Final results of the study of the astrophysically important $^{22}Ne(\alpha,n)^{25}Mg$ reaction using indirect techniques at sub-Coulomb energies

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The slow neutron capture process (s-process) that take place in Asymptotic Giant Branch (AGB) stars is responsible for the formation of about half of the elements beyond Iron [1], and the neutrons for this process mainly come from two main neutron source reactions of which one is the $^{22}Ne(\alpha,n)^{25}Mg$ reaction. Direct experimental measurements for this reaction at astrophysical energies are difficult to carry out due to very low cross section at energies relevant for astrophysics. This reaction was studied using an indirect technique, the $^{22}Ne(^{6}Li,d)^{26}Mg$ reaction performed at sub-Coulomb energies to study the near alpha-threshold resonances in ^{26}Mg [2]. By using energies close to the Coulomb barrier, the dependence of the extracted partial alpha-widths (Γ_α) on the optical model potentials and the number of nodes in the cluster wave functions can be dramatically reduced.

This reaction was carried out using the Multipole-Dipole-Multipole (MDM) Spectrometer at Texas A&M University. Effective experimental energy resolution of these measurements was about 80 keV. Fig. 1 shows the excitation energy spectrum for the states in ^{26}Mg populated in $^{22}Ne(^{6}Li,d)^{26}Mg$ reaction covering the entirety of the Gamow energy window for this reaction. The state at 11.3 MeV

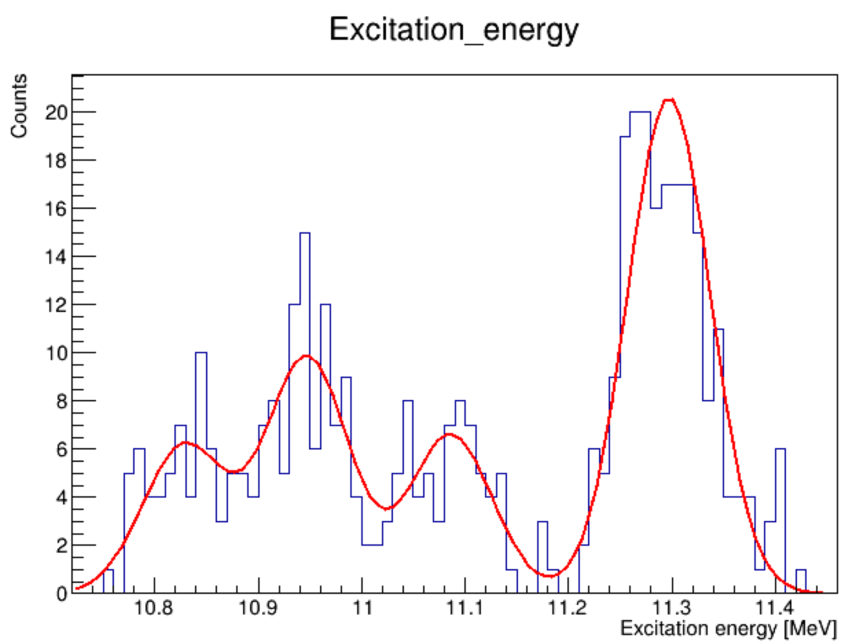

FIG. 1. Spectrum of ^{26}Mg excited states populated in $^{22}Ne(^{6}Li,d)^{26}Mg$ reaction.

provides the most dominant contribution for the reaction rate of the $^{22}Ne(\alpha,n)^{25}Mg$ reaction at astrophysical energies and is the lowest excitation energy state that has been observed in direct $^{22}Ne(\alpha,n)^{25}Mg$ measurements [1].

None of the states observed in this experiment have definitive spin-parity assignment, in spite of the fact that these states have been observed previously [3,4]. Distorted-Wave Born Approximation (DWBA) calculations using the code FRESCO shows that low angular momentum (*L* values of 2 or less) assignments for the transferred alpha particle is preferred for the conditions of the present work. The Γ_α calculated using the experimental cross sections appears not to depend on the form factor potential parameters, and correspondingly the number of nodes of the wave function. However, FRESCO code does not allow calculations of transfer to unbound states. Hence, in order to extract Γ_α of the relevant states in ^{26}Mg which are α-unbound, first the widths were calculated using a bound-state approximation with a maximum uncertainty of ~30% due to the uncertainties of the optical model parameters, and then extrapolated to unbound energies. Additional analysis of α-transfer reactions populating states in ^{26}Mg at higher energies of Li beam (32 MeV [4] and 82 MeV [3]) leads to a conclusion that 1^- is the most likely spin-parity assignment for the dominate state at 11.3 MeV state. The strength of this resonance seems to be a factor of ~2 smaller than the strength established in direct measurements for the $^{22}Ne(\alpha,n)^{25}Mg$ reaction [3]. This results in significant decrease of the $^{22}Ne(\alpha,n)^{25}Mg$ reaction rate. Also, the relatively large value of Γ_α for this state (about 15% of single-particle) indicates the importance of α-clustering for this (α,n) reaction.

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