Electron Capture Reactions and Beta Decays in Steller Environments

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Gamow-Teller transition strengths in fp-shell nuclei are studied by shell model calculations with the use of new shell model Hamiltonians, GXPF1 [1]. The distributions of the strengths are found to be generally more fragmented compared to those obtained by KB3G [2]. The difference of the distribution of the strength leads to different reaction cross sections or rates in stars, for example, the enhancement of the neutrino-induced ^{56}Ni (ν, ν'p) ^{55}Co reaction cross section and production rate of ^{55}Mn in population III stars [3].

Electron capture reactions on Ni, Fe and Co isotopes are investigated by shell model calculations in steller environments. The capture rates depend sensitively on the distribution of the GT strength. The rates are found to be smaller for GXPF1 compared to KB3G in many of Fe and Ni isotopes such as ^{58}Ni and ^{52,54,56}Fe at temperatures T = (3∼10) $\times 10^9$ K and densities $\rho Y_e \simeq 10^7 \sim 10^9$ mole/cm^3. In particular, for ^{58}Ni, this reduction of the capture rates is found to be consistent with the rates obtained from experimental GT strength in ^{58}Ni [4]. In case of ^{60}Ni, the capture rates increase for GXPF1 compared to KB3G due to the existence of the GT strength at a low excitation energy, E_x =0.7 MeV for GXPF1. This is consistent with the observed large GT strength, B(GT$_+$) =0.95±0.15 at E_x =0.65 MeV [5].

Beta decays of the N=126 isotones are studied by shell model calculations taking into account both the GT and first-forbidden (FF) transitions. The FF transitions are found to be important to reduce the half-lives by twice to several times of those by the GT contributions only [6]. Implications of the short half-lives of the waiting point nuclei on the r-process nucleosynthesis will be discussed for various astrophysical conditions. .

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