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ORIGINAL ARTICLE

The nuclear structure and associated electron capture rates on odd-Z nucleus ^{51}V in stellar matter

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Abstract The Gamow-Teller strength distribution function, $B(GT)$, for the odd Z parent ^{51}V, $N - Z = 5$, up to 30 MeV of excitation energy in the daughter ^{51}Ti is calculated in the domain of proton-neutron Quasiparticle Random Phase Approximation (pn-QRPA) theory. The pn-QRPA results are compared against other theoretical calculations, (n, p) and high resolution (d, ^{2}He) reaction experiments. For the case of (d, ^{2}He) reaction the calibration was performed for $0 \leq E_j \leq 5.0$ MeV, where the authors stressed that within this excitation energy range the $\Delta L = 0$ transition strength can be extracted with high accuracy for ^{51}V. Within this energy range the current pn-QRPA total $B(GT)$ strength 0.79 is in good agreement with the (d, ^{2}He) experiment's total strength of 0.9 ± 0.1. The pn-QRPA calculated Gamow-Teller centroid at 4.20 MeV in daughter ^{51}Ti is also in good agreement with high resolution (d, ^{2}He) experiment which placed the Gamow-Teller centroid at 4.1 ± 0.4 MeV in daughter ^{51}Ti. The low energy detailed Gamow-Teller structure and Gamow-Teller centroid play a sumptuous role in associated weak decay rates and consequently affect the stellar dynamics. The stellar weak rates are sensitive to the location and structure of these low-lying states in daughter ^{51}Ti. The calculated electron capture rates on ^{51}V in stellar matter are also in good agreement with the large scale shell model rates.

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1 Introduction

Supernovae are crucial to our very existence and for the dynamical/morphological development of the universe. They are also at the nexus of many of the great debates raging among astronomers. These explosions have enriched the galaxy with oxygen we breathe, the iron in our blood, the calcium in our bones and teeth, and silicon which is used in the semiconductor-based electronic industries having enormous applications in this modern world. The weak interactions soften and smooth the landscape of star for gravity. These two forces play a pivotal role in cooking the material inside stellar kilns and play preeminent role in the make up of galaxies and stars formation and their physical death (supernova explosion). This is not only true for the star's energy budget but these forces help each other in a certain sense to change the composition of the stellar matter and entropy as well. When the ratio of neutrons to protons is low, electron capture is a more probable process to occur. The processes mediated by charge-changing weak interaction are (1) electron capture, (2) positron capture, (3) β^- decay in nucleus, (4) β^+ decay. Gamow-Teller (GT) transitions play a preeminent role in the collapse of stellar core in the stages leading to a Type-II supernova. The GT strength distributions from ground and excited states are used for the calculation of weak decay rates for the core-collapse supernova dynamics and for probing the concomitant nucleosynthesis problem (Nabi and Rahman 2005, 2007, 2011; Fujita et al. 2005; Zhi et al. 2011; Sasano et al. 2012).

The incarnation of the core-collapse mechanism is the conversion of a fraction of the gravitational energy into ki-