Direct measurement of the $^{11}\text{C}(\alpha,p)^{14}\text{N}$ stellar reaction at CRIB

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The hot $pp$-chains are extended $pp$-chains up to $A = 11$ mass region close to the proton drip line in low-metallicity and high-mass stars where there are not enough CNO seeds to produce thermonuclear energy to stabilize themselves. $^{11}\text{C}$ is an unstable nuclide and possibly exists in one of the hot $pp$-chain branches. The $^{11}\text{C}(\alpha,p)^{14}\text{N}$ reaction could be an important breakout path from the $pp$-chain region to the CNO region, on which its contribution is estimated as large as of the triple-$\alpha$ process in some cases.

Recent simulations of the $\nu p$-process in type II supernovae also suggest that this reaction path could considerably contribute to synthesis of CNO elements at 1.5-3 GK and finally affect the amount of the nucleosynthesis around $A = 100$.

These theoretical predictions related to the $^{11}\text{C}(\alpha,p)^{14}\text{N}$ reaction are based on the Hauser-Feshbach cross section since there are experimental data only on the time-reverse reaction cross sections by activation method. The level density of the compound nucleus $^{15}\text{O}$ is as high as 8 states/MeV above the $^{11}\text{C}+\alpha$ threshold and the Hauser-Feshbach cross section for the $p + ^{14}\text{N}(\text{g.s.})$ channel agrees well with the experimental results. However, it remains possible that the time-reverse cross section data are not precise, or unknown cross section for the $p' + ^{14}\text{N}^*$ channels differ from the ones by Hauser-Feshbach calculation, or resonant processes are dominant at temperatures around 1 GK.

In order to reduce these uncertainties, the first direct measurement has recently been performed by means of the thick-target inverse-kinematics method with low-energy $^{11}\text{C}$ beams from the CNS Radioactive Ion Beam separator (CRIB). The setup simply consists of two beam profile monitors, a $^4\text{He}$ gas target and three sets of $\Delta E$-$E$ position-sensitive silicon telescopes. The experiment covered $E_{CM} = 0.5$-5 MeV which includes the corresponding stellar temperature range 1-3 GK. The excited states of the $^{14}\text{N}$ in the final channels were identified from the time-of-flight information between the beam monitor and the Si telescope. We will report the newly determined cross sections as well as the reaction rate.