Evaporation residue excitation function for reactions populating isotopes of Ra

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Introduction

Comprehending the nuclear reaction dynamics and the factors determining its outcome in the superheavy mass region is challenging [1]. The effect of neutron excess in evaporation-residue (ER) survival probability against fission in heavy ion fusion reactions is a matter of considerable interest. The quasi-fission (QF) process [2], in which the system reseparates before reaching a compact compound nucleus (CN), is a significant hurdle in forming heavy and superheavy ERs in heavy-ion induced reactions. It is reported that QF is present in ^{30}Si+^{186}W reaction [3]. Conclusive evidence of QF can be inferred from anomalous fission fragment angular anisotropies [4], broadened fission fragment mass distributions [5], mass-angle correlations [6] and a strong reduction in ER cross-section [3]. We have previously studied the fission fragment mass ratio distribution for the reactions ^{30}Si + ^{182,184,186}W populating the CN ^{212,214,216}Ra [7]. These systems show larger mass ratio widths when compared with theoretical calculations. The result indicates the onset of QF in the ^{30}Si + ^{182,184,186}W reactions. Here, we report the study of the ER cross-section measurements for the reactions ^{28,30}Si+^{182,184,186}W populating isotopes of Ra.

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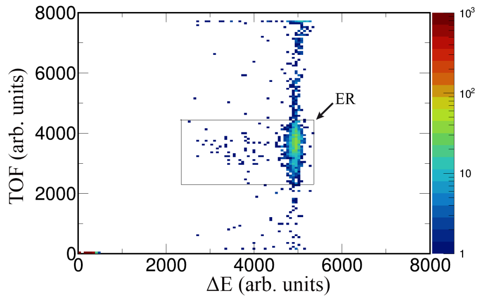

FIG. 1: ΔE versus TOF for ^{30}Si+^{184}W at 160 MeV beam energy. .

Experimental Details

The ER excitation function measurement was performed at the 15UD Pelletron + LINAC accelerator facility of IUAC. Pulsed ^{28,30}Si beam with 2 μs pulse separation was used to bombard the isotopically enriched ^{182,184,186}W targets of thickness 400 μg/cm^2, 200 μg/cm^2 and 300 μg/cm^2 respectively on 25 μg/cm^2 thick carbon backing at laboratory energies in the range of 133 to 192 MeV. ERs were separated from the intense beam background using HYbrid Recoil mass Analyzer (HYRA) [8]. Two silicon detectors were used inside the target chamber, placed at θ = ±26°, to detect the Rutherford scattered beam-like particles for absolute normalization of ER cross secions. These detectors were also used for positioning the beam at the center of the target. The ERs reaching the focal plane were detected using a position sensitive multiwire proportional counter (MWPC). A two-dimensional spectrum of time of flight (TOF) versus energy loss was used to separate the ERs from the beam background. TOF spectrum was generated by taking the MWPC anode as a start signal and the radio frequency pulse used for beam pulsing served as a stop signal. The energy loss (ΔE) vs TOF spectrum helped in unambiguous identification of ERs from the beam-like and the target-like contaminations. FIG. 1 shows the two-dimensional plot of ΔE versus TOF at 160 MeV beam energy.

Analysis and Results

Total ER cross sections (σ_{ER}) can be calculated using the relation

$$\sigma_{\mathrm{ER}} = \frac{Y_{\mathrm{ER}}}{Y_{\mathrm{mon}}}\left(\frac{d\sigma}{d\Omega}\right)\Omega_{\mathrm{M}}\frac{1}{\varepsilon_{\mathrm{HYRA}}}. \quad (1)$$

where $\mathrm{Y_{ER}}$ is ER yield at the focal plane, $\mathrm{Y_{mon}}$ is the yield of elastically scattered projectiles registered by the monitor detector, $\left(\frac{d\sigma}{d\Omega}\right)$ is the differential Rutherford scattering cross section, Ω_{M} is the solid angle subtended by the monitor detector, and $\varepsilon_{\mathrm{HYRA}}$ is the transmission efficiency of the HYRA.

ER excitation function measurement for ^{30}Si+^{186}W is already reported [3] and from these cross-section values we calculated the $\varepsilon_{\mathrm{HYRA}}$ for different energies. In order to remove the geometrical effects, the cross-sections are normalised by πR_B^2 where R_B is the barrier radius obtained from CCFULL.

FIG. 2 depicts the reduced ER cross-sections for five systems, which are populating isotopes of Ra, at various $\mathrm{E/V_B}$, where E is the energy in center of mass frame and $\mathrm{V_B}$ is the barrier in center of mass. A clear effect of N/Z ratio may be noticed in the ER cross-sections, where system having larger N/Z show higher ER cross-section. In mass angle distribution studies [7], all the 3 reactions, ^{30}Si+^{182,184,186}W show significant QF, among these, the reaction using neutron deficient target shows larger mass width at similar $\mathrm{E/V_B}$. In this study as well we have noticed lower ER cross-section for lighter isotope of Ra. Also in FIG. 2 we can see that, the same CN (^{212}Ra) is populating through different beam and target, and they are showing different cross-sections. More theoretical calculations including dinuclear system calcuations are in progress to explore this observations.

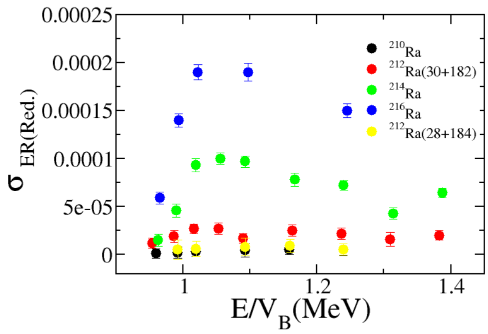

FIG. 2: Reduced ER cross-section vs $\mathrm{E/V_B}$ of isotopes of Ra.

Acknowledgments

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