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Thermonuclear reaction rate of $^{57}\mathrm{Cu}(p,\gamma)^{58}\mathrm{Zn}$ in rp-process

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The thermonuclear reaction rate of $^{57}\mathrm{Cu}(p,\gamma)^{58}\mathrm{Zn}$, which depends exponentially on the neutron-deficient nuclide $^{58}\mathrm{Zn}$ mass, is of great importance to understand how the rp-process proceed beyond the $^{56}\mathrm{Ni}$ waiting point in type-I X-ray bursts.
So far the uncertainty of $^{57}\mathrm{Cu}(p,\gamma)^{58}\mathrm{Zn}$ reaction rate is dominated by the 50~keV uncertainty of the proton separation energy (S_p) of $^{58}\mathrm{Zn}$~[1,2] propagated from its mass [3], which was determined indirectly by measuring the Q value of a double charge-exchange reaction $^{58}\mathrm{Ni}(\pi^+,\pi^-)^{58}\mathrm{Zn}$ nearly 40 years ago [4].
Recently, We directly measured the mass of $^{58}\mathrm{Zn}$ by using $B\rho$-defined isochronous mass spectrometry~[5], resulting in a more precise proton separation energy of $S_p(^{58}\mathrm{Zn}) = 2227(36)$~keV.
With this new S_p value, the thermonuclear rate of the $^{57}\mathrm{Cu}(p,\gamma)^{58}\mathrm{Zn}$ reaction has been reevaluated to be higher than the most recently published rate~[2] by a factor of up to 3 in the temperature range of 0.2~GK
$lesssim T$
$lesssim$ 1.5~GK.
The new rate is used to investigate its astrophysical impact via one-zone post-processing type-I X-ray burst calculations.
It shows that the updated rate and new $S_p(^{58}\mathrm{Zn})$ value result in noticeable abundance variations for nuclei with $A = 56$-59 and a reduction in $A = 57$ abundance by up to 20.7%, compared with the results using the recently published rate.

References

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