Study of projectile breakup processes on elastic scattering and fusion fission reactions around the Coulomb barrier

Shradha Dubey[1]*, S. Mukherjee[1], D. C. Biswas[2]

[1]*Department of Physics, Faculty of Science, The M. S. University of Baroda, Vadodara-390002, India.*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai – 400085, India.*

**email: shradha30686@gmail.com*

Introduction

The Heavy ion reactions with weakly bound and tightly bound projectile (^{6,7}Li, ^{9}Be,^{10,11}B) on different targets are being studied at near the Coulomb barrier energies since the last many years. Effect of coupling between the relative motion and the intrinsic degrees of freedom of the participating nuclei is manifested as a "threshold anomaly" (TA) in the energy dependence behaviour of the real part of the effective interaction potential [1]. The measurements of the elastic scattering angular distributions determine parameters of the real and imaginary parts of the optical model potential parameters. From systematic analysis of elastic scattering measurements involving tightly bound nuclei, the so called "threshold anomaly" (TA) has been observed in a number of systems [2]. This has been understood in terms of couplings of elastic channel to the direct reaction channels that generate an additional attractive real dynamic polarization potential. In case of scattering of loosely bound projectiles a different type energy dependence from that of TA is observed, which has been known as 'breakup threshold anomaly' (BTA). In case of BTA, a repulsive real dynamical potential is generated due to couplings of breakup channels to the elastic scattering. There are some contradictory observations regarding BTA. For ^{7}Li + ^{80}Se, TA has been observed, whereas for ^{6}Li + ^{80}Se, the BTA has been reported [3]. Therefore, more measurements involving heavy targets and weakly bound projectile are required to understand the systematics of TA and BTA.

The present thesis mainly focuses the study of threshold anomaly and breakup threshold anomaly effects on elastic and quasi elastic scattering channels that involve stable but weakly bound and tightly bound nuclei, namely ^{6,7}Li and ^{10,11}B on heavy mass target ^{232}Th. With this objective, in the present thesis, two different experiments have been performed for ^{6,7}Li+^{232}Th and ^{10,11}B+^{232}Th reactions at around the Coulomb barrier energies. In depth, elastic scattering angular distributions for ^{6,7}Li + ^{232}Th systems have been carried out. The quasi elastic scattering and transfer angular distribution have been carried out for ^{10,11}B+^{232}Th systems. Also, simultaneous dispersion relation study obtained for this systems. From the elastic scattering angular distributions, energy dependences of optical potential parameters and reaction cross sections have been obtained.

Experimental Details

The experimental measurement for elastic scattering angular distribution for ^{6,7}L + ^{232}Th and ^{10,11}B + ^{232}Th systems were carried out at BARC-TIFR pelletron facility, Mumbai India. To measure the scattered particles, Four ΔE-E silicon surface barrier detector telescopes and two monitor detectors were mounted inside the general purpose scattering chamber.

Results and Discussion

Elastic scattering angular distribution measurements have been carried out for the ^{6,7}Li + ^{232}Th systems at several bombarding energies from below to well above the Coulomb barrier. The experimental data have been analysed by using the ECIS [4] WSP and SPP double-folding forms of phenomenological optical potentials. The relevant parameters that give a best fit to the elastic scattering angular distribution were obtained through a χ^2-minimization procedure. The behavior of the corresponding parts of the potential as a function of energy is consistent with a situation close to the threshold anomaly for the ^{7}Li + ^{232}Th system. The increasing trend around the barrier of the imaginary part of the phenomenological potential as a function of

energy indicates the absence of the usual threshold anomaly for the ^{6}Li + ^{232}Th system and this may be interpreted as evidence of the breakup threshold anomaly. The enhanced reaction cross sections have been observed at sub-barrier energies for the ^{6}Li + ^{232}Th system in comparison to the ^{7}Li + ^{232}Th system. It will be interesting to have more exclusive measurements in order to understand the higher breakup probabilities for the ^{6}Li projectile [5].

Further, in this thesis work we have carried out the simultaneous measurement of the quasi-elastic scattering and transfer angular distributions in ^{10,11}B+^{232}Th systems for bombarding energies from 10% below to 20% above the Coulomb barrier. Optical model analysis of the experimental data have been performed to determine both the real and the imaginary parts of the optical potential as a function of beam energy. It is observed that as the bombarding energy decreases, the imaginary potential decreases and real potential increases. The behavior of the corresponding potential parameters as a function of energy is consistent with the usual threshold anomaly, confirming the tightly bound characteristics of both the projectiles, ^{10,11}B. The reaction cross section obtained from the optical model analysis show large enhancement for the ^{10}B+^{232}Th system in comparison to the ^{11}B+^{232}Th system at sub-barrier energies. The reduced reaction cross sections have been obtained for both ^{10,11}B + ^{232}Th reactions and compared with the reactions of other projectiles (^{6,7}Li) with ^{232}Th target.

For the analysis of angular distribution of the transfer reaction products, we have measured the yield of ^{12,13}C, ^{9,10}Be, and ^{6,7}Li at various angles for both ^{10,11}B+^{232}Th systems. The same telescopes were used for the measurement of both quasi-elastic as well as transfer products and we have normalized the data at various angles with the yield of the monitor detectors. The transfer cross sections were obtained from the yield of the transfer products at various angles comparing with the calculated Rutherford scattering cross sections at forward angles. The transfer products show a bell-shaped angular distribution at energies above the Coulomb barrier and the grazing angle shifts towards back angles at sub-barrier energies [6,7].

Acknowledgment:

The author (SD) acknowledges the operating staff of the TIFR-BARC pelletron for smooth functioning of the machine during the experiments. Also, the financial support by DAE-UGC-CSR-Kolkata is thankfully acknowledged.

References:

[1] C. Mahaux, et al., Nucl. Phys. A **449**, 354 (1986).

[2] G. R. Satchler, Phys. Rep. **199,** 147 (1991).

[3] L. Fimiani et al., Phys. Rev. C **86**, 044607 (2012).

[4] J. Raynal, Phys. Rev. C **23,** 2571 (1981**).**

[5] S. Dubey et al., Phys. Rev. C 89, 014610 (2014).

[6] Shradha Dubey, et al., EPJ Web Conf. 86, 00008 (2015).

[7] S. Dubey et al., Phys. Rev. C 94, 064610 (2016).