Study of $^{48}$Ti induced reactions in sub-barrier region forming $^{106}$Cd$^*$ and $^{106}$Sn$^*$ compound systems at $E_{CN}^\ast \sim 48$MeV

Rupinder Kaur$^{1,2}$, BirBikram Singh$^2$,*, Mandeep Kaur$^2$, Maninder Kaur$^3$, Varinderjit Singh$^3$, and B.S. Sandhu$^1$

$^1$Department of Physics, Punjabi University, Patiala-147002, India.
$^2$Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib-140406, India.
$^3$Department of Physical Sciences, I.K.G. Punjab Technical University, Kapurthala-144603, India.

Introduction

The study of the heavy ion reactions give immense information about nuclear structure and the reaction dynamics. The deformation and the orientation effects of the participating nuclei play an important role in the reaction process. Thus, a relevant difference in the nuclear structure may lead to significant change in the sub-barrier fusion excitation functions [1]. It has been observed that fusion cross section, $\sigma_{fus}$ also depends on the N/Z ratio in the sub-barrier region [1].

Keeping in view such observations we intend to explore dynamics of compound nuclei (CN) $^{106}$Cd$^*$ and $^{106}$Sn$^*$ formed via $^{48}$Ti$^*$ induced reactions in sub barrier region with in the dynamical cluster decay model (DCM) [2]. A work in the same mass region has been carried out previously [3], within DCM, and it is observed that there is negligible contribution from the intermediate mass fragments, IMFs to the $\sigma_{fus}$ and the light particles, LPs (A≤4) have larger contribution in the same. It is relevant to mention here that the missing structure information in statistical models is included in the DCM through preformation probability ($P_0$). The available experimental data [1] has been fitted by the only parameter of DCM, i.e. neck length $\Delta R$, for both the spherical as well as oriented considerations. It is important to note here that one of decaying compound nucleus is magic i.e. $^{106}$Sn$^*$ has proton shell closure, Z = 50. In the present work, we try to investigate effect of shell closure in the reaction dynamics along with the N/Z dependence in sub-barrier regime (having studied the decay of CN $^{106}$Cd$^*$ and $^{106}$Sn$^*$ with N/Z = 1.2 and 1.1, respectively), within the model calculations.

Methodology

The DCM [2, 3] of Gupta and collaborators is worked out in terms of collective co-ordinates of mass (and charge) asymmetries. In terms of above said co-ordinates, for $\ell$-partial waves, the compound nucleus decay cross-section is given by

$$\sigma = \frac{\pi}{k^2} \sum_{l=0}^{l_{max}} (2l + 1) P_0 P; \quad k = \sqrt{\frac{2\mu E_{cm}}{\hbar^2}}$$

Where, $\mu = [A_1 - A_2/(A_1 + A_2)]m$, is the reduced mass, with m as the nucleon mass and $\ell_{max}$ is the maximum angular momentum. P is the barrier penetration probability and $P_0$ is the preformation probability at a fixed R on the decay path. The structure information in $P_0$ enters through the fragmentation potential $V_R(\eta, \beta_\lambda, \theta_i, T)$ for hot and compact orientations, which is calculated as,

$$V_R(\eta, \beta_\lambda, \theta_i, T) = \sum_{i=1}^{2} [V_{LD,M}(A_i, Z_i, T)] + \sum_{i=1}^{2} [\delta U_i] \exp\left(-\frac{T^2}{T_0^2}\right) + V_C(R, Z_i, \beta_\lambda, \theta_i, T) + V_p(R, A_i, \beta_\lambda, \theta_i, T) + V_\ell(R, A_i, \beta_\lambda, \theta_i, T)$$

Here $V_{LD,M}$ and $\delta U$ are, respectively, the liquid drop and shell correction energies, $V_C$, $V_p$ and $V_\ell$ are the Coulomb, proximity and angular momentum dependent potentials.

*Electronic address: birbikram.singh@sggswu.edu.in
TABLE I: The DCM calculated $\sigma_{\text{fus}}$ of CN $^{106}$Cd* and $^{106}$Sn*, formed in the reactions $^{48}$Ti+$^{58}$Fe and $^{48}$Ti+$^{58}$Ni, and their comparison with the experimental data [1].

<table>
<thead>
<tr>
<th>Reaction</th>
<th>N/Z</th>
<th>$E_{\text{c.m.}}$ (MeV)</th>
<th>$T$ (MeV)</th>
<th>$\ell_{\text{max}}$ (h)</th>
<th>$\Delta R$ (fm)</th>
<th>$\sigma_{\text{fus}}^{\text{DCM}}$ (mb)</th>
<th>$\sigma_{\text{fus}}^{\text{Expt.}}$ (mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{48}$Ti+$^{58}$Fe$\rightarrow^{106}$Cd*</td>
<td>1.2</td>
<td>72.0</td>
<td>2.070</td>
<td>72</td>
<td>1.314</td>
<td>1.305</td>
<td>34.8</td>
</tr>
<tr>
<td>$^{48}$Ti+$^{58}$Ni$\rightarrow^{106}$Sn*</td>
<td>1.1</td>
<td>80.0</td>
<td>2.075</td>
<td>70</td>
<td>1.170</td>
<td>1.366</td>
<td>57.0</td>
</tr>
</tbody>
</table>

FIG. 1: The variation of fragmentation potential $V$ (MeV) with fragment mass $A_2$ for the decay of CN $^{106}$Cd* and $^{106}$Sn* at $E_{\text{CN}} \sim 48 MeV$ for $\ell = 0$ and the respective $\ell_{\text{max}}$-values.

Calculations and Discussions

Fig.1 shows the variation of fragmentation potential with fragment mass $A_2$ for the decay of CN (a) $^{106}$Cd* and (b) $^{106}$Sn* at two extreme $\ell$-values. It is noticed that at $\ell = 0$, the light particles (LPs) are more dominant whereas with the increase in $\ell$-values the fission fragments starts competing with LPs for spherical as well as deformed configuration for the decay of both the CN under study. The fission fragments in the decay of both the CN show little prominence in comparison to the LPs at $\ell_{\text{max}}$-value. They are minimized little more in comparison to the LPs (apparently, this behaviour is explicit for more number of fission fragments in case of compound nucleus $^{106}$Sn*), particularly for the spherical considerations, whereas for the choice of oriented nuclei LPs regains prominence at both the extreme $\ell$-values. The potential energy surface (PES) are nearly same for both the considerations for the decay of CN $^{106}$Cd* and $^{106}$Sn*. However, for the magic compound system $^{106}$Sn* the change in the PES is quite evident at the $\ell_{\text{max}}$-value. It is motivating to investigate the preliminary result to further explore the fact that whether this change in PES is attributed to the magicity of the compound system or the N/Z ratio.

Table I presents the preliminary results of the DCM calculated $\sigma_{\text{fus}}$ and their comparison with the experimental data [1]. The calculated $\sigma_{\text{fus}}$ for both the reactions are in good comparison with the experimental data, for both the spherical as well as oriented configurations of the nuclei. Here, we observe that the $\sigma_{\text{fus}}$ is enhanced for the neutron deficient magic compound nucleus i.e. $^{106}$Sn* having N/Z = 1.1. Work is in progress.

References