Experimental Investigation of Near Barrier Fusion and Scattering with Loosely Bound Stable Nuclei

Mandira Sinha[1,2]
[1] *Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata-700064 and*
[2] *Gurudas College, Narikeldanga, Kolkata-700054, INDIA*

Introduction

The nuclear reaction involving loosely bound nuclei is an interesting topic in the recent years, which is not yet fully understood. There are almost no experimental attempts in the light mass target region to explore novel features, like fusion enhancement/suppression, weakening of threshold anomaly etc, observed around the Coulomb barrier in reaction involving weakly bound nuclei with heavy mass targets. So precise measurements of fusion cross section (for the first time) and elastic angular distribution for reactions with loosely bound projectiles ^{6,7}Li with light deformed target ^{28}Si, were performed at energies from below to well above the barrier.

Above barrier fusion for ^{6,7}Li+^{28}Si

The total fusion excitation functions for ^{6,7}Li+^{28}Si systems at above barrier energies were measured using the characteristic γ-ray method, at the BARC-TIFR Pelletron (Mumbai) with ^{6,7}Li beam at energies E_{lab}=11-24 MeV and 11.5-26 MeV respectively. The target of natural silicon (192μg/cm^2) sandwiched between two thin Au layers (40-100μg/cm^2) was prepared by the electron gun evaporation technique at SINP. The γ-rays were detected using a Compton suppressed Clover detector placed at 55° with respect to the beam axis and a Faraday cup was used for beam normalisation purposes. The efficiency of the detector was obtained with standard radioactive sources like, ^{152}Eu, ^{133}Ba, ^{207}Bi. The total fusion (TF= CF+ICF) cross sections were extracted as the ratio of the total experimentally measured γ-ray cross sections and the corresponding branching factor F_γ, are shown in Fig. 1 and Fig. 2. The fusion results were compared with 1D BPM predictions using the code CCFULL (no coupling) with the optical model parameters (V_0= 130 MeV, r_0= 0.97 fm, a_0= 0.63 fm), which were found out by fitting the high energy experimental fusion data of the nearest tightly bound projectile-target system ^{11}B+^{27}Al [1]. The 1D BPM prediction describes well the experimental fusion results [2, 3], upto $2V_b$ energy but beyond this, it over predicts the data by about 15-20% for ^{7}Li and 12-17% for ^{6}Li.

In order to confirm this underprediction a second complementary measurement of the fusion cross section for ^{7}Li+^{28}Si was done using a different technique, viz., evaporation α-method at E_{lab}=16-26 MeV at IUAC Pelletron (New Delhi). Two charged particle ΔE-E (S.B) telescope detectors were used with two monitors at forward angles (±9.8°). The fusion cross sections were extracted from the measured alpha angular distribution at some backward angles using the code PACE2 and CCFULL and are displayed in Fig. 1. The γ-ray and α-method for ^{7}Li+^{28}Si yield similar fusion cross section at above barrier energies.

Sub- barrier fusion for ^{6,7}Li+^{28}Si

The total fusion cross sections of ^{6,7}Li+^{28}Si systems at near and sub-barrier energies were also measured by characteristic γ-ray method at IOP Pelletron (Bhubaneswar), with ^{6,7}Li beam at energies, E_{lab}=7-10 MeV and 7-11.5 MeV respectively. A self-supported thin Si target (175μg/cm^2) and one HPGe detector placed at 125° with respect to the beam axis was used. The total fusion cross section was extracted from total experimentally measured γ-ray cross sections and for ^{6}Li also measured from summing channel and single γ-ray cross section. Below the barrier fusion results [3, 4] for both systems show some sort of enhancement compared to 1D BPM prediction. Introduction of coupling with the rotational state

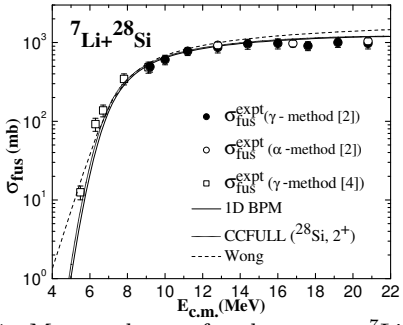

FIG. 1: Measured σ_{fus} for the system ^{7}Li+^{28}Si compared with 1D BPM, Rotational coupling, Wong prediction.

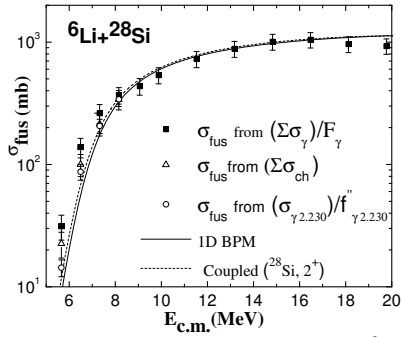

FIG. 2: Measured σ_{fus} for the system ^{6}Li+^{28}Si [3] compared with 1D BPM, Rotational coupling.

(2$^+$, 1.779 MeV) of ^{28}Si improves the fit to some extent. The enhancement for ^{6}Li was found larger than that for ^{7}Li.

Elastic Scattering of ^{6,7}Li+^{28}Si

As a part of our simultaneous investigation of elastic scattering and fusion, we have measured elastic angular distributions of ^{7}Li+^{28}Si at energies 11.5-26 MeV and of ^{6}Li+^{28}Si at 16, 21 MeV. The measurements at E_{lab}>16 MeV were done along with the experiment for the fusion measurement by α- method (at IUAC) and for ^{7}Li experiment performed at energies 11.5, 13 MeV at TIFR-BARC pelletron. The present elastic scattering data with the existing data [5] are analysed using the phenomenological WS potential using the code ECIS94. Two sets of optical model potential parameters, with surface (OM1) and volume type (OM2) imaginary potential, were obtained from fitting the elastic scattering data. The extracted reaction cross sections are similar for both sets of parameters and yielded larger cross section for ^{6}Li compared to ^{7}Li. Around the barrier the real and imaginary OM potential parameters are found to vary with energy. The energy dependence behavior of the potentials, the real and imaginary strengths (OM2) were estimated at the average crossing radii (R_{av}). The normal threshold anomaly is not observed for both the systems, where the energy dependence study of these potentials showed a decreasing tendency with decreasing energy for both real and imaginary strength at near barrier energies. The OM2 parameters extracted from the elastic scattering fit at higher energies, fail to describe 1D BPM and also fusion data. We did not find any consistent set of OM parameters that describes both fusion and elastic scattering phenomena for both systems.

Summary and Conclusion

Fusion cross sections at above and sub-barrier energies have been experimentally measured for ^{6,7}Li+^{28}Si systems. The results showed sub-barrier fusion enhancement and some sort of suppression at well above the barrier (E> $2V_b$). The rotational coupling to the first excited state of ^{28}Si partially explained the enhancement. A consistent set of OM parameters was extracted from best fit to the elastic scattering data. The energy dependence of effective potential parameters around the Coulomb barrier, is explored. Threshold behaviour of real and imaginary potentials was found somewhat different from usually observed for medium and heavy mass targets.

References

[1] R.M. Anjos *et al.*, Phys. Rev. **C42**, 354 (1990).
[2] Mandira Sinha *et al.*, Phys. Rev. **C 76**, 027603 (2007).
[3] Mandira Sinha *et al.*, Eur. Phys. J. **A 44**, 403 (2010).
[4] Mandira Sinha *et al.*, Phys. Rev. **C 78**, 027601 (2008).
[5] A. Pakou *et al.*, Phys Rev, **C 69**, 054602 (2004); Phys. Lett B **556**, 21 (2003).