2 - 16 Thermonuclear Reaction Rates in rp Process of *sd* Shell Nuclei*

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Recently, we have constructed a new set of isospin non-conserving (INC) shell-model Hamiltonians as a combination of isospin conserving (IC) Hamiltonian, Coulomb interaction and effective isospin-symmetry breaking forces of nuclear origin[1]. The advantage is that Coulomb effects are taken into account with great care, thus the new approach allows one to describe more accurately and to predict unknown nuclear level schemes and decay modes. Since the approximate isospin-symmetry becomes broken, a realistic amount of isospin-mixing in nuclear states is thus introduced. Among numerous applications to the structure of proton-rich nuclei, we used the new Hamiltonian to calculate resonant reaction and non-resonant reaction (direct capture) rates of radiative proton-capture reactions important for astrophysical rp process. The following thermonuclear reaction rates have been investigated: ^{23}Al(p,γ)^{24}Si, ^{25}Al(p,γ)^{26}Si, ^{28}P(p,γ)^{29}S, ^{29}P(p,γ)^{30}S, ^{35}Ar(p,γ)^{36}K, ^{31}Cl(p,γ)^{32}Ar and ^{32}Cl(p,γ)^{33}Ar.

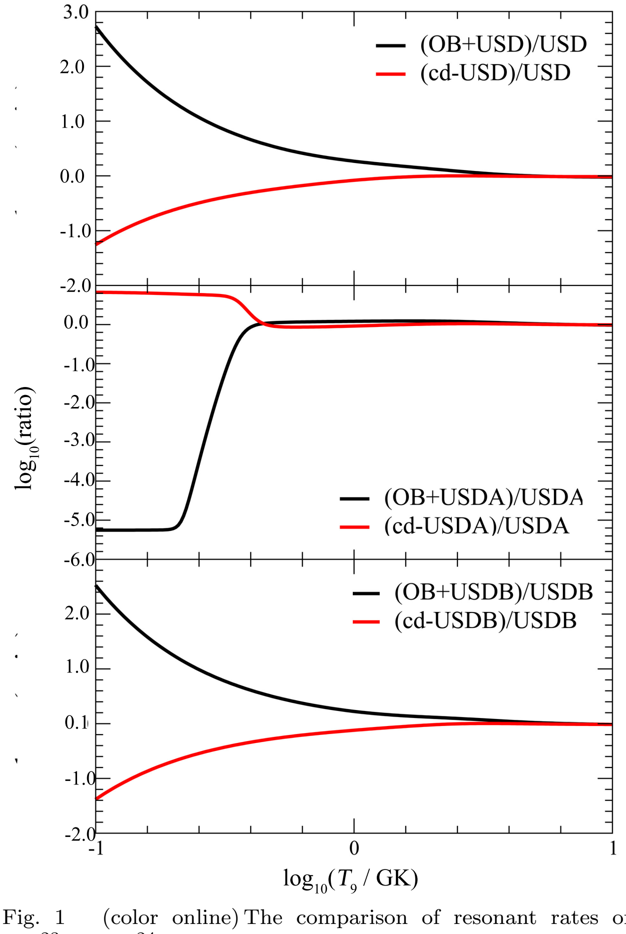

Fig. 1 (color online) The comparison of resonant rates of ^{23}Al(p,γ)^{24}Si calculated by IC and INC Hamiltonians. The INC Hamiltonians of OB+USD, OB+USDA, OB+USDB were constructed in Ref. [5]; whereas (cd-USD), (cd-USDA), (cd-USDB) are INC Hamiltonians in Ref. [1]. USD, USDA, USDB are IC Hamiltonians in Ref. [6].

In fact, the necessary nuclear structure input for the calculation of a thermonuclear reaction rate are energy levels, proton-capture and gamma-decay widths. However, precise experimental data on the level scheme above the proton separation threshold is not always available for many nuclei of interest. The missing information could be either adopted from its mirror nucleus (if known), or estimated from its mirror nucleus and theoretical coefficients of the isobaric multiplet mass equation (IMME), or calculated directly from the large scale shell-model approach using an INC shell-model Hamiltonian. Using the latter method, we found that the produced theoretical energy levels are closer to experimental data than level schemes proposed previously by IC Hamiltonians. In addition, isospin mixing effects influence the spectroscopic factors and electromagnetic transition strengths, modifying thus spectroscopic factors and gamma widths. Large-scale computations have been performed with ANTOINE shell-model code[2].

The total reaction rate consists of resonant reaction (res) and direct capture (dc) rates of proton capture on ground state and on thermally excited states in the target nucleus weighted with their individual population factors,

$$N_A\langle\sigma v\rangle = \sum_i \frac{(2J_i+1)\exp(-E_i/kT)}{\sum_n(2J_n+1)\exp(-E_n/kT)} \times (N_A\langle\sigma v\rangle_{\mathrm{res}\,i} + N_A\langle\sigma v\rangle_{\mathrm{dc}\,i})\,\mathrm{cm^3s^{-1}mol^{-1}} \quad , \tag{1}$$

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where J_i (J_n) and E_i (E_n) are the angular momentum and the corresponding resonance energy of a parent's state, respectively. For the detail formulation of resonant and direct capture parts of a thermonuclear (p,γ) reaction rate, see Ref. [3]. According to Ref. [4], we confirmed that proton capture on excited states of target nucleus also contribute to the total rp process rates, *e.g.* ^{32}Cl(p,γ)^{33}Ar and ^{31}Cl(p,γ)^{32}Ar. We plan to further investigate importance of rp processes ^{24}Al(p,γ)^{25}Si and ^{34}Cl(p,γ)^{35}Ar reaction rates.

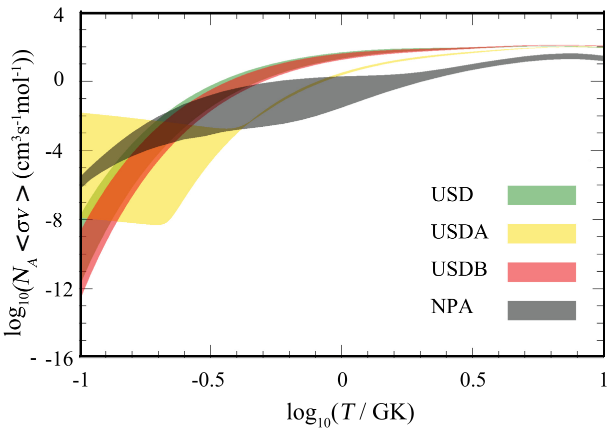

Fig. 2 (color online) Comparison of resonant reaction rates of ^{23}Al(p,γ)^{24}Si produced from shell model with INC Hamiltonians based on USD, USDA, and USDB, to rates yielded from statistical method in Ref. [7].

Fig. 1 presents a typical preliminary result comparing ratios of our rates and rates generated by INC Hamiltonians of Ref. [5] to rates obtained from IC Hamiltonians[6] ^{23}Al(p,γ)^{24}Si reaction. Significant deviation of the rate can be noticed at temperatures $0.01 \leq T/\mathrm{GK} \leq 1$. Moreover, Fig. 2 shows a typical preliminary result of comparison of resonant reaction rates of ^{23}Al(p,γ)^{24}Si produced from the INC shell model to a statistical method analysis[7]. The reaction rate generated from USDA-based INC Hamiltonian is significantly different from those obtained from USD- and USDB-based INC Hamiltonians. This is due to the difference in the predicted position of resonance energies. Both profiles of reaction rate obtained from the microscopic shell model deviates from that estimated by the statistical model. Presently, we are in progress to identify the astrophysical impact of these new rp reaction rates. Results will be published elsewhere.

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