Fission fragment distribution of ^{181}Re* nucleus formed via ^{12}C induced reaction

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Introduction

Nuclear fission has been an important and interesting field of nuclear physics for a long time. As far as heavy-ion induced fission is concerned, it is extensively investigated in terms of various statistical and dynamical models, but the proper understanding of the emitting fission fragments is not yet fully accomplished. The proper knowledge of the various outgoing fragments at a particular beam energy is very essential, as it provides the respective half-life and the other characteristics of the decaying fragment. In view of this, the decay of hot and rotating compound nucleus ^{181}Re* formed in the reaction ^{12}C + ^{169}Tm at beam energy $E_{Lab.}$=89.25 MeV [1] is analyzed using the dynamical cluster-decay model (DCM) [2]. We have carried out the calculations to analyze the mass distribution of fission fragments in the decay of above mentioned compound system and then compared the DCM observed emitting fission fragments with the ones identified in the experiment [1]. Also, the total fission cross-sections are addressed in reference to the available experimental data. Further, an attempt has been made to predict the fission emission times of the various fragments emitting from ^{181}Re* nucleus.

Methodology

The dynamical cluster model (DCM) [2] uses the collective coordinates of mass and charge asymmetries ($\eta = \frac{A_1-A_2}{A_1+A_2}$ and $\eta_Z = \frac{Z_1-Z_2}{Z_1+Z_2}$), the relative separation R, and the multipole deformations $\beta_{\lambda i}$ and orientations θ_i (i=1, 2) of daughter and cluster nuclei which allows to define the decay cross sections σ and half-life $\tau_{1/2}$, or the decay constant λ as,

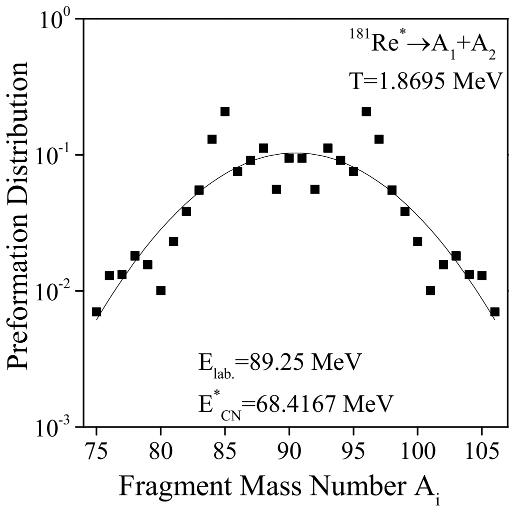

FIG. 1: The preformation distribution as a function of fragment mass number A_i in the decay of compound nucleus ^{181}Re* at ℓ=ℓ_{max}=124$\hbar$.

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P \quad (1)$$

$$\lambda = \nu_0 P_0 P, \qquad \tau_{1/2} = \frac{\ln 2}{\lambda} \quad (2)$$

Here, ν_0 is the assault frequency, P_0 corresponds to cluster preformation probability and P is the barrier penetrability which is calculated using WKB approximation. The structure information of the decaying nucleus is contained in P_0 via the fragmentation potential defined as:

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

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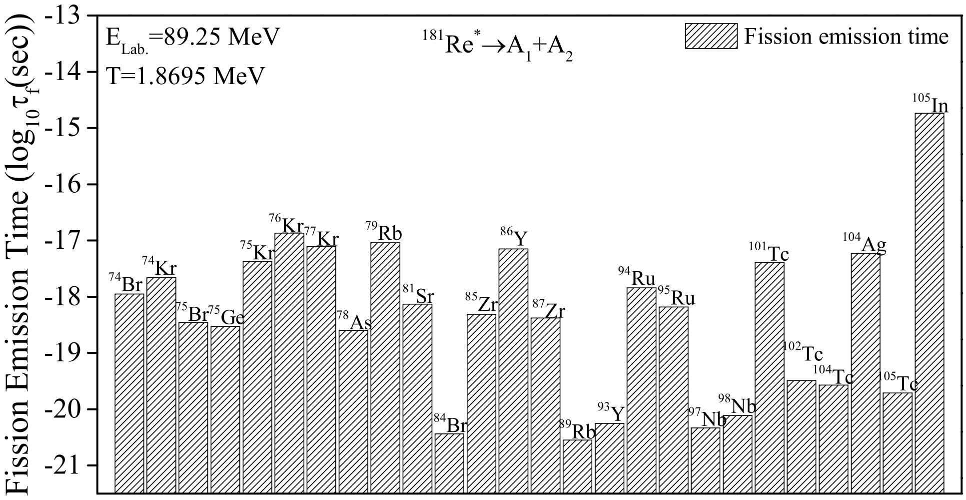

FIG. 2: The DCM predicted fission emission times τ_f (sec) for various probable outgoing fragments at E_{lab}=89.25 MeV

where V_C, V_P and V_ℓ are, respectively, the Coulomb, nuclear proximity and centrifugal potentials. The normalized fractional cluster preformation probability P_0 at a fixed R (=R_a=R_t+ΔR, the first turning point) is obtained by solving Schrodinger Equation in η-coordinates and reads as:

$$P_0 = |\psi[\eta(A_i)]|^2 \frac{2}{A}\sqrt{B_{\eta\eta}}, \qquad (4)$$

Calculations and Results

In order to look for the dynamics of ^{12}C + ^{169}Tm reaction forming ^{181}Re* compound nucleus, we have applied DCM at the highest beam energy $E_{Lab.}$=89.25 MeV in reference to data of [1] to explore the fission distribution and the related properties. In the present analysis, the calculations have been performed using spherical choice of fragmentation only. Firstly, the preformation probability P_0 is plotted as a function of fragment mass A_i, for the decay of ^{181}Re* compound system depicting the fission region as shown in Fig.1. The figure shows that the mass distribution of ^{181}Re* nucleus is symmetric and best fitted with one Gaussian function. This outcome is in nice agreement with the experimental results and the DCM based fission fragments are found to be similar to the ones identified in the experiment [1]. The mass range of these fragments corresponds to region A∼74-107 as depicted in Fig.1. Further, the total fission cross sections are calculated by using Eq. (1) for neck length ΔR=1.225 fm. The DCM estimated cross sections ($\sigma_{fiss.}$=301 mb) are in close agreement with experimental cross-sections ($\sigma_{fiss.}$=304.2 mb) [1]. In addition to this, the fission emission times (τ_f) of the identified fragments are predicted at the same neck value and the results are depicted in Fig.2. It is observed that the value of τ_f lies in the range of 10^{-20} to 10^{-15} seconds. This result is in line with the experimental data on fission emission times. The above analysis in terms of the preformation probability and emission time gives an overview of the fission of ^{181}Re* nucleus. It would be of further interest to investigate the decay patterns of the same compound system by taking the deformations and orientations into account.

References

[1] A. Sood, P.P. Singh, R. N. Sahoo et. al, Phys. Rev. C 96, 014620 (2017).

[2] K. Sharma, G. Sawhney, M. K. Sharma and R. K. Gupta, Nucl. Phys. A 972, 1 (2018).