Fusion and fragmentation analysis of $^{122}Ba^*$ formed in ^{58}Ni + ^{64}Ni reaction around near barrier energy region

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Introduction

The main objective of this paper is to address the experimental fusion cross-sections for ^{58}Ni + ^{64}Ni reaction measured by A. M. Stefanini[1] in the energy range $E_{c.m.} = 86 - 105$ MeV and to carry out the fragmentation analysis. The fusion mechanism of the ^{58}Ni + ^{64}Ni reaction is analyzed in terms of energy dependent Woods-Saxon potential (EDWSP) model [2] and the fragmentation analysis is investigated within the framework of the Dynamical Cluster-decay Model (DCM)[3]. In the EDWSP model, the energy dependent nature of Woods-Saxon potential induces barrier modification effects and explain the energy dependence of fusion cross-sections of the chosen reaction satisfactorily. The decay process of the compound nucleus ^{122}Ba* exhibited via symmetric fusion channel ^{58}Ni + ^{64}Ni is analyzed by using the DCM [3]. The ER cross-sections are addressed by varying the neck-length parameter (ΔR) of the model, for the deformed choice of fragmentation (β_2 deformed fragments) and the DCM calculated cross-sections lie in fair agreement with the experimental data.

Methodology

The fusion process of the studied reaction is examined by using EDWSP model where the Woods-Saxon parametrization of nuclear potential has been adopted. The potential depth V_0 is defined below

$$V_0 = [({A_P}^{2/3} + {A_T}^{2/3}) - (A_P + A_T)^{2/3}] \times [2.38 + 6.8(1 + I_P + I_T)\frac{A_P^{1/3}A_T^{1/3}}{(A_P^{1/3} + A_T^{1/3})}]MeV \quad (1)$$

where, $I_P = \frac{N_P - Z_P}{A_P}$ and $I_T = \frac{N_T - Z_T}{A_T}$ are isospin asymmetry of the participating systems. In EDWSP approach, the energy dependent diffuseness parameter a is given below as:

$$a(E) = 0.85[1 + \frac{r_0}{[13.75({A_P}^{-1/3} + {A_T}^{-1/3})(1 + exp(\frac{\frac{E_{c.m.}}{V_{B0}} - 0.96}{0.03}))]}] \quad (2)$$

where the range parameter (r_0) is directly connected with the geometrical shape of fusing partners ($R_0 = r_0({A_P}^{1/3} + {A_T}^{1/3})$). The decay analysis of the compound nucleus(^{122}Ba*) formed via fusion of ^{58}Ni + ^{64}Ni is done by using DCM model. In DCM [3], the structural information about the decay of the compound nucleus enters in the preformation probability through fragmentation potential $V_R(\eta,T)$, defined as:

$$V_R(\eta, T) = \sum_{i=1}^{2}[V_{LDM}(A_i, Z_i, T)] + \sum_{i=1}^{2}[\delta U_i]\exp(-T^2/T_0^2) + V_C(R, Z_i, \beta_{\lambda i}, \theta_i, T) + V_P(R, A_i, \beta_{\lambda i}, \theta_i, T) + V_\ell(R, A_i, \beta_{\lambda i}, \theta_i, T) \quad (3)$$

Calculations and discussions

In Fig. 1(a), the EDWSP calculated fusion cross-sections of ^{58}Ni + ^{64}Ni reaction are shown along with the experimental data in the center of mass energy. In EDWSP

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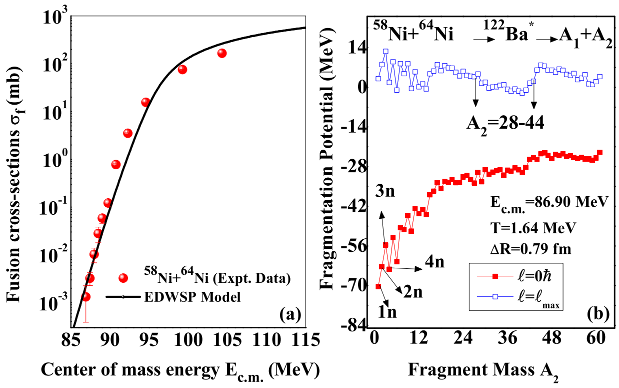

FIG. 1: (a)Fusion cross-sections calculated by usinf EDWSP model plotted in terms of $E_{c.m.}$ along with experimental cross-sections and (b) fragmentation potential plotted in terms of A_2 for $^{122}Ba^*$ at lowest $E_{c.m.}$=86.90 MeV and extreme angular momentum values.

model, as consequence of energy dependence in the Woods-Saxon potential, EDWSP becomes more attractive in nature as compared to the standard Woods-Saxon potential. In this sense, the EDWSP modifies the barrier profile of the interaction barrier and reduces the effective fusion barrier between the participants. Thus, the EDWSP model predicts much larger fusion cross-sections as compared to the output of the one dimensional barrier penetration model(BPM) and hence fairly describes the behavior of fusion cross-section of the present reaction in near and sub-barrier energy regions as evident from Fig.1(a). The barrier height (V_{B0}=98.66 MeV), barrier position (R_B=10.69 fm) and barrier curvature ($\hbar\omega$=3.97 MeV) corresponding to the Coulomb barrier are used in Wong formula [4] for theoretical calculations. For the studied reaction, the range parameter r_0 =1.090 fm has been taken and other potential parameters for calculations are defined in Eq.(1) to Eq.(2). In this regard, the EDWSP intrinsically considers the effects of dominant channel couplings due to energy dependency of the interaction potential.

The fragmentation structure of ^{122}Ba* is investigated through the fragmentation potential and it is plotted in Fig. 1(b) for all the probable exit channels of the decaying systems ^{122}Ba* at minimum E$_{c.m.}$=86.90 MeV and extreme angular momentum values [ℓ = $0\hbar$ and ℓ_{max}= $64\hbar$]. At lower ℓ-states, the magnitude of fragmentation potential is lower for lighter mass particles (LPs) as compared to heavy mass fragments, signifying that the emergence of ERs is favored at lower ℓ-states. The higher magnitude of fragmentation potential for heavier fragments suggests that their probability of emergence in the decay channel is relatively small. However, at higher ℓ-states structural changes are observed and the fragmentation potential of heavier fragments become comparable to that of the ERs, indicating the emergence of IMF and HMF in the exit channel also. In addition to this, α-structuring is also visible for lighter mass region (A$_2$ $\leq$ 10) for ^{122}Ba* that refers to the odd-even effect, showcasing that even mass nuclei are more energetically favored as compared to odd-mass nuclei.

References

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