Rf* compound nucleus are underway and will be published elsewhere.

Acknowledgments

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