Evaporation residue cross-sections studies for ^{188,190}Hg CN systems.

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Introduction

Fusion process between massive nuclei has been extensively investigated so far. It is well known that in reactions involving heavy projectile-target combinations, complete fusion is significantly hindered due to large coulomb repulsion force. The fusion probability rapidly decreases as the charge product Z_PZ_T of the projectile and target nuclei increases. The fusion process depends not only on charge product but also on nuclear structure of interacting nuclei [1]. The enhancement in evaporation residue(ER) cross-sections for the reactions initiated by targets having neutrons equals to magic numbers has been reported earlier [2, 3].

In this work, the dependence of fusion on nuclear shell structure of colliding nuclei has been investigated for the two systems ^{48}Ti + ^{140,142}Ce populating compound nuclei ^{188,190}Hg, respectively. Here, ^{140}Ce target is neutron shell closed (N_T=82) but ^{142}Ce have 84 neutrons. The effect of neutron shell closure on fusion probability can be examined by determining the ER cross-sections for these systems.

Experimental details

The first stage of HYRA spectrometer [4] was utilized to perform the experiment. A pulsed ^{48}Ti beam from 15 UD Pelletron + LINAC accelerator with separation 2μs was bombarded on ^{140,142}Ce targets at beam energies 240, 250 and 257 MeV (including energy loss from 1.1mg/cm^2 Ni window foil, carbon backing and half thickness of target). The thickness of targets ^{140,142}Ce was 212μg/cm^2 and 225μg/cm^2, with a thick carbon backing of 24μg/cm^2 and 18.8μg/cm^2 respectively. Two silicon surface barrier detectors (SSBD's) were placed in the target chamber at an angle of at ±24º w.r.t. beam direction, for the detection of the elastically scattered ^{48}Ti ions. 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 multi-wire proportional counter (MWPC) of dimensions 6 inch X 2 inch was used for detecting the ERs at the focal plane of the separator. A two dimensional time of flight (TOF) spectrum was generated using anode of MWPC as start and RF of beam as stop. The energy loss (ΔE) vs. TOF spectra helped to separate the ER's from the beam like and target like contaminations as shown in Fig. 1.

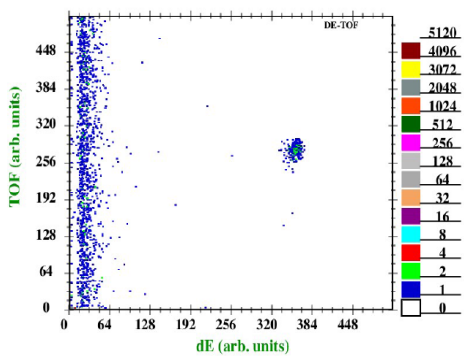

Fig. 1(a) 2D TOF vs. cathode spectrum and (b) 1D cathode spectrum of MWPC at 257 MeV beam energy.

Analysis

The total ER cross-section can be calculated by using the cross-section formula [6]

$$\sigma_{ER} = \frac{Yield\ (ER) X\ AT}{3.76\ X\ Np\ X\ NT\ X\ t} \cdot \frac{1}{\eta HYRA} \quad (1),$$

where, A_T is the mass number of target nuclei (a.m.u), N_P is the number of projectile nuclei absorbed per unit time or beam current (particle nanoamperes or pnA), N_T is the number of target atoms/cm^2 or thickness(μg/cm^2) , t is the length of irradiation (seconds) and η_{HYRA} is the transmission efficiency of HYRA.

The ER yield was obtained from two-dimensional plot of TOF and energy loss using CANDLE software, and η_{HYRA} was estimated using the calibration system ^{48}Ti + ^{122}Sn for which the transmission efficiency has been already measured at two energies [7]. The angular distributions for the systems ^{48}Ti + ^{140,142}Ce were compared with the ^{48}Ti + ^{122}Sn system to estimate the η_{HYRA} using TERS code [5].

The absolute ER cross-sections were then extracted by scaling using the 1DBPM. The absolute ER cross-sections (in mb) w.r.t. center of mass energy, $E_{C.M.}$ in MeV for the two systems are shown in Fig.2.

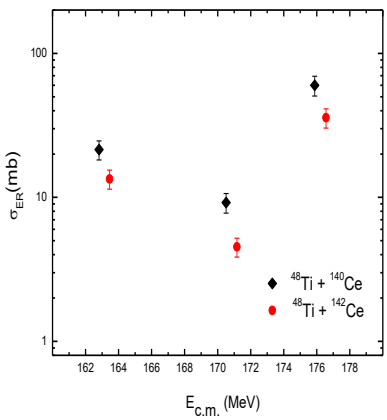

Fig. 2 The extracted absolute ER cross-sections vs. $E_{C.M.}$ for ^{48}Ti + ^{140}Ce and ^{48}Ti + ^{142}Ce systems.

Results

The absolute ER cross-section presented for the systems ^{48}Ti + ^{140,142}Ce at three energies ranging from 160-176 MeV in center-of-mass frame, which are well above the Coulomb barrier. It has been found that the ER cross-sections for ^{48}Ti + ^{140}Ce (N_T = 82) are about two times more than the other system ^{48}Ti + ^{142}Ce with more no. of neutrons. The present result confirms the effect of neutron shell closure effect on the fusion probability and the dependence of the fusion on the shell structure of projectile and target nuclei. However, the decrease in the ER cross-sections for the two systems has been observed at beam energy 250 MeV. More measurements are required to to understand the dynamics of these systems at energies both above and below the Coulomb barrier. We planned to perform the experiment using the HYRA separator to measure the ER cross-sections for these systems at more energies points around the barrier.

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