Study of heavy ion reactions with weakly bound nuclei

D. Patel*
Physics Department, Faculty of Science,
M. S. University of Baroda, Vadodara-390002, India

Introduction

Heavy ion reactions with weakly bound nuclei (^{6,7}Li, ^{9}Be) are being studied at near barrier energies since the last few decades. Further, the availability of radio active ion beams (RIBs) have enhanced the importance of reaction studies with stable weakly bound nuclei due to the similarity in structural properties of stable and unstable weakly bound nuclei that serves a testing ground for unstable weakly bound nuclei[1]. During the nuclear interaction, in the field of target nuclei the weakly bound nuclei having a lower breakup threshold can be directly broken into two fragments (core + valence) or it can be broken after nucleon transfer. This breakup channel affects the other associated reaction channels such as transfer, fusion, elastic and quasi-elastic scattering.

The present thesis mainly focuses the study of breakup coupling effects on elastic and fusion channels that involve stable but weakly bound nuclei, namely ^{6,7}Li. With this objective three different experiments have been performed for ^{7}Li+^{27}Al, ^{7}Li+^{159}Tb and ^{6,7}Li+^{209}Bi reactions at around the Coulomb barrier energies. In depth, elastic scattering angular distributions for ^{7}Li+^{27}Al, ^{159}Tb systems have been carried out. Also, simultaneous study of elastic and fusion channels have been done for the reaction of ^{7}Li with ^{27}Al. From the elastic scattering angular distributions, energy dependences of optical potential parameters and reaction cross sections have been obtained. Moreover, fusion barrier distributions were obtained from the quasi-elastic scattering excitation functions at back angles for ^{6,7}Li+^{209}Bi systems. The coupled-channels calculations using Fresco code, have been performed to describe the experimental results.

*Electronic address: `dipika.physics@gmail.com`

Experimental Details

The experimental measurement for ^{7}Li+^{27}Al was carried out at FOTIA facility, BARC, Mumbai. For ^{7}Li+^{159}Tb, ^{6,7}Li+^{209}Bi systems, the measurements were done using TIFR facility, Mumbai. To measure the scattered particles, silicon surface barrier (SSB) detectors were used. Quasi-elastic scattering data were acquired at backward angles.

Results and Discussion

In case of tightly bound nuclei, the real part of potential shows bell shaped structure near the barrier energy and the imaginary part decreases below the barrier energy which is known as 'Threshold Anomaly'. In contrast to this for weakly bound nuclei (^{6,7}Li, ^{9}Be), the imaginary part of the optical potential increases at below the Coulomb barrier energy and remains unchanged at above the Coulomb barrier energy which is termed as 'Breakup Threshold Anomaly (BTA)'. For the observation of TA or BTA, some contradictions have been seen in the reactions that involves weakly bound nuclei. The projectile breakup may lead to suppression in fusion cross sections due to the loss of flux in incident channel or it may enhance the fusion cross sections by coupling to elastic and other reaction channels below the Coulomb barrier energy regime. In this regards, many conflicting results have been reported in the literature in different mass region of target-projectile systems. This suggests that a simultaneous measurements of elastic scattering and fusion cross section can be more reliable for better understanding of breakup coupling effects. In the present investigation for ^{7}Li+^{27}Al system, the energy dependence of the optical model potential does not give strong conclusion regarding the presence of the 'TA' or the 'BTA' which is consistent with earlier results in the literature[2]. However, for ^{7}Li+^{159}Tb system, the behavior of real and imaginary parts of the optical potential may indicate the presence of 'TA' [3]. For ^{7}Li+^{27}Al system, the CDCC and transfer calculations have been carried out to see the breakup and $1n$-transfer coupling effects on elastic scattering angular distributions. The $1n$-transfer was found to be more dominant as compared to breakup channel particularly at above barrier energies. Similarly, in the reaction of ^{7}Li+^{159}Tb system, the effect of breakup coupling is very small. For ^{7}Li+^{27}Al system, the fusion cross sections at energies near the Coulomb barrier were obtained from the measured alpha evaporation spectra at backward angles. The calculated fusion cross sections from the CDCC+transfer calculations using FRESCO, are also compared with the present fusion cross sections. The obtained fusion cross sections by the BPM calculation was found in better agreement with the experimental data. The systematic study of reduced total reaction cross sections for ^{7}Li-projectile and variety of target nuclei in the mass range from A=27 to 232, may show target mass dependences at below the barrier energies.

The another alternative method that can help in understanding of breakup coupling is the extraction of fusion barrier distribution from quasi-elastic scattering. Measuring barrier distribution from quasi-elastic scattering at back angle data is much easier with smaller experimental uncertainties as compared to fusion excitation function. Unlike the tightly bound nuclei, in case of weakly bound nuclei, there is a difference between barrier distributions that are obtained from quasi-elastic and fusion excitation functions. This has led the interest to obtain the fusion barrier distribution from quasi-elastic scattering for ^{6,7}Li+^{209}Bi systems and to compare with the one obtained from fusion cross sections [4]. For both the ^{6,7}Li+^{209}Bi systems, it has been observed that the fusion barrier distributions obtained from quasi-elastic and fusion excitation function measurements are consistent only when BU and/or transfer channels are added to the quasi-elastic events. For ^{6}Li+^{209}Bi system CRC calculations are also done to understand the $1n$-transfer effects on fusion barrier distributions, which shows negligible effect of this channel. Simultaneous calculation for breakup and transfer with the reduced binding energy of core and valence particle have been carried out to reproduce the relative contribution of breakup and $1n$-stripping channels for the reaction of ^{6}Li with ^{208}Pb and ^{209}Bi.

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