Quasi-elastic, break-up and fusion reactions

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Introduction

The study of heavy ion nuclear reactions, especially the couplings with the various channels has achieved a great interest. Elastic scattering is one of the most important channels to be measured for studies of nuclear structure via nuclear reactions since it can be used to constrain the optical model potentials (OMPs) that are necessary for generating the distorted waves of the entrance and exit channels [1]. The coupling between the elastic scattering and different reaction mechanisms plays the vital role for the energy dependence of the optical potential produced by polarization potentials. The role should be especially noticeable in the case of fusion of weakly bound/unbound neutron/proton rich nuclei consisting of extended neutron/proton distributions coupled to a core. The studies of elastic scattering of radioactive ions can lead to the discovery of new phenomena that can verify various theoretical models [2]. The break-up of the neutron/proton rich nuclei in the stage of approaching the target nuclei may cause the decrease of the fusion cross section compared to the value for the stable isotopes of the same element.

Several experiments were performed to assess the situation. In particular, the measurements involving weakly bound stable and unstable nuclei with heavy targets were reported [3-9]. From the theory side, a detailed Continuum Discretized Coupled Channels (CDCC) calculation was reported for the fusion of ^{11}Be with ^{208}Pb [10]. It was difficult to draw definitive conclusions concerning the CF cross section since this method cannot evaluate the contribution from the sequential process. The calculation of the incomplete fusion within the CDCC, needed to obtain the CF, is still being investigated [11]. The status of the fusion of weakly bound stable and unstable nuclei is therefore that of an on-going extensive effort both in theory and experiment.

Discussion of the Results

It is a well-established fact that the near barrier elastic scattering of tightly bound heavy ions shows up behavior of the energy dependence of the interacting optical potential (OP) known as Threshold Anomaly (TA). This situation changes in the scattering of weakly bound nuclei. These nuclei have very low breakup threshold energies and so, have a large breakup (BU) probability. At energies above the barrier, fusion cross sections are usually larger than BU cross sections, but at energies close to the barrier, the opposite occurs, and furthermore, BU probabilities remain large even at energies below the Coulomb barrier [3-6]. Patel et al., had observed that 1n-transfer coupling on elastic scattering is equally important for one of the light mass system (^{7}Li + ^{27}Al), particularly at above-barrier energies. Some recent results on elastic scattering angular distributions are given elsewhere [4-6].

Some new interesting phenomena of the elastic scattering induced by light radioactive ion beams were discovered. Y.Y Yang et al., [11] has observed that the quasi-elastic-scattering angular distribution for ^{8}B + ^{nat}Pb at approximately three times the Coulomb barrier energy is essentially identical to those for weakly bound nuclei ^{6}Li and ^{7}Be at similar relative energies. They have also observed negligible contributions from the inelastic scattering channels in the quasi-elastic scattering data within the angular range covered in their measurement [10, 11]. There are some other measurements with ^{8}B as a projectile [12]. The total cross sections, fusion cross sections, breakup cross sections, electric quadrupole moment, and longitudinal momentum distributions of ^{7}Be fragments produced in (^{8}B,

^{7}Be + p) breakup reactions have been measured. Some elastic-scattering experiments have also been reported for ^{8}B.

Summary

The present talk will be an attempt to discuss a few measurements of fusion, elastic scattering in terms of TA/BTA phenomena and breakup reactions being carried out by the author and his collaborators during the last several years for a few weakly bound and unbound systems. Fusion and elastic scattering measurements using different stable weakly bound projectiles, such as (^{6,7}Li, ^{10,11}B), unstable one-proton halo projectile (^{8}B), and non-halo unstable projectile (^{8}Li, ^{10,11}C) will be presented in fusion and scattering measurements on a few target nuclei.

The conclusion will point to the need to get more precise data for better explanation of ICF following break-up, take the CDCC to its limit of validity, and get a better description of the ion–ion interaction.

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