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α width of ^{18}Ne(6.15 MeV, 1^-)

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Data for the ^{14}C(^{6}Li,d)^{18}O(6.20) reaction, at 20 MeV, provides an α spectroscopic factor of 0.23 for this 1^- state. Assuming equal spectroscopic factors for mirror states, the computed α width for ^{18}Ne(6.15) is 3.9(1.0) eV.

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For a state that is unbound to α decay, if its α-particle spectroscopic factor S_α is known, then the α width of the state can be computed from the relation $\Gamma_\alpha = S_\alpha \Gamma_{\alpha sp}$, where $\Gamma_{\alpha sp}$ is the α single-particle (sp) width calculated in a potential model. The computed sp width is quite sensitive to the geometrical parameters of the potential. Thus, for example, if the spectroscopic factor is from a nuclear-structure calculation (shell model, cluster model, etc.), then care must be exercised to choose realistic values of those potential parameters. The more usual situation is that the spectroscopic factor is obtained from analysis of an α-transfer reaction, such as (^{6}Li,d) or (^{7}Li,t). In that case, the experimental cross section is compared to results of a distorted-wave Born-approximation (DWBA) calculation, and S_α is extracted as $S_\alpha = \sigma_{\text{exp}}/\sigma_{\text{DWBA}}$. The dependence of σ_{DWBA} on the parameters of the potential well is similar to that of $\Gamma_{\alpha sp}$. For example, increasing the radius of the well increases the value of $\Gamma_{\alpha sp}$ and σ_{DWBA}, the latter leading to a decrease in S_α. Thus the product $S_\alpha \Gamma_{\alpha sp}$ is much less sensitive to changes in these parameters than is either factor of the product. For this reason, it is crucial that, if combining S_α and $\Gamma_{\alpha sp}$ to get a width, the same potential-well parameters should be used throughout.

Another simplification occurs when the transition to the state in question can be compared to another in the same or another nearby nucleus, preferably with the same L value and a similar Q value, and one whose α width is known [1,2]. Then the entire process [3] involves only a set of ratios: ratios of experimental cross sections, of DWBA cross sections, of sp widths, and actual widths. The procedure is described in some detail in Ref. [3]. For nuclei just above ^{16}O, the 1^- and 3^- states of ^{20}Ne [4] with large S_α's are especially useful. Such a comparison led to an evaluation [1–3] of the α width for the $3/2^+$ state at 4.03 MeV in ^{19}Ne. The present Rapid Communication involves the use of this procedure to extract S_α for the 1^- state at 6.20 MeV in ^{18}O, and then the α width of its mirror at 6.15 MeV in ^{18}Ne. This state is important because it dominates the astrophysical reaction of ^{14}O(α,p) for temperatures $T_9 \lesssim 2$. The last step of the process involves the assumption of equal S_α's for mirror states.

A minor complication concerns the question of how much of the measured cross section corresponds to direct α transfer. For strong states, other reaction mechanisms are not important. But, for weak states, a small compound-nucleus (CN) component must be estimated and subtracted.

The present study uses the ^{14}C(^{6}Li,d)^{18}O reaction at $E(^6\text{Li}) = 20.0$ MeV. The target was a gold-backed foil of about 50 μg/cm^2, nominally enriched to 90% in ^{14}C. The same target was used in investigations of the ^{14}C(t,p) reaction [5]. In that work, a comparison of yields from the ^{12}C(t,p) reaction with this target with those from an enriched (99.99%) ^{12}C target revealed that the ^{12}C content of the ^{14}C target was 18.5%. This impurity is important because we are interested in the 1^- state at 6.20 MeV in ^{18}O, and at forward angles, the peak corresponding to this state has the same d energy as that for the ^{12}C(^{6}Li,d) reaction to the 2^+ state at 6.92 MeV in ^{16}O. For this reason, data were also acquired for the latter reaction on an enriched ^{12}C target, under identical conditions.

Outgoing deuterons were momentum analyzed in a multi-angle spectrograph and detected with nuclear-emulsion plates in the focal planes. Analyzing yields of peaks from the ^{12}C impurity that were clearly resolved led to the conclusion that the ^{12}C content of the ^{14}C target was 18.8%—quite close to the value determined in the (t,p) experiments. At a center-of-mass (c.m.) angle of 13.9°, the measured cross section for the ^{18}O(6.20 MeV) state is 58.2(2.4) μb/sr. This uncertainty is from statistics and from impurity subtraction. There is an additional uncertainty of about 20% in the total ^{14}C target thickness, which we withhold until the end, and then include it. The estimated CN contribution is small, but not negligible—about 13(5) μb/sr. These results are listed in Table I. Various sources of uncertainty are itemized in Table II. As mentioned above, the DWBA cross sections depend on r_0 and a of the potential well, but they also depend on the number of assumed quanta q of relative motion. For the present 1^- state the possibilities are $q = 7$ and 9, with 7 most likely. I have performed the analysis for both values. The α potential well has $r_0 = 1.40$ fm, $a = 0.60$ fm, with $R = r_0(14)^{1/3}$. With a direct α-transfer cross section of 45.2(5.5) μb/sr, the resulting S_α's are 0.23(4) for $q = 7$ and 0.19(3) for $q = 9$. This spectroscopic factor is itself of interest. A recent investigation of the ^{6}Li(^{14}C,d) and ^{7}Li(^{14}C,t) reactions provided values of the asymptotic normalization coefficients (ANCs) for this state, but they did not quote a spectroscopic factor.

The primary interest here, however, is not with this state in ^{18}O, but with its mirror in ^{18}Ne. Alpha sp widths for the latter are 17 and 26 eV for $q = 7$ and 9, respectively. If we assume S_α's for mirror states are equal, then the present S_α's lead to calculated α widths of 3.9(1.0) and 4.9(1.2) eV for $q = 7$ and 9. These final uncertainties include the additional 20% from target thickness mentioned earlier. Harss, *et al.* [6] used the ^{17}F(p,α) reaction, in reverse kinematics, to study states in this region of excitation in ^{18}Ne. Their α width for this state was

TABLE I. Results of the reaction ^{14}C(^{6}Li,d)^{18}O(6.20 MeV).

Quantity	Value	
$d\sigma/d\sigma$[a]	58.2(2.4) μb/sr	
After CN subtraction	45.2(5.5) μb/sr	
	$q=7$	$q=9$
S_α	0.23(4)	0.19(3)
$\Gamma_{\alpha sp}$(^{18}Ne) (eV)	17 eV	26 eV
Γ_α (^{18}Ne) (eV)	3.9(6)	4.9(8)
	3.9(1.0)[c]	4.9(1.2)[c]
Γ_α other (eV)[b]	3.2^{+5}_{-2}	

[a]At an incident energy of 20 MeV and a c.m. angle of 13.9°.
[b]Reference [6].
[c]Includes 20% target thickness uncertainty.

3.2^{+5}_{-2} eV. The present result is in agreement with that result, but with significantly smaller uncertainty.

TABLE II. Contributions to total uncertainty.

Source	Percentage
Statistics	2.1
Impurity subtraction	3.5
CN subtraction	8.6
Target thickness	20
Γ_α (^{20}Ne, 1^-)	10
DWBA	7
Total	25.3

In summary, data and analysis are presented for the ^{14}C(^{6}Li,d)^{18}O(6.20 MeV,1^-) reaction. Analysis required subtraction of yield from the 18.8% ^{12}C impurity in the ^{14}C target, and subtraction of about 22% CN contribution. The result is (for $q=7$) $S_\alpha = 0.23$, and an α width of 3.9(1.0) eV for the mirror state at 6.15 MeV in ^{18}Ne. This width is consistent with an earlier value, but has a smaller uncertainty.

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