Effect of angular momentum variation in heavy-ion induced fusion reaction

Utkarsha Mishra, Punit Dubey, Mahesh Choudhary, Aman Sharma, Namrata Singh, Ajay Kumar
Banaras Hindu University, Varanasi, India -221005
E-mail: utkarshmishra22@bhu.ac.in

Introduction

- Heavy ion fusion reaction offers the good opportunity to learn variety of non-equilibrium nuclear dynamics such as nucleon transfer, shape evolution, energy dissipation and that is the way to study the reaction mechanism to determine the details of evaporated light particles like α, proton, γ-rays or fission from the compound nucleus.

- Dynamical model computer code HICOL was given by Feldmeier[1], which help us to calculate the time needed for various process like evolution of shape, energy dissipation in the collision and so on.

- Here we have studied the impact of angular momentum by using two different kinds of reactions (symmetric and asymmetric), which lead to the formation of the same compound nucleus with the same angular momentum and excitation energy.

- The transfer of kinetic energy is influenced by the angular momentum of the colliding nuclei and dissipation is reduced for reactions with higher angular momentum, as the angular momentum can suppress the transfer of energy to other degrees of freedom.

- In order to examine the nucleus at high spin or high temperature, fusion reactions are useful tools.

Theoretical Analysis

- In this study, we have calculated the variation of compound nucleus formation time with the angular moment as shown in Fig.1 for the two different reactions that make the same compound nucleus [2,3].

- Dynamical model code HICOL is employed to calculate the formation time of a compound nucleus at different values of angular momentum.

- We can see in Fig.1 that the symmetric reaction has a longer formation time than the asymmetric system as the angular momentum increases, which indicates that the symmetric reaction has the more dissipative evolution of a compound nucleus.

- From Fig. 1, it is clear that the compound nucleus ($^{107}In^*$) formed through $^{51}V + {}^{56}Fe \rightarrow {}^{107}In^*$ has a long formation time compared to the $^{32}S + {}^{75}As \rightarrow {}^{107}In^*$.

- High angular momentum leads to a higher degree of deformation in the colliding nuclei, which can hinder the transfer of energy to other degrees of freedom. By studying the dissipative development of the composite nucleus [4], we can gain a better understanding of the fusion mechanism and the variables that impact it.

- Experiments have revealed that compound nuclei with greater excitation energy prefer to form in fusion processes with higher angular momentum. This is due to the fact that the added rotational momentum adds to the system's total kinetic energy, which in turn raises the excitation energy of the compound nucleus overall.

- Angular momentum may prevent the energy from being transferred to other degrees of freedom and nuclei in collision experience more distortion at high angular momentum.

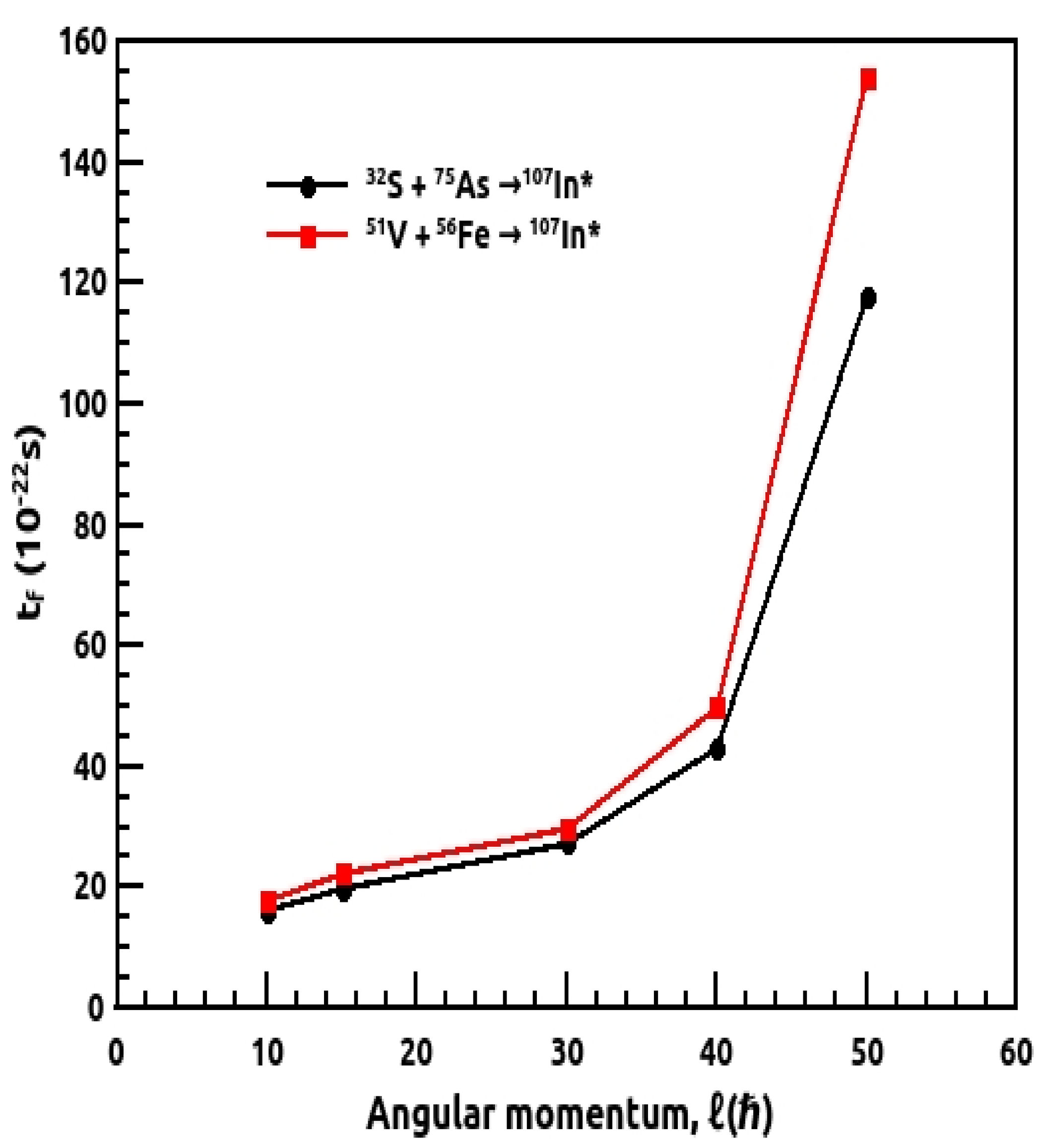

Fig.1: The influence of angular momentum on compound nuclear formation time.

- From Fig.2(a). in the case of a symmetric reaction, the higher angular momentum values fuse slowly and are saturated at lower excitation energies.

- From Fig 2(b). in the case of an asymmetric system, fusion and saturation occur at high excitation of the compound nucleus, followed by a symmetric reaction [5].

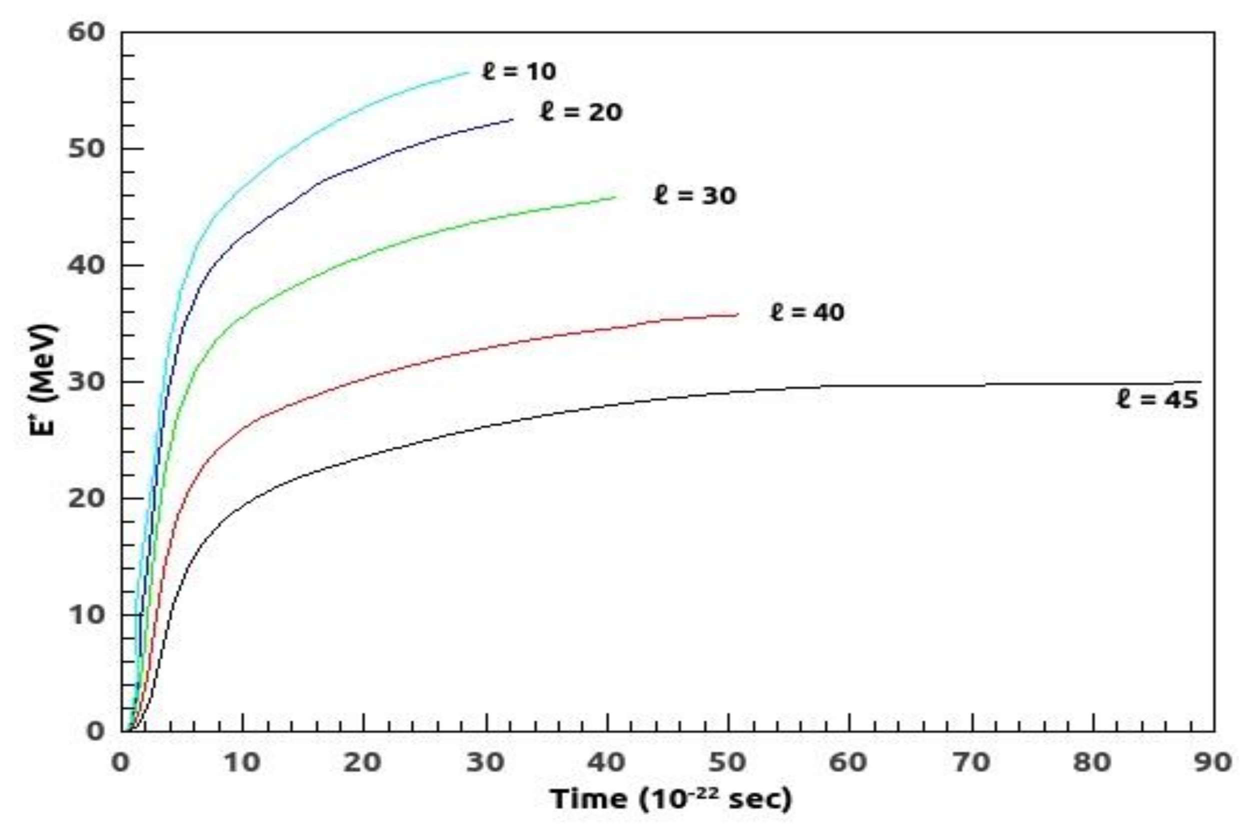

Fig.2(a)

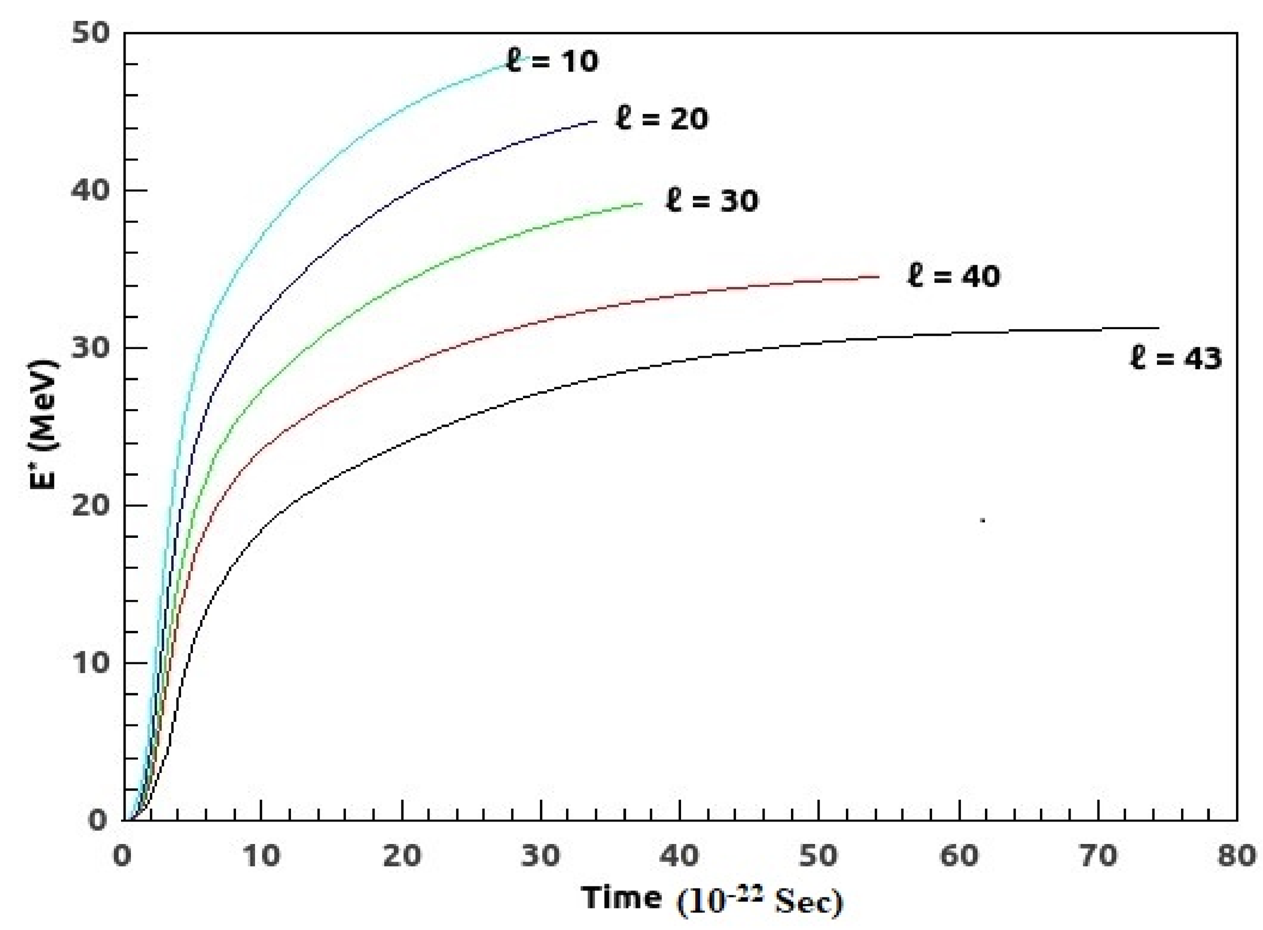

Fig.2(b)

Fig.2 Variation of the time of formation for compound nucleus with the thermal excitation energy on different values of angular momentum in Fig.2(a) for the $^{51}V + {}^{56}Fe \rightarrow {}^{107}In^*$ and Fig.2(b) for the $^{32}S + {}^{75}As \rightarrow {}^{107}In^*$.

Conclusion

- In the present study, we examined the effect of the angular momentum on the formation time of the compound nucleus and found that for all ℓ-values, the compound nucleus formation time is higher for symmetric systems compared to that for asymmetric systems.

- Additionally, we found that an asymmetric reaction carries larger values of the compound nucleus' excitation energy on various values of angular momentum than a symmetric reaction because due to dissipative evolution of compound nucleus.

References :

[1] H. Feldmeier et.al., Nucl. Phys. A 435, 229 (1985).
[2] Ajay Kumar et.al., Phys. Rev. C 68, 034603 (2003).
[3] Ajay Kumar et.al., Phys. Rev. C 70, 044607 (2004).
[4] N.K. Rai et.al., Phys. Rev. C 98, 024626 (2018).
[5] J. Kaur et. al., Phys. Rev. C 66, 034601 (2002).