Time-reversal measurement of the *p*-wave cross sections of the ^{7}Be$(n,\alpha)^4$He reaction for the cosmological Li problem†

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The primordial abundances of light elements produced in the Big Bang nucleosynthesis (BBN) provide important insights into the early universe. Accurate estimation of the primordial abundances is crucial for testing cosmological theories by comparing the predicted values with the observations.

A comparison between the theoretical predictions and observations is in good agreement with those for helium and deuterium. However, there remains a serious problem: the ^{7}Li abundance does not agree with any theoretical BBN calculations. This discrepancy is known as the cosmological lithium problem, and has been of great interest in recent years.[1)] Several ideas have been proposed to solve this problem. One idea is to improve the current understanding of the stellar processes that exhaust lithium in metal-poor stars. Other ideas are to find new physics beyond the standard BBN model, e.g., a cosmological variation of the fundamental constants,[2)] decay of supersymmetric particles,[3)] and so on. However, there is no experimental evidence to confirm these models.

From the viewpoint of nuclear physics, nuclear-reaction rates involved in the BBN theory should be examined. The main process of the ^{7}Li production in the BBN is the electron-capture decay of ^{7}Be, which is synthesized in the ^{3}He(^{4}He,γ)^{7}Be reaction. Direct measurements of the cross section for the ^{3}He(^{4}He,γ)^{7}Be reaction were extensively carried out in the past, and uncertainties in this thermonuclear reaction rate are now very small. There is no room to modify the ^{7}Be production rate to solve the lithium problem.[4)]

It was pointed out that the ^{7}Li abundance would be greatly reduced in the BBN calculation if the destruction rate of ^{7}Be is enhanced. One of the candidate channels for destroying ^{7}Be is the ^{7}Be$(n,\alpha)^4$He reaction. Unfortunately, the ^{7}Be$(n,\alpha)^4$He reaction at the cosmological energy has been scarcely examined.

Very recently, we have measured the total cross section for the ^{4}He$(\alpha,n)^7$Be reaction, which is the time reverse reaction of the ^{7}Be$(n,\alpha)^4$He reaction. Using the detailed balance principle, the total cross section of the ^{7}Be$(n,\alpha)^4$He reaction for *p*-wave neutrons at low energies down to $E_{c.m.} = 0.20$ MeV was obtained, as shown in Fig. 1, for the first time. The solid circles and squares show the total cross sections of the (n,α) reaction on the ground and first excited states in ^{7}Be. The shaded area presents the effective-energy window for the *p*-wave reaction at $T_9 = 0.6$–0.8.

The cross sections evaluated by the indirect methods are compared with the present results. The estimation from p + ^{7}Li scattering[5)] is plotted by the open triangles in Fig. 1, whereas the cross section from the evaluated nuclear data library ENDF/B-VII.1[6)] based on the R-matrix analysis of several indirect reactions is shown by the dashed line. It was found that these evaluated cross sections are very close to the present data for the ^{7}Be$_{g.s.}(n,\alpha)^4$He reaction.

The cross section for the ^{7}Be$(n,\alpha)^4$He reaction was first estimated by Wagoner,[7)] as shown by the solid line in Fig. 1. Currently, this evaluation is widely used in the BBN calculations. The present values of the ^{7}Be$(n,\alpha)^4$He cross sections are much smaller than the Wagoner's calculation. Thus, we concluded that the present results suggest that the ^{7}Be$(n,\alpha)^4$He reaction does not solve the cosmological lithium problem.

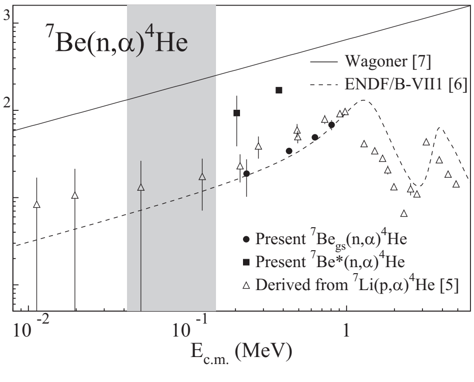

Fig. 1. Measured total cross sections for the ^{7}Be$(n,\alpha)^4$He reaction compared with the previous evaluations.

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