Fusion of neutron-rich light nuclei: an intersection of nuclear astrophysics and nuclear science

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The outer crust of an accreting neutron star is an interesting environment in which nuclear reactions may occur. Observational astronomy has detected phenomena, designated X-ray superbursts, in which an accreting neutron star releases as much energy in a few hours as our sun does in a decade. It has been proposed that the fusion of neutron-rich light nuclei in the outer crust heats the crust and triggers the X-ray superburst. In order for this scenario to be realized an enhancement in the fusion cross-section of neutron-rich nuclei as compared to their $\beta$-stable counterparts is necessary. To examine whether such an enhancement exists requires a systematic measurement of fusion excitation functions with both stable and radioactive beams. As the intensity of radioactive beams will be low we have developed an experimental method capable of measuring the fusion excitation function with a beam intensity of $10^4$ – $10^5$ ions/sec. In our initial measurements we have examined fusion in $^{16,18}$O + $^{12}$C at near and sub-barrier energies. Evaporation residues (ER) formed by the de-excitation of the fusion product are identified and the total cross-section was measured along with the energy and angular distributions of the ERs. Comparison of the measured excitation function with state-of-the-art microscopic calculations indicates an increased cross-section relative to the model in the sub-barrier domain. Future experiments with both stable and radioactive beams at Florida State University, GANIL, and ReA3 aim to extend these measurements to $^{19,20}$O + $^{12}$C and $^{18,19}$O + $^{18}$O.