Nuclear Weak Rates for Astrophysical Processes in Stars

T. Suzuki[1,2], S. Chiba[3], T. Yoshida[4], A. B. Balantekin[5], T. Kajino[2,4,6],M. Honma[7], Y. Tsunoda[8], N. Tsunoda[8], and N. Shimizu[8]

[1]Department of Physics, College of Human. and Sci. Nihon University, Tokyo 156-8550, Japan
[2]National Astronomical Observatory of Japan, Tokyo 181-8588, Japan
[3]Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology, Tokyo 152-8550, Japan
[4]Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan
[5]Department of Physics, University of Wisconsin, Wisconsin 53706, USA
[6]School of Physics and Nuclear Energy Engineering, Beihan University, Beijing 100083, China
[7]Center for Mathematical Sciences, University of Aizu, Fukushima 965-8580, Japan
[8]Center for Nuclear Study, The University of Tokyo, Tokyo 113-0033, Japan

We have updated nuclear weak rates relevant to the study of astrophysical processes in stars. Neutrino-induced reaction cross sections, electron-capture and β-decay rates at stellar environments are obtained with new shell-model Hamiltonians that prove to be successful in describing spin responses - Gamow-Teller and spin-dipole transitions - in nuclei.

ν-nucleus reaction cross sections on ^{12}C [1], ^{13}C [2], ^{16}O [3], ^{40}Ar [4], ^{56}Fe, and ^{56}Ni [5] have been updated and applied to nucleosynthesis in supernovae (SNe) [1,3,5], ν detection [2-4] and study of ν properties such as mass hierarchies [6]. The total and partial cross sections for various channels are tabulated for ^{12}C, ^{13}C and ^{16}O. Coherent elastic scattering cross sections are also evaluated for ^{12}C and ^{13}C and sensitivity to neutron distributions are investigated [7].

Electron-capture and β-decay rates in pf-shell and sd-shell nuclei at stellar environments have been updated with GXPF1J [8] and USDB, respectively. They have been used to study synthesis of iron-group nuclei in type Ia SNe [9], and nuclear URCA processes in degenerate O-Ne-Mg cores in stars with 8-10 solar masses [10]. Nuclear pairs, ^{23}Na-^{23}Ne and ^{25}Mg-^{25}Na, are found to be important for the cooling of the core, and the final fate of the stars is sensitive to the nuclear weak rates as well as their mass. The rates for sd- and pf-shell nuclei are tabulated. Extension of the study to e-capture and β-decay rates for neutron-rich nuclei along and near N=50 is in progress, where evaluations of forbidden transitions in pf-gds shells become crucial. The rates are important for stellar core-collapse processes. The rates for nuclei in the island of inversion important for nuclear URCA processes in the neutron star crusts are also under study.

[1] T. Suzuki et al., Phys. Rev. C 74, 034307 (2006); T. Yoshida et al., ApJ. 686, 448 (2008).
[2] T. Suzuki , B. Balantekin, and T. Kajino, Phys. Rev. C 86, 015502 (2012).
[3] T. Suzuki, S. Chiba, T. Yoshida et al., Phys. Rev. C 98, 034613 (2018).
[4] T. Suzuki and M. Honma, Phys. Rev. C 87, 014607 (2013).
[5] T. Suzuki, M. Honma, K. Higashiyama et al., Phys. Rev. C 79, 061603 (R) (2009).
[6] K. Nakazato, T. Suzuki, and M. Sakuda, PTEP 2018, 123E02 (2018).
[7] T. Suzuki, B. Balantekin, T. Kajino, and S. Chiba, submitted.
[8] T. Suzuki, M. Honma, H. Mao, T. Otsuka, and T. Kajino, Phys. Rev. C 83, 044619 (2011).
[9] K. Mori, M. Famiano, T. Kajino, T. Suzuki et al., ApJ. 833, 179 (2016).
[10] H. Toki, T. Suzuki, K. Nomoto, S. Jones, and R. Hirschi, Phys. Rev. C 88, 015806 (2013); T. Suzuki, H. Toki, and K. Nomoto, ApJ. 817, 163 (2016).