XI H: Cluster Effects in Astrophysics

MEASUREMENT OF ALPHA-WIDTHS IN ^{16}O RELEVANT TO ASTROPHYSICS

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ABSTRACT

Several different α-transfer reactions, $^{12}C \rightarrow {}^{16}O$, have been studied at high bombarding energies with magnetic spectrometers. Line-widths, α-spectroscopic factors, S_α, and reduced α-widths, γ_α^2 and θ_α^2, have been determined for levels in ^{16}O, including several of importance in astrophysics.

The $^{12}C(\alpha,\gamma)^{16}O$ reaction rate is of vital importance in the burning of helium stars[1] but is extremely difficult to measure at stellar temperatures ($E_\alpha \gtrsim 300$ keV).[2] The alpha width of the bound 7.12 MeV $J^\pi=1^-$ level in ^{16}O determines the $^{12}C(\alpha,\gamma)^{16}O$ rate at low energies.[3] The α-width for this level has been inferred from $^{12}C/^{16}O$ abundances[3] and postulated to be small, $\theta_\alpha^2(7.1) \lesssim .03$. Early measurements of $\theta_\alpha^2(7.1)$ from (^{6}Li,d) and (^{7}Li,t) are unreliable due to compound nucleus decay. High bombarding energies appear to be clearly preferable[4] .

We have therefore studied the reactions $^{12}C(^6Li,d)$ and (^{7}Li,t) as well as $^{12}C(^{10}B,^6Li)$, ($^{11}B,^7Li$) and ($^{11}B,^7Li^*$) at high bombarding energies. Spectra are displayed in figs. 1 and 2.

As expected, ($^{11}B,^7Li$),(^{7}Li,t) and (^{6}Li,d) populate α-cluster states in ^{16}O. Surprisingly ($^{10}B,^6Li$) and ($^{11}B,^7Li^*$) also preferentially populate α-cluster states (but to a much lesser degree), which is unexpected based on accepted shell-model wave-functions for $^{10,11}B$ and $^{6,7}Li$. An analysis of the data indicates $\theta_\alpha^2(7.1) = 0.14 \pm 0.04$ and $\theta_\alpha^2(9.6) \approx 0.6$. Thus $\theta_\alpha^2(7.1)$ is larger than earlier determinations.[3] In addition, line-width measurements of $\Gamma_{c.m.}(9.6)$ indicate $\Gamma_{c.m.} = 390 \pm 60$ keV, which is much smaller than the accepted value (510 ± 60 keV). We compare, in fig. 3 , values of S_α deduced from (^{7}Li,t) with recent theoretical calculations[5,6] for ^{16}O.

A large value of $\theta_\alpha^2(7.1)$ could imply a large stellar helium burning rate which would deplete ^{12}C in old stars. In any case it appears that α-transfer reactions cannot be used to justify a small α-width for the 7.12 MeV $J^\pi=1^-$ level in ^{16}O.

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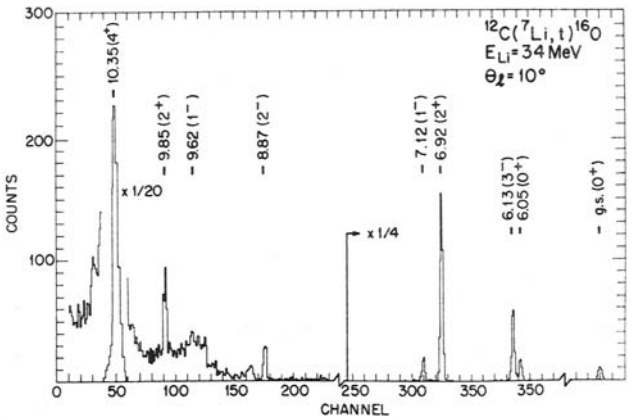

Fig. 1 Spectrum from (Li,t) taken at LASL

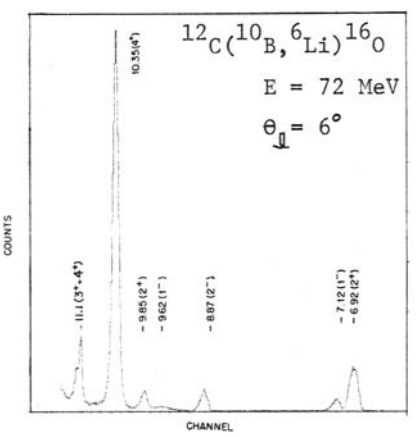

Fig.2 (^{10}B, ^{6}Li) spectrum

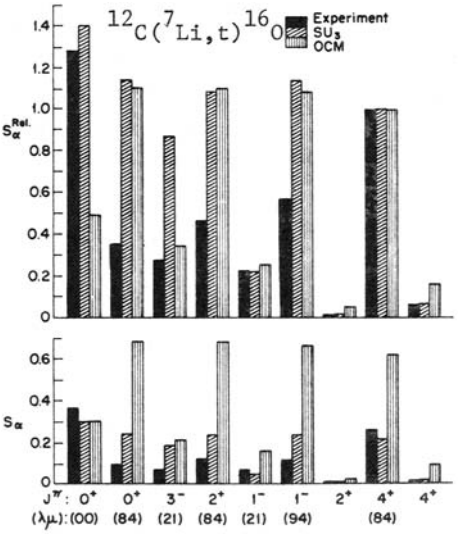

Fig. 3 Comparison of S_α with theory[5,6]