Determination of $^8\text{B}(p,\gamma)^9\text{C}$ reaction rate from $^9\text{C}$ breakup

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In low-metallicity supermassive stars, the proton capture reaction of $^8\text{B}$, $^8\text{B}(p,\gamma)^9\text{C}$ is expected to be important to synthesize the CNO elements. Because of the difficulties in measuring the $^8\text{B}(p,\gamma)^9\text{C}$ cross section $\sigma_{p\gamma}$ at very low energies, several alternative reactions have been proposed [1, 2, 3] to indirectly determine the astrophysical factor $S_{\text{18}}(\varepsilon)$, which is defined by

$$ S_{\text{18}}(\varepsilon) = \sigma_{p\gamma} \exp[2\pi\eta] $$

($\varepsilon$: the $^8\text{B}$ relative energy in the center-of-mass frame, $\eta$: the Sommerfeld parameter). There is, however, a significant discrepancy of about 50% between the $S_{\text{18}}(0)$ obtained by the Coulomb dissociation method [3] and the ANC method [1, 2].

In this paper, we reinvestigate the Coulomb dissociation [3] (elastic breakup) and the proton removal process [2] of $^8\text{C}$ by means of coupled-channel calculation with a three-body ($p + ^8\text{B} + \text{target}$) model. We use the ANC method [4] for both reactions. The main purpose of the present study is to show the consistency between the two values of $S_{\text{18}}(0)$ extracted from these two types of breakup, and thereby determine $S_{\text{18}}(0)$ with high reliability. The detail of our calculation is shown in the Ref. [5].

First, we analyze the elastic breakup $^{208}\text{Pb}({}^9\text{C},p{}^8\text{B})^{208}\text{Pb}$ at 65 MeV/nucleon. In Fig. 1, we show the breakup cross section as a function of $\varepsilon$. We have included the experimental efficiency $\epsilon(\varepsilon)$ [6] and resolution $\Gamma$ in the calculation. In order to determine $S_{\text{18}}(0)$ we fit the theoretical result (dashed line) to the experimental data [3], and the solid line is obtained. The renormalization factor is 1.10, which results in $S_{\text{18}}(0) = 63.7$ eVb.

Second, we analyze the one-proton removal reaction of $^9\text{C}$ at 285 MeV/nucleon on $^{12}\text{C}$ and $^{27}\text{Al}$ targets. The calculated cross section $\sigma_{p\gamma}$ is renormalized to fit the experimental value taken from Ref. [7], which determines $S_{\text{18}}(0)$. These values are summarized in the right panel of Fig. 1. One sees that the two results of $S_{\text{18}}(0)$, corresponding to $^{12}\text{C}$ and $^{27}\text{Al}$ targets, agree well with each other. By taking an average of the two values, we obtain $S_{\text{18}}(0) = 63.7$ eVb.

We here remark that in our three-body coupled-channel analysis, the values of $S_{\text{18}}(0)$ extracted from two different breakup reactions, 67.3 eVb (elastic breakup) and 63.7 eVb (proton removal), show very good agreement. This indicates reliability of the present analysis and the result of $S_{\text{18}}(0)$. As a principal result of the present study, we obtain $S_{\text{18}}(0) = 66 \pm 10$ eVb. The detailed discussion concerned with the difference of the result between present and previous is given in Ref. [5].

References