Spin-isospin responses by charge-exchange reactions and implications for astrophysics

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Gamow-Teller (GT) transitions, aside from their interest from the nuclear structure point of view, play very important roles in various phenomena in nature. In nucleosynthesis, the β-decay of nuclei along the s- and r-processes determine the paths that these processes follow and the abundances of the elements synthesized. In supernova collisions, GT transitions are of paramount importance in the pre-supernova phase where electron capture occurs on neutron-rich *fp*-shell nuclei at the high temperatures of giant stars. Electron capture is mediated by GT transitions. Electron capture removes the electron pressure that keeps the star from collapsing precipitating a cataclysmic implosion followed by a huge explosion throwing much of the star material into space and leaving a neutron star or black hole behind. In 2ν2β-decay, virtual GT transitions via 1^+ states of the intermediate nucleus, determine the rate and therefore the lifetime of 2β-decaying nuclei. This will be discussed extensively in this conference by Frekers [1]. The 0ν2β-decay is much more interesting since if it occurs it establishes the Majorana character of the neutrino and allows a determination of its mass. However, a good determination of the matrix element connecting both ground states is important. Here, in addition to GT transitions that are important in 2ν2β-decay, higher multipolarity spin-isospin modes play an important role in determining this matrix element. Experimental aspects of this will be discussed.

In this talk, the motivation behind performing charge-exchange reactions at intermediate energies (≥ 100 MeV/u) with high energy resolution will be discussed. The correspondence between measuring GT strength via charge-exchange reactions and through charged-current (CC) neutrino scattering, including electron capture, will be discussed. The experimental techniques for performing (^{3}He,*t*) and (*d*,^{2}He) reactions will be presented in detail and the DWBA method to extract Fermi and GT strengths will be discussed. After discussing the case study of ^{58}Ni for which the GT$^+$ strength has been determined by measuring the (*n*,*p*), (*d*,^{2}He) and (*t*,^{3}He) reactions at and near 0°, the (*d*,^{2}He) measurements on several *fp*-shell nuclei will be presented. The results will be compared to results of large shell-model calculations using the KB3G interaction. The centroids of the GT$^+$ strengths for these nuclei are compared to independent-particle shell-model and large-basis shell-model calculations. The effects of these on supernova collapse, the resulting Y_e (electron-to-baryon ratio), and the mass of the residual neutron star will be briefly discussed.

[1] D. Frekers, talk at NDM12.