International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

Study of the Effect of Entrance Channel Parameters in Lithium Induced Fusion Reactions

Savitha S

GFGC, Devanahalli, Bengaluru Rural District, Karnataka, India
Corresponding Author Email: *saviblr2015[at]gmail.com*

Abstract: ***The study delves into the details of Lithium induced fusion reactions focussing on their dependence on the entrance channel parameters such as the Coulomb interaction parameter, mass asymmetry and charge asymmetry. The findings suggest the importance of charge and mass of the target nucleus on the fusion cross section and hence on the fusion probability. The fusion cross section is optimal at certain projectile energies and depends on the charge asymmetry and mass asymmetry of the interacting nuclei. The insights gained from the study are expected to enhance our understanding of nuclear fusion dynamics.***

Keywords: fusion probability, mass asymmetry, charge asymmetry, projectile energy

1. Introduction

Nuclear fusion is a process by which heavy nuclei can be produced by the interaction of projectile and target nuclei. The nuclear fusion cross section is a measure of the probability of fusion reaction as a function of energy of the incoming particle. However, many parameters affect the probability of fusion between two interacting nuclei. These parameters are called entrance channel parameters. These parameters strongly influence the collision between the interacting nuclei and formation of a compound nucleus. The interacting nuclei are similarly charged hence experience Coulomb repulsion. Heavier charged nuclei require higher collision energies to fuse; their fusion cross section is strongly affected by the Coulomb barrier. In addition to Coulomb barrier there is nuclear potential barrier arising from the nuclear forces between the interacting nuclei. To overcome higher barrier, higher incident energies are generally required to increase the probability of fusion reactions. The reduced mass of the interacting nuclei affects the relative velocity and the quantum mechanical probability of penetrating the barrier. Hence mass asymmetry becomes an important parameter in the fusion process. Other factors that influence the fusion probability are nuclear energy levels, spin, parity nuclear radius, its deformation, angular momentum and internal structure of the nuclei [1].

2. Methodology

In the current study, the dependence of entrance channel parameters on the fusion probability of Lithium induced reactions is examined. Lithium is a light nucleus whose constituent particles are held together relatively weakly by nuclear forces.The experimental data for the present study are taken from Nuclear Reactions Video Project (NRV) [2]. NRV is a database containing low energy experimental data on nuclear reactions and properties. About eight Lithium induced nuclear reactions are considered for this study and are shown in Table 1.

The methodology involves studying the effect of entrance channel parameters such as mass asymmetry, charge asymmetry and Coulomb interaction parameters on fusion probability.

The mass asymmetry, $\eta = |(A_1 - A_2)/(A_1 + A_2)|$,
charge asymmetry, $\alpha = |(Z_1 - Z_2)/(Z_1 + Z_2)|$and

Coulomb interaction parameter, $\chi = Z_1 Z_2/\left(A_1^{1/3} + A_2^{1/3}\right)$, where terms Z_1, Z_2, A_1 and A_2, are the atomic numbers and mass numbers of the interacting nuclei.,The above parameters play an important role in the fusion process and formation of compound nucleus [3]. Further, to examine the effect of centre of mass energy of the projectile on the fusion cross section, the experimental data obtained from the sources [5-12] are analysed.

3. Discussions

Nuclear fusion reactions induced by Lithium ions are listed in Table1. The entrance channel parameters are calculated for the reactions considered and shown in Table1. The ratio (E_{cm}/V_B) is an important dimensionless quantity that compares the incident energy to the barrier height. If the ratio is less than 1, it is considered as a sub barrier region, and the fusion probability is lower. When the ratio is nearly equal to one, it is considered a near barrier region and the reaction probability rapidly increases with projectile energy. If the ratio is greater than 1, the reaction is classically bound to occur and the region is considered as above barrier region [4]. Fusion cross sections for the considered reactions are calculated for (E_{cm}/V_B) between the range 1.5 to 2.5, it is found that fusion cross section increases with the target mass and charge. As the charge asymmetry and mass asymmetry increases, the fusion cross section increases. It is also found that the increase in Coulomb repulsion increases barrier potential which in turn affects the fusion cross section.

Table 1: List of entrance channel parameters and barrier potential and their effect on cross section

Reaction	Mass Asymmetry (η)	Charge Asymmetry (α)	Coloum interaction parameter (χ)	Barrier Potential (V_B) in MeV	Cross section in mb for Ecm/VB (1.5-2.5)
$^{6}Li + ^{9}Be$ à$^{15}N^{*}$ [5]	0.2	0.142857	3.079336	1.712	40.47
$^{6}Li + ^{12}C$ à$^{18}F^{*}$ [6]	0.333333	0.333333	4.383561	2.59	367.64
$^{6}Li + ^{16}O$ à$^{22}Na^{*}$ [7]	0.454545	0.454545	5.534262	3.436	609.01
$^{6}Li + ^{24}Mg$ à$^{30}P^{*}$ [8]	0.6	0.6	7.65761	5.093	789.65
$^{6}Li + ^{28}Si$à$^{34}Cl^{*}$ [9]	0.647059	0.647059	8.65397	5.904	1016
$^{6}Li + ^{59}Co$à$^{65}Zn^{*}$ [10]	0.815385	0.8	14.18693	10.812	991.88
$^{6}Li + ^{64}Ni$ à$^{70}Ga^{*}$ [11]	0.828571	0.806452	14.44178	11.101	1203
$^{6}Li + ^{64}Zn$ à$^{70}As^{*}$ [12]	0.828571	0.818182	15.47334	11.961	869

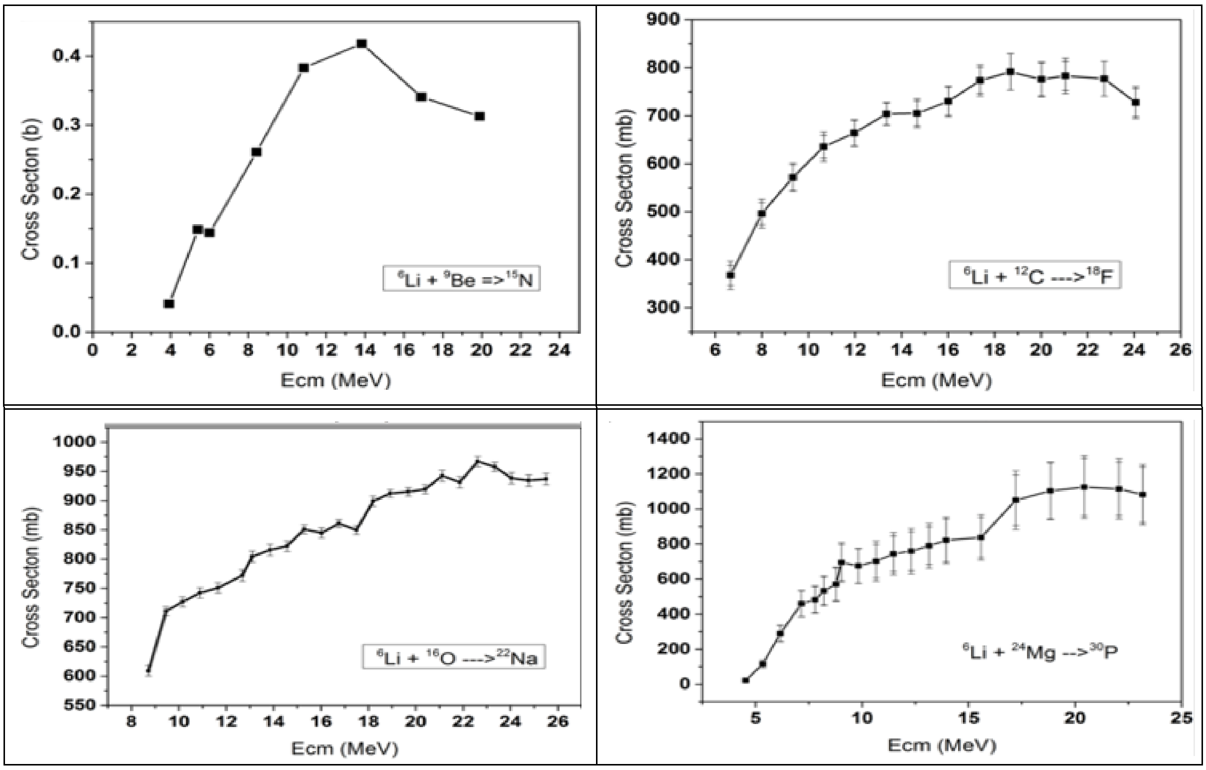
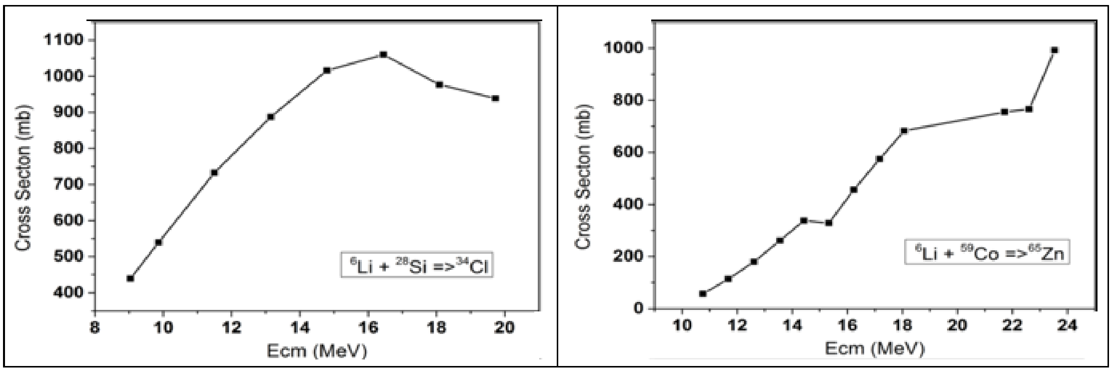


Figure 1: Variation of cross section with centre of mass energy

Figure 1 and Figure 2 show the variation of fusion cross section with centre of mass energy, and it is observed that with the increase in projectile energy the fusion cross section increases and reaches a maximum value and then decreases. The peak energy is called the Gamow energy. The increase in Ecm enhances the probability of overcoming the barrier potential, hence the cross section increases. The peak in cross section indicates maximum probability of reaction occurrence and the fall after the peak is due to nuclear structure effects, deformation and reduced resonance effects [13].



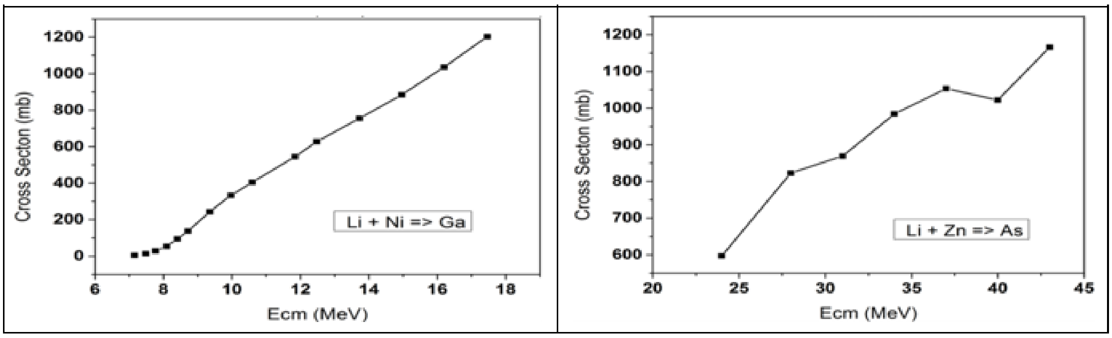


Figure 2: Variation of cross section with centre of mass energy

4. Summary and Conclusion

The results of all the reactions induced by weakly bound projectiles, such as Li, show a strong influence of entrance channel parameters on reaction dynamics. In weakly bound projectile systems, the possibility of breakup, transfer, and inelastic excitation is stronger compared to complete fusion. It is observed that mass asymmetry and charge asymmetry are higher for heavier targets, and this has a strong effect on fusion cross section and probability of fusion reactions. Projectile energy is another important parameter that strongly influences the fusion cross section. Therefore, it can be concluded that the fusion probability depends not only on the barrier height but on how strongly the entrance channel couples to all the available reaction channels.

References

[1] H.C. Manjunatha, N. Sowmya, et al. Nuclear Physics A 1032(2023) 122621
[2] V.I. Zagrebaev, A.S. Denikin, A.V. Karpov, et al. NRV, web knowledge base on low-energy nuclear physics, http://nrv.jinr.ru/.
[3] H.C. Manjunatha, N Sowmya et al, Physical Review C, **102**, (2020) 064605
[4] Luna Pellegri , Nuclear Structure and Reactions, (2024), iThemba labs
[5] J. Takahashi, M. Munhoz, E.M Szanto et al, Physical Review Letters, 78(1997)30
[6] L.C. Dennis, K.M. Abdo, A.D. Frawley et al., Physical Review C, 26 (1982) 981
[7] J.F. Mateja, A.D. Frawley, L.C. Dennis et al., Physical Review C, 33 (1986) 1649
[8] M. Ray, A.Mukherjee, M.K. Pradhan et al., Physical Review C, 78(2008) 64617
[9] MandiraSinha, H. Majumdar, P. Basu et al., European Physical Journal A, 44 (2010)403
[10] C. Beck, F.A. Souza, N. Rowley et al., Physical Review C, 67 (2003)054602
[11] Md. MoinShaikh, Subinit Roy, S. Rajbanshi et al., Physical Review C, 90 (2014) 24615
[12] I. Padron, P.R.S. Gomes, R.M. Anjos et al., Physical Review C, 66 (2002)044608
[13] Hood J.T., Introduction to Nuclear Reactions, CRC Press, 2003.