Study of Barrier Distributions from Quasielastic Scattering Cross Sections towards Superheavy Nuclei Synthesis

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The study of Coulomb barrier distributions is of fundamental importance in understanding heavy-ion induced fusion reactions towards syntheses of superheavy nuclei[1, 2]. Cross sections of the reactions for producing new elements are predicted to be much smaller than those for the existing elements[3–5]. They are also known to be particularly sensitive to the incident energy. One of the most direct information for determining the optimum incident energy is provided by the barrier distribution. This work aims at precisely obtaining the barrier distribution of heavy-ion induced reactions by measuring the quasielastic (QE) scattering, in order to clarify the relation between the barrier distribution and the optimum incident energy at which the evaporation residue cross section is maximized. To this end, the excitation functions of QE scattering cross sections $\sigma_{\rm QE}$ relative to the Rutherford cross sections $\sigma_{\rm R}$ for ^{48}Ca+^{208}Pb, ^{50}Ti+^{208}Pb, ^{48}Ca+^{238}U, ^{22}Ne+^{248}Cm, ^{26}Mg+^{248}Cm, ^{30}Si+^{248}Cm, ^{34}S+^{248}Cm, ^{40}Ar +^{248}Cm, ^{48}Ca+^{248}Cm and ^{50}Ti+^{248}Cm systems were measured. What is new in this method is measuring the recoiled nuclei at forward angles ($\theta \sim 0^\circ$) using GARIS. This method enables us to derive the barrier distribution for angular momentum $l \sim 0$ concerned with superheavy nuclei synthesis. The QE scattering events were well separated from deep-inelastic events by using GARIS and its focal plane detectors. The QE barrier distributions were extracted for the 10 reaction systems previously noted, and were compared to coupled-channels calculations, and were compared to evaporation residue cross-sections. The calculation results indicate that the deformation of actinoide target nucleus, the vibrational and rotational excitations of the colliding nuclei, as well as neutron transfers before contact, affect the structure of the barrier distribution. The peak of the 2n evaporation cross-section of the cold fusion reactions ^{48}Ca+^{208}Pb and ^{50}Ti+^{208}Pb – relevant to the synthesis of No (atomic number $Z = 102$), Rf ($Z = 104$) – emerged at the same energy as a local maximum of the barrier distributions. The evaporation residue cross-section of the hot fusion reactions ^{22}Ne+^{248}Cm, ^{26}Mg+^{248}Cm, ^{48}Ca+^{238}U and ^{48}Ca+^{248}Cm – relevant to the synthesis of Sg ($Z = 106$), Hs ($Z = 108$), Cn ($Z = 112$) and Lv ($Z = 116$), which are the frontier of the known superheavy nuclei – peak at an energy between experimental average Coulomb barrier height and the Coulomb barrier height for a side collision, where the projectile approaches along the short axis of a prolately deformed nucleus. This suggests that the hot fusion reactions take advantage of a compact collision geometry with the projectile impacting the side of the deformed target nucleus.

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