STUDIES ON THE PROPERTIES OF NUCLEAR REACTIONS INDUCED BY LOOSELY BOUND NUCLEI

C. K. Phookan*
Department of Physics, Haflong Government College, Haflong - 788819, INDIA

Introduction

During the last one and a half decades, a large amount of experimental work has been done on reactions induced by loosely bound projectiles (^{6}Li, ^{7}Li and ^{9}Be) [1]. Having low breakup threshold energy (^{6}Li $\rightarrow$ ^{4}He + ^{2}H ; E_α= 1.48 MeV), these projectiles are easily susceptible to breakup. As a result these reactions display interesting features like fusion suppression. As the theoretical side is largely unexplored, hence, the present thesis embodies theoretical work carried on some important properties of these reactions.

Study of barrier parameters

In the first part of our study we determine the barrier parameters of thirteen number of reactions induced by loosely bound projectiles. For determination of the barrier parameters we choose eight different versions of the proximity potential and these are Prox 77, Prox 88, Bass 73, Bass 77, Bass 80, CW 76, BW 91 and AW 95. The results of all the potentials are found to be satisfactory. However, the potentials Bass 80 and BW 91 are found to be most effective in reproducing the height (V_B) and position (R_B) of the barrier, respectively [2]. For the reaction ^{6}Li+^{152}Sm, the deviations of the barrier parameters from the empirical values is found to be unusually large, and this is attributed to the large static deformation ($\beta_2 = 0.26$) of the target (^{152}Sm). On application of the correction of the Coulomb potential for the deformed target, the new values of the barrier parameters are found to be much closer to the empirical values. Study of the nature of the potentials for the case of deformed target reveals the emergence of distinct potential pocket for the potentials Bass 77, Bass 80, BW 91 and AW 95 in addition to the potentials Prox 77 and Prox 88 for which the pocket exists even for the spherical target case [2].

Study of fusion cross section

In the second chapter we study the fusion cross section for the reactions ^{6}Li+^{209}Bi, ^{9}Be+^{208}Pb, ^{7}Li+^{209}Bi and ^{6}Li+^{152}Sm using the Wong's formalism [2]. The fusion cross section is also calculated from the single barrier penetration model (SBPM) using the code CCFULL [3]. The fusion cross section calculated from Wong's formalism is found to be in agreement with the SBPM cross section, and is also found to be fractionally greater than the experimental cross section. The reason for the decrease of the experimental cross section is because of projectile breakup, and this phenomenon is called fusion suppression. Also, we find that fusion cross section calculated from Bass 80 barrier parameters give a much better reproduction of the SBPM cross section. For the reaction ^{6}Li+^{152}Sm, fusion cross section is calculated considering the cases of spherical as well as deformed target. The fusion cross section for the case of deformed target is in much better agreement with the results of the SBPM cross section than the case of spherical target [2].

Model for fusion suppression

In the third chapter we develop a semiclassical model for the explanation of fusion suppression. Technically speaking, fusion suppression is the ratio between the experimental and the theoretical fusion cross section. The cause of fusion suppression is due to breakup

*Electronic address: chinmoy.phookan@gmail.com

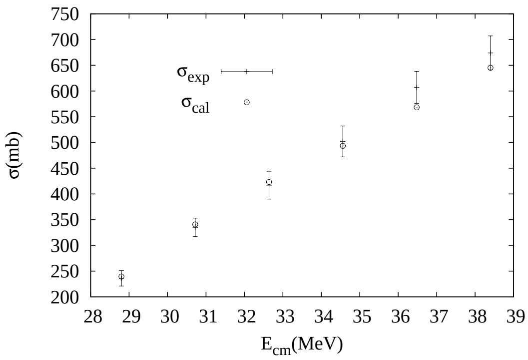

FIG. 1: $\sigma_{\rm cal}$ and $\sigma_{\rm exp}$ vs $E_{\rm cm}$ (MeV) for the reaction ^{6}Li+^{144}Sm.

of the projectile before collision with the target nucleus. We apply the model to the three ^{6}Li induced reactions : ^{6}Li+^{209}Bi,^{6}Li+^{144}Sm and ^{6}Li+^{152}Sm [4]. The basic idea of the model is to find out the cutoff impact parameter for fusion. Then the fraction of projectiles undergoing breakup within the cutoff impact parameter for fusion is determined which is then directly related to the fusion suppression factor. The cutoff impact parameter for fusion is determined by the single barrier penetration model (SBPM), as fusion cross section above the barrier can be approximated by the results of SBPM. We apply the two-dimensional classical trajectory method for determining the fraction of projectiles undergoing breakup. From the three-body Lagrangian for the system of target and two-body projectile, the classical equations of motion are obtained. For obtaining the initial conditions, we propose a semiclassical model of the ^{6}Li nucleus. Then two postulates are proposed for the model [4]. From the calculations, the distance between the deuteron and the α-particle comes out to be 2.27 fm. Using the initial conditions, numerical solutions are obtained and the trajectories are studied. Three distinct types of trajectories are obtained and these are : scattering-like, incomplete fusion and no-capture breakup. Then a breakup condition is defined for a trajectory or projectile.

Taking a sample of fifty trajectories at each impact parameter, the breakup fraction is determined. Then a formula is proposed for the explanation of fusion suppression according to which fusion suppression is given by the average of breakup fractions calculated at different impact parameters. The range of impact parameters lie between a head-on collision (b_i=0) and the cutoff impact parameter for fusion (b_i=b_c). On application of the above formula to the three ^{6}Li induced systems, we find that there is excellent agreement between the experimental fusion cross section (σ_{exp}) and the calculated fusion cross section (σ_{cal}) [4]. In Fig. 1, the results are displayed for the reaction ^{6}Li+^{144}Sm. However, for the reaction ^{6}Li+^{152}Sm there is slight disagreement at higher energies because of deformed nature of the ^{152}Sm target [4].

Conclusion

The work presented in the thesis is far from complete, and there is tremendous future research prospect. Calculation of the barrier parameters could be done by using other nuclear potentials like, the double-folding or the Skyrme nuclear potentials. The model of fusion suppression could also be generalized to a three–dimensional model. Finally, a fully quantum mechanical model of fusion suppression could be attempted in future even though it may be a highly challenging task.

ACKNOWLEDGEMENT

I would like to thank my guide Dr. Kushal Kalita, Dept. of Physics, Gauhati University for providing invaluable help, support and encouragement throughout my research.

References

[1] M. Dasgupta *et al.*, *Phys. Rev. C*, **70**, 024606 (2004)

[2] C. K. Phookan and K. Kalita, *Nuclear Physics A*, **899**, 29, (2013).

[3] K. Hagino *et al.*, *Comp. Phys. Comm.*, **123**, 143 (1999)

[4] C. K. Phookan and K. Kalita, *Journal of Phys. G : Nuclear and Particle Physics*, **40**, 125107 (2013).