Direct Capture in Nuclear Astrophysics: The Cases of $^{17}O(p, \gamma)^{18}F$ and $^{4}He(^{3}He, \gamma)^{7}Be$

Abstract

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Direct radiative capture is a non-resonant one-step nuclear reaction mechanism that in principle does not involve the formation of a compound nucleus. In the absence of strong resonance inside the Gamow window, direct capture can be the dominant contribution to astrophysically important reaction rates. The present thesis studies two such reactions, $^{17}O(p, \gamma)^{18}F$ and $^{3}He(\alpha, \gamma)^{7}Be$.

$^{17}O(p, \gamma)^{18}F$ influences hydrogen-burning nucleosynthesis in several stellar sites, such as red giants, asymptotic giant branch (AGB) stars, massive stars and classical novae. In the relevant temperature range for these environments (T_9 = 0.01- 0.4), the main contributions to the rate of this reaction are the direct capture process, two low lying narrow resonances (E^{lab}_R = 70 and 193 keV) and the low energy tails of two broad resonances (E^{lab}_R= 587 and 714 keV). Previous measurements and calculations give contradictory results for the direct capture contribution which in turn increases the uncertainty of the reaction rate. In addition, very few published cross section data exist for the high energy region that might affect the interpretation of the direct capture and the broad resonances contributions in the lower energy range. In this work we present a measurement of the reaction at a wide proton energy range (E^{lab} = 360 - 1625 keV) and at several angles (θ_{lab} = 0◦, 45◦, 90◦, 135◦).

$^{3}He(\alpha, \gamma)^{7}Be$ is important for the neutrino production in the sun's core and the production of ^{7}Li during the big bang nucleosynthesis. Due to the low level density of ^{7}Be, the reaction mechanism is almost entirely non-resonant at the relevant energies. Recent experiments have improved the uncertainty of the reaction but some discrepancies still exist. In the present work, a relatively wide energy window was measured, E_{CM} = 0.300 − 1.450 MeV, by detecting the prompt gamma-rays from the reaction. The use of a compact helium jet gas target ensured high gamma-ray detection efficiency. The results are compared with literature.