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Roles of spin-dependent transitions in nuclei on astrophysical processes in stars

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Due to recent advances in shell-model studies on spin modes in nuclei, precise evaluations of Gamow-Teller (GT) strengths become feasible and electron-capture and β-decay rates in stellar environments have been updated.
The weak rates in sd-shell obtained with the USDB Hamiltonian are applied to nuclear Urca processes in O-Ne-Mg cores in stars with 8-10 solar masses [1,2]. The Urca processes for the nuclear pairs with A=23 and 25 are found to be important for the cooling of the core [1].
Here, the weak rates important for the Urca processes in accreted neutron star crusts [3] are investigated. The e-capture and β-decay rates are evaluated for the nuclear pair with A=31, ^{31}Al $\leftrightarrow$ ^{31}Mg, in sd-pf shell and the pair with A=61, ^{61}V $\leftrightarrow$ ^{61}Cr, in fp-gd shell. ^{31}Mg belongs to the island of inversion, where admixtures of sd- and fp-shells become important. Energy levels in ^{31}Mg are found to be well reproduced with the use of EEdf1 interaction obtained by the extended Kuo-Krensiglowa (EKK) method [4], which can properly treat Q-box calculations in two-major shells without divergence problems. The weak rates evaluated with the EKK method prove to lead to Urca processes.
The GT strengths in ^{61}V is evaluated with the GXPF1J Hamiltonian [5]. The calculated strength between the ground states of ^{61}V and ^{61}Cr is found to be consistent with the recent experimental data [6]. This suggests that the Urca process for the A=61 pair would be more moderate than considered before. Results with an extension to the fp-gd shell-model space will be also reported.
The weak rates in fp-shell obtained with the GXPF1J are applied to nucleosynthesis in Type Ia supernova explosions [7]. The electron screening effects are taken into account [8]. Overproduction problem of neutron-rich iron-group elements for the previous weak rates is found to be considerably suppressed.

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