Study of evaporation residue cross-section for ^{48}Ti + ^{140,142}Ce systems.

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Introduction

For understanding the reaction mechanism of heavy compound nucleus (CN), the study of evaporation residue (ER) cross-section plays a vital role. For heavier systems, the probability of formation of CN is strongly influenced by the properties of the di-nuclear system at contact configuration, where entrance channel plays a major role in reaction dynamics [1]. Nuclear structure of the colliding nuclei also plays a key role, which influence the fusion probability. In some of the recent studies the dependence of the fusion reaction on the nuclear shell structure of projectile and target nuclei was also investigated and the importance of N = 82 in the heavy ion fusion reaction was proposed. It was reported that shell closure of one of the interacting nuclei can lead to the enhanced ER cross-section and helps in the synthesis of heavy nuclei [2]. Keeping these points in mind, a systematic measurement of ER cross-sections for ^{48}Ti + ^{140,142}Ce, ^{124}Sn systems was performed [3]. Here, ^{140}Ce target is neutron shell closed (N_T=82) but ^{142}Ce have 84 neutrons. By comparing the ER cross-sections of these systems, the effect of neutron shell closure on fusion probability can be examined. The ER excitation function for third system (^{48}Ti + ^{124}Sn) was also measured at few energy points to estimate the transmission efficiency of the spectrometer.

Experimental Set-up

The experiment was carried out in HYbrid Recoil mass Analyzer (HYRA) [4] by using 15 UD Pelletron + LINAC accelerator facility at IUAC, New Delhi. ER cross-section measurements were taken using pulsed beam of ^{48}Ti with 4μs separation at laboratory energies ranging from 205 to 257 MeV (including energy loss from 1.1mg/cm^2 Ni window foil, carbon backing and half thickness of target). Thin isotopically enriched targets ^{140,142}Ce of thickness 212μg/cm^2 and 225μg/cm^2, with a thick carbon backing of 24μg/cm^2 and 18.8μg/cm^2 respectively and for calibration purpose, target ^{124}Sn with thickness of 162μg/cm^2 were used in the experiment. Elastically scattered ^{48}Ti ions were detected by two silicon surface barrier detectors placed at ±24° w.r.t. beam direction. For all beam energies, helium gas pressure in HYRA was set to 0.30 Torr. HYRA magnetic field settings were calculated using a simulation program TERS [5]. The ERs were separated from other contaminants using HYRA spectrometer and were detected by a position sensitive multi-wire proportional counter (MWPC) of dimensions 6 inch X 2 inch placed at the focal plane of the spectrometer. A time of flight (TOF) spectrum was generated using anode of MWPC as start and RF of beam as stop. The logical OR signal of two monitor detectors and MWPC anode was the master strobe for data acquisition system.

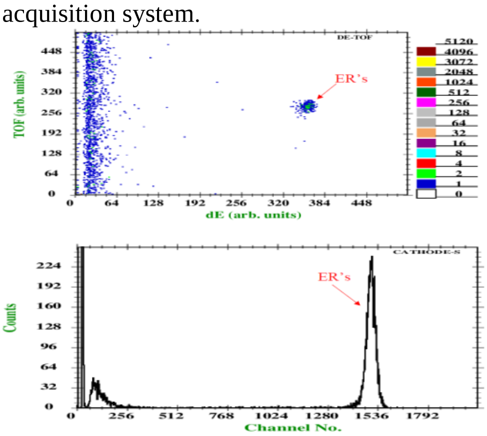

Fig. 1(a) 2D TOF vs. cathode spectrum and (b) 1D cathode spectrum of MWPC at 257 MeV beam energy.

A two dimensional plot was generated by using TOF and energy loss (ΔE) signal of MWPC for ^{48}Ti + ^{142}Ce system at beam energy of 257 MeV, which separates the ERs from beam background is shown in Fig. 1.

Analysis

The formula to calculate ER cross-section is given by

$$\sigma_{ER} = \frac{Yield(Mon)}{Yield(ER)} . \left(\frac{d\sigma}{d\Omega}\right) . \Omega_{Mon} . \frac{1}{\eta HYRA},$$

where, Yield(ER) is the ER yield at the focal plane, Yield(Mon) is the average yield from both monitor detectors (left and right), $(\frac{d\sigma}{d\Omega})$ is the differential Rutherford scattering cross-section, Ω_{Mon} is the solid angle subtended by the monitor detectors and η_{HYRA} is the efficiency of HYRA. The ER yield was obtained from two-dimensional plot of TOF and energy loss, and yield of monitor detectors from the one-dimensional single spectrum using CANDLE software.

Experimentally extracted normalized ER cross-sections (in arbitrary units) w.r.t. laboratory energy, E_{lab} in MeV for the two systems are shown in Fig.2. In this preliminary analysis, the efficiency of gas filled separator is assumed to be same for both the systems.

Results

The preliminary relative ER cross-section measured for both the systems around and below barrier energies are found to be almost same within error bars. At above barrier energies, the cross-sections for ^{48}Ti + ^{140}Ce was few orders of magnitude larger than those for the reaction ^{48}Ti + ^{142}Ce. At the highest energy, the measured cross sections for ^{48}Ti+^{142}Ce is found to be larger as compared to ^{48}Ti+^{140}Ce. This difference in two energies is not very clear from this preliminary analysis. Though ^{140}Ce target is shell close (N_T=82) one may expect a difference in ER cross sections for these two systems. The present result indicates that the fusion of massive nuclei depends on the shell structure of colliding partners. In one of the recent fission mass distributions measurements [1], less Quasi-fission was observed for shell closed nuclei. More such measurements are necessary to disentangle the QF and shell effect. Furthermore, it would be of considerable interest to populate the same CN with different entrance channel mass asymmetries to explore the possible role of entrance channel on fusion probability. Using HYRA spectrometer, we plan to extend such experiments on ER cross-section measurements for ^{48}Ti + ^{136,140,142}Ce and ^{32}S + ^{156}Gd systems. A detail analysis of the results will be presented.

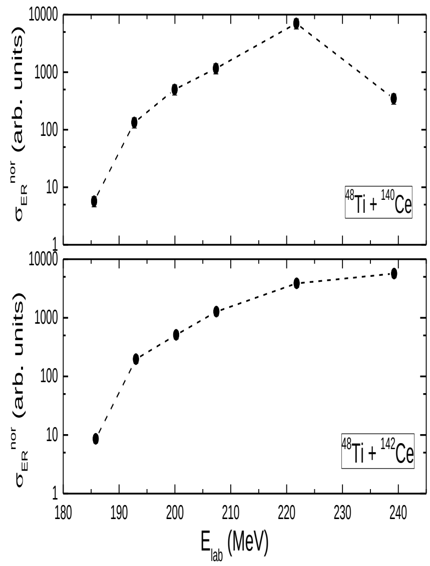

Fig. 2 Preliminary normalized ER cross-sections for (a) ^{48}Ti + ^{140}Ce and (b) ^{48}Ti + ^{142}Ce systems.

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