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2 - 15 Thermonuclear Reaction Rates in rp Process of ^{64}Ge(p, γ)^{65}As and ^{65}As(p, γ)^{66}Se for Type-I X-ray Bursts*

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We have derived new thermonuclear ^{64}Ge(p, γ)^{65}As and ^{65}As(p, γ)^{66}Se reaction rates based on recently evaluated proton separation energies[1] and large-scale shell model (LSSM) calculation. The precisely measured or evaluated proton separation energies of $S_{\rm p}(^{65}{\rm As})$ and $S_{\rm p}(^{66}{\rm Se})$, are (90 ± 85) keV and (1720 ± 310) keV, respectively. We utilized one-zone post-processing type I X-ray burst model[2] to investigate the astrophysical impact of our new rates. We found that the new experimental $S_{\rm p}(^{65}{\rm As})$, resonant energies and spectroscopic factors estimated from LSSM significantly affects the productions of nuclide in the range of $64\le A\le110$ about one to ten times compared to currently available JINA data sets, REACLIB[3].

The total reaction rate includes the 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,

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

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 of resonant part of a thermonuclear(p, γ) reaction rate, see Ref.[4]. Here, we point out that direct capture rates of both rp processes only contribute at temperature regime below ~0.2 GK. The temperature range of thermonuclear runaways on the surface of accreting neutron stars generating X-ray bursts is much more higher[2]. Hence, the sole contributor of both ^{64}Ge(p, γ)^{65}As and ^{65}As(p, γ)^{66}Se reaction rate is resonant proton capture.

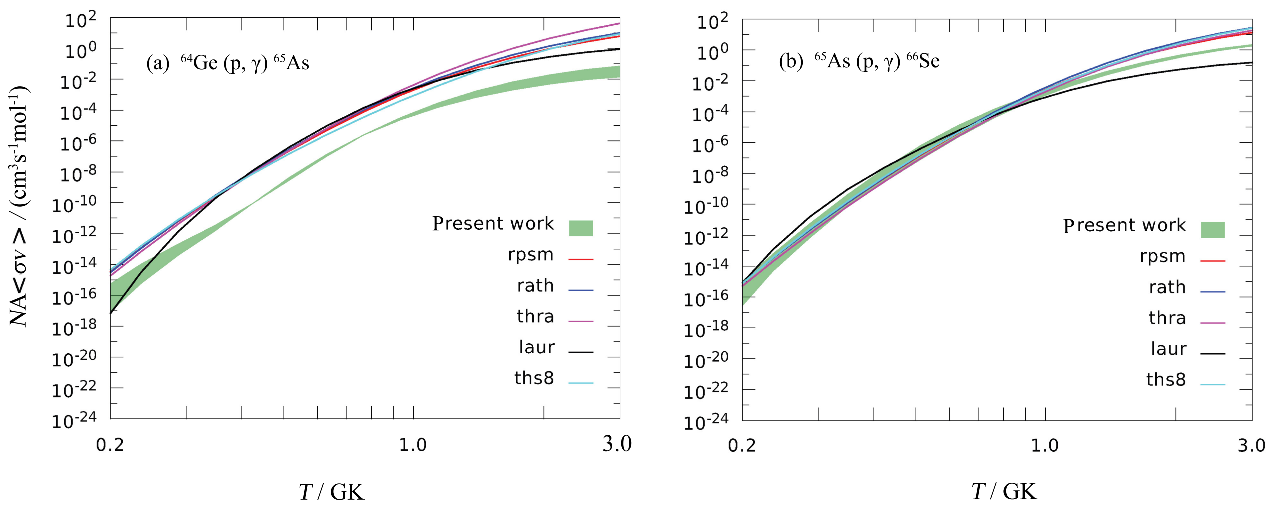

Fig. 1 (color online) Comparison of thermonuclear in rp process reaction rates derived in present work with REACLIB[3].

The key ingredients to obtain the total reaction rates are energy levels, spectroscopic factors, proton and γ widths. However, precise experimental informations of level schemes of proton-rich nuclei $A\ge60$, are either not always available or rather scarce. When such shortcomings happen in a final nucleus, we supplement them with LSSM calculation with referring to mirror partner. In the present work, spectroscopic factors and electromagnetic widths have been calculated from nuclear wave functions obtained from numerical diagonalization of isospin conserving Hamiltonian of *pf* shell, namely GXPF1a[5]. The calculation was carried out by ANTOINE[6] and NuShellX@MSU[7] shell-model codes. Fig. 1 shows the preliminary results comparing our rates with data compiled by JINA collaboration[3]. The data sets of rpsm, rath, thra, and ths8 were generated from Hauser-Feshbach statistical model; whereas laur data was derived on outdated $S_{\rm p}$ values, see Ref. [3] for detail description.

In our preliminary results, the overall ratios of nuclide productions based on our reaction rates to productions based on REACLIB rates for type I X-ray burst simulations[2] are about one to ten times. We investigated that the newly measured $S_{\rm p}(^{65}\rm As)$ is more negative[8], decreasing the Q value and causing more production of ^{64}Ge than ^{65}As. Secondly, present rate of ^{65}As(p, γ)^{66}Se is lower than rates of other data sets, except the rate of *laur* data set in temperature regime $T[GK] \geq 0.9$, c.f. Fig. 1(b). The *laur* data set implemented larger Q value for ^{65}As(p, γ) rates, causing more extensive *rp* process and yielding over production of nuclide above $A=65$. Using present rates, we found less productions of ^{65}As and ^{66}Se, and less extensive rp process of ^{65}As(p,γ)^{66}Se, these two factors reduce the abundances of nuclide $A \geq 65$. Presently, we are in progress of checking the astrophysical impact of these new rates, and results will be published elsewhere.

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