Statistical model calculation for the neutron multiplicity data of ^{19}F + ^{181}Ta system

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Introduction

Study of fusion-fission phenomena in heavy-ion reaction remains a topic of great interest even today. When Projectile and target nucleus come into contact, they form a composite system. During this process nucleons (protons & neutrons) are exchanged between target and projectile, consequently energy and angular momentum are transferred. The system undergoes a complex dynamical evolution, reaching equilibrium in all degree of freedom and resulting in the formation of a compound nucleus.

The resulting compound nucleus have high excitation energy and angular momentum due to which it can decay through fission or particle emission. Several theoretical and experimental measurements have been studied for the calculation of pre-scission neutron multiplicity (ν_{pre}) and fusion cross-section. In several studies observed that dissipation has an important role to increase the pre-scission neutron multiplicity. It is demonstrated that dissipation slows down the fission process and reduces the fission width which further increase in the emission of light particle. After the emission of light particle and γ-rays a residual nucleus is formed having new excitation energy and angular momentum. This process remains to continue until either the compound nucleus undergoes fission or an evaporation residue is formed. In case of fission further emission can take place during the transition from saddle to scission, which contribute to pre-scission multiplicity (n, p, α).

In present work, we have calculated the pre-scission neutron multiplicities, fusion cross section, and evaporation residue cross-section for the system ^{19}F+^{181}Ta system populating the compound nucleus ^{200}Pb. Further, we have made a statistical model calculation for the same system to look for the effect of dissipation in the neutron multiplicity data. These calculations are performed using the code CCFULL and statistical model code VECSTAT [1-3] including different values of dissipation parameter.

Statistical model Calculation

Pre-scission neutron multiplicity, fission cross-section and evaporation residue cross-section have been measured for ^{19}F+^{181}Ta by Hinde et al. [1] with excitation energy 50 MeV to 90 MeV.

Statistical model calculations are based on the assumption that after the projectile and target nucleus interact, a completely equilibrated compound nucleus is formed, with no consideration given to contributions from non-compound nucleus (NCN) events such as fast-fission and quasi-fission (QF). The formed compound nucleus has high excitation energy and angular momentum, it can decay either by fission or particle emission (n, p, α) leading to the creation of evaporation residue. The fission width was calculated using Kramer's formula and decay width for the emitted particle was determined using Weiskopf formula.

$$\Gamma_K = \frac{\hbar\omega_g}{2\pi} \exp -\left(\frac{VB}{T}\right) \sqrt{1+\left(\frac{\beta}{2\omega_s}\right)^2} - \frac{\beta}{2\omega_s} \quad (1)$$

ω_g and ω_s are the frequency of the harmonic oscillator potentials. Usually, constant values are used for ω_g and ω_s.

$$\gamma = \frac{\beta}{2\omega_s}$$

β is the dissipation strength, used as a free parameter in statistical model calculations and it is used to fit the experimental data.

Result and Discussion

Pre-scission neutron multiplicities, fission cross section and evaporation cross-section have been already measured for the $^{19}F+^{181}Ta$ system available from literature survey. We have calculated pre-scission neutron multiplicity and fusion- cross-section for the same system using statistical model calculation for energy range E_{cm} = 70 to E_{cm}= 105 MeV.

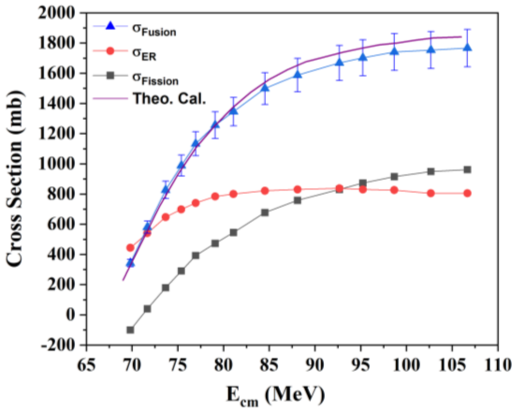

Fig.1. Variation of fusion cross section with different center of mass energies (E_{cm}).

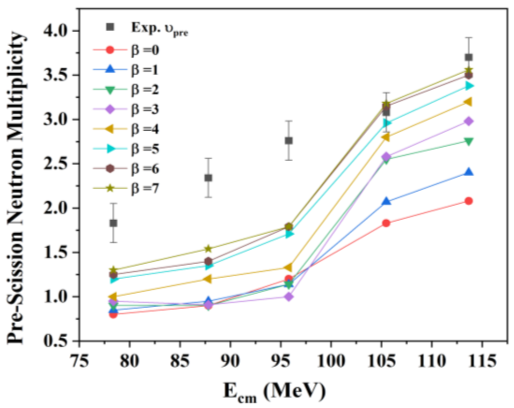

Fig.2. Variation of pre-scission neutron multiplicity with E_{cm} for different value of β.

We have compared theoretical calculations as shown in fig.1. with experimental results existing in literature survey [1]. The fusion cross section was calculated from CCFULL, we have taken same value of V_0 = 72.48 MeV (depth of Woods-Saxon potential), R_0 = 1.40 (fm) (radius parameter), and A_0 = 0.69 (fm) (surface diffusion parameter) with variation of deformation parameter of projectile and target at different energies. The excitation states of both the target and projectile are taken into account. The CCFULL takes into account all the possible mutual excitations channels between the projectile and target excitations. We have taken coupling in the target as rotational, while vibrational coupling is taken for the projectile. Spin distribution have been taken from CCFULL at each energy points and rotational collective enhancement (CELD) effect is also included in VECSTAT calculations. shell effect included in level density and shell correction applied to barrier height. no orientation effect was included in the calculation of the fission width.

Conclusion

We have compared our statistical model calculations with experimental values, It was found that pre-scission neutron multiplicity increases as dissipation strength increases and at two higher energies with higher value of dissipation neutron multiplicity matches with experimental values. At lower energies even at higher values of dissipation it does not match with experimental measurements. This observation may be attributed to the limitations of the model. Further improved calculations are in progress will be presented in the symposium.

Acknowledgements

One of the authors (Basant Sura) acknowledges University grants commission for providing the financial assistance for his research work under the NET-JRF fellowship scheme through Ref. No. - 221610081344 in the form of fellowship for carrying out the research work.

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