A study of fusion suppression in the 48Ti+138Ba reaction

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Introduction

Research into the formation of heavy nuclei has contributed important information into the reaction dynamics of fusion process. Overcoming the Coulomb barrier alone does not guarantee the formation of a compound nucleus(C.N.) in the nuclear reactions involving heavy reaction partners. The factors influencing the dynamical evolution of composite system, after the contact of two heavy nuclei, is not yet fully understood.

The formation of heavy nuclei involves three distinct steps with each step has its own influence in the formation of final product. First, the interacting nuclei overcome the Coulomb barrier which is repulsive in nature and approach close enough so that attractive nuclear force come into play. This results in the capture of projectile inside the Coulomb barrier. Second, the composite system or the di-nuclear system (D.N.S.) undergo shape evolution towards a compact mononuclear shape or C.N. Finally, the composite system(C.N.) so formed should survive fission to form evaporation residue (E.R.). Among these, the second step is considered to be both most complex and least understood stage in the formation of a heavy nucleus[1]. The competition between fusion-fission and Q.F. during the evolution of the composite system is a very complex process. This competition is found to be influenced by entrance channel properties such as charge product of the entrance channel [2,3], deformation alignment [4,5] , magicity [6] and asymmetry of the projectile and target N/ Z ratios [7]. A detailed study of all these factors will throw more light into the complex process of evolution of the composite system which ultimately results either in the formation of compact compound nucleus or in Q.F.

The influence of magicity and target deformation is studied by comparing the results of recently conducted ER cross section measurement of ^{48}Ti + ^{138}Ba[8] with ^{86}Kr+ ^{100}Mo[9] and are plotted in fig.1, for the excitation energies in the range of 30-75MeV. In the two systems considered, former system is asymmetric and the latter is comparatively symmetric system. Hence the Coulomb repulsion will be maximum for latter and this narrows the probability of compound nucleus formation for the same excitation energies considered. But what is observed is a reverse trend and it is

Reaction	Nucleus	β_2	N	Z	$\frac{N}{Z}$	$\Delta\frac{N}{Z}$	Magicity
$^{48}Ti+^{138}Ba$	Ti	0.28	26	22	1.18		-
$(Z_pZ_t$=1232)						0.28	
	Ba	0.09	82	56	1.46		N=82
$^{86}Kr+^{100}Mo$	Kr	0.13	50	36	1.38		N=50
$(Z_pZ_t$=1512)						0	
	Mo	0.16	58	42	1.38		-

Table 1: A comparison between different physical parameters of the two systems.

explained in the forthcoming sections. The different physical parameters of both system are shown in table1.

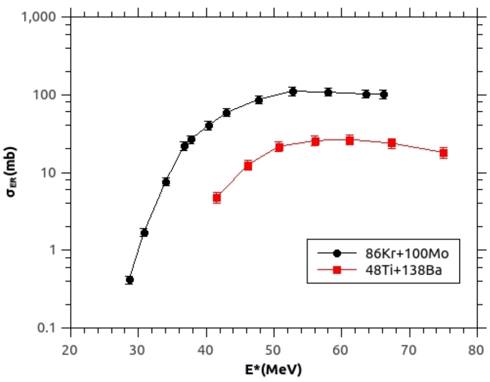

Figure 1: A comparison of ER cross sections between symmetric and asymmetric systems, forming the same compound nucleus. Lines guide the eye in both curves.

Discussion

1. Influence of deformation

Static deformation of the heavy reaction partner affects nuclear collisions [10] because the capture barrier height depends on the relative orientation of the projectile nucleus and the deformation axis of statistically deformed heavy reaction partner [11]. Among the two reactions studied, ^{48}Ti+ ^{138}Ba has largest deformation parameter with β = 0.28 for ^{48}Ti. The study of reorientation effect of deformed projectile on a target has shown the hindrance to fusion at sub barrier energies[12]. This is due to the formation of an elongated composite system which re-separates before the equilibration in all degrees of freedom. The relative collision of ^{138}Ba with the tip of the prolate deformed titanium nucleus is attributed to the reduction in the fusion probability of ^{48}T i + ^{138}Ba reaction.

2. Influence of iso-spin asymmetry

The effect of spherical quantum shell is found to affect the fusion dynamics of heavy ion collision. The isospin asymmetry is quantified by the difference between N/Z ratios of the initial colliding nuclei. This difference is interpreted as Δ (N/Z) in this paper. From table 1, it can be seen the value of Δ(N/Z) is maximum for ^{48}Ti + ^{138}Ba reaction with 0.28. It has been reported that magic numbers in the entrance channel with large isospin asymmetry increase Q.F. [13] and it is reflected in the reduction of E.R. cross sections . A rapid equilibration takes place in the early stage of the collision which has large isospin values and modifies the identities of the colliding partners. The transfer of nucleons result in the fast equilibration of N/Z in the two fragments in the early stage of the collision. At higher excitation energies the shell effect will vanish completely and it behaves like a non-magic system.

We interpret it as the underlying reason for the reduced cross section of ^{48}Ti + ^{138}Ba reaction, even though it is the asymmetric system among the two reactions under study.

Conclusion

Even though both systems show a suppression in the fusion ER, the influence of deformation among the colliding partners and the effect of iso-spin asymmetry are attributed to the enhanced fusion suppression of the asymmetric system.

References

[1] V. I. Zagrebaev et al, J.Phys. G: Nucl. Part. Phys. 31, 825(2005).
[2] C. C. Sahm et al, Z. Phys. A 319, 113(1984).
[3] A. C. Berriman et al, Nature (London) 413, 144(2001).
[4] D. J. Hinde et al, Phys. Rev. Lett.74, 1295 (1995).
[5] D. J. Hinde et al, Phys. Rev. C 53, 1290 (1996).
[6] G. Mohanto et al, Phys. Rev.C 97, 0054603 (2018).
[7] C. Simenel et al, Phys. Lett.B 710, 607 (2012).
[8] K.K. Rajesh et al, Proceedings of the DAE Symp. on Nucl. Phys. 62, 510 (2017)
[9] W. Reisdorf et al, Nuclear Physics A444 (1985) 154-188
[10] D.J. Hinde et al, EPJ Web of Conferences 163, 00023 (2017)
[11] M. Dasgupta et al, Annu. Rev. Nucl.Part.Sci. 48, 401 (1998)
[12] C. Simenel et al, arXiv:nucl-th/0401044v5 28 Jul 2004
[13] C. Simenel et al, Physics Letters B 710 (2012) 607611