Doorway States in the $^{12}C(^{12}C,\gamma)^{24}Mg$ Radiative Capture Process

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Radiative capture, the complete fusion of heavy ions without particle emission, is a powerful tool both for reaction mechanism studies and for populating interesting states. Several distinct mechanisms can contribute and each has a characteristic mass, energy and spin dependence, so it is not obvious which process will dominate. The $^{12}C+^{12}C$ system, with its strongly resonant fusion cross-section, has a historic place in heavy-ion studies. The relationship between the resonances and underlying structure is still not clear, though many different models have been used to try to understand the data.[1] The pioneering work of Sandorfi and Nathan [2] revealed the direct link between the entrance channel and the fused ^{24}Mg residue, and the importance of “one-step” cooling by very high energy gamma rays ($E\gamma > 20$MeV). However, it has never been clear that this was the dominant mechanism, nor what the total radiative capture cross-section was. We have performed several new studies to elucidate this issue. Firstly, we used Gammasphere at LBNL as a total energy calorimeter to measure $^{12}C(^{12}C,\gamma)^{24}Mg$ capture and investigate “multi-step” cooling. Secondly, we used the Argonne FMA to directly count residues and determine the total radiative capture cross-section. Finally, we used the DRAGON facility at TRIUMF to investigate near barrier resonances. Many interesting new features were observed. These include the observation that the total radiative capture cross section is always much larger than that observed by Sandorfi and Nathan, often several microbarns, and multi-step decay is the dominant mechanism. Rather few decay paths are involved, almost all the decays pass through a handful of doorway states near 10 MeV in excitation. For resonances with J>4, the decay is almost never to the yrast line, but appears to strongly populate the K=2 quasi-gamma band. The possibility of identifying “molecular” transitions will be discussed, and that of better measuring the width of the resonant structures. Finally, the question of radiative capture in other systems will be addressed. This research was supported in part by the US Department of Energy, Office of Nuclear Physics, under contract W-31-109-ENG-38.

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