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

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ABSTRACT

Several different $\alpha$-transfer reactions, $^{12}$C $\rightarrow^{16}$O, have been studied at high bombarding energies with magnetic spectrometers. Line-widths, $\alpha$-spectroscopic factors, $S_{\alpha}$, and reduced $\alpha$-widths, $\gamma_{\alpha}^2$ and $\theta_{\alpha}^2$, 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 but is extremely difficult to measure at stellar temperatures ($E_{\alpha} \approx 300$ keV). 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. The $\alpha$-width for this level has been inferred from $^{12}$C/$^{16}$O abundances and postulated to be small, $\theta_{\alpha}^2(7.1) \approx .03$. 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.

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

As expected, ($^{11}$B,$^7$Li), ($^7$Li,t) and ($^7$Li,d) populate $\alpha$-cluster states in $^{16}$O. Surprisingly ($^{10}$B,$^6$Li) and ($^{11}$B,$^7$Li$^*$) also preferentially populate $\alpha$-cluster states (but to a much lesser degree), which is unexpected based on accepted shell-model wave-functions for $^{10}$B and $^{7}$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. 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 $\pm$ 60 keV). We compare, in fig. 3, values of $S_{\alpha}$ deduced from ($^7$Li,t) with recent theoretical calculations 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 $\alpha$-transfer reactions cannot be used to justify a small $\alpha$-width for the 7.12 MeV $J^\pi=1^-$ level in $^{16}$O.

*Supported in part by the National Science Foundation.
†Supported by the U. S. Department of Energy.

ISSN: 0094-243X/78/752/$1.50 Copyright 1978 American Institute of Physics
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Fig. 1 Spectrum from \(^{(7Li,t)}\) taken at LASL

Fig. 2 \(^{10B,6Li}16O\) spectrum

Fig. 3 Comparison of \(S_\alpha\) with theory\(^5,6\)