Proton widths and spectroscopic factors in ^{19}F at $E_x = 8$–11 MeV

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For states of ^{19}F from $E_x = 8.1$ to 10.9 MeV, I have examined the proton spectroscopic factors from the reaction ^{18}O(d, n) and compared them with spectroscopic factors computed from the proton widths. Even though the widths cover a range greater than a factor 10^5, the two sets of spectroscopic factors agree to within about a factor of 2.

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I. INTRODUCTION

The spectroscopic factor of a nuclear state is a measure of the single-particle character of that state. Usually, the experimental determination of S, for a proton, say, involves a measurement of an angular distribution in a proton transfer reaction, such as (d, n) or (^{3}He, d). A distorted-wave Born approximation (DWBA) cross section is then calculated, and S is determined from the ratio $C^2S = \sigma_{\rm exp}/\sigma_{\rm th}$, where $\sigma_{\rm th}$ is the DWBA cross section for $C^2S = 1$. Here, C is an isospin Clebsch-Gordan coefficient. The ratio is usually taken at the maximum of the angular distribution. If the reaction is considered to be more complicated than simple direct one-step transfer, then more complex calculations (coupled channels, adiabatic Born approximation, etc.) can be done. But, ultimately, it is primarily the magnitude of the cross section that determines S.

If the state being considered is unbound (with respect to proton emission in the present example), there is another procedure to obtain the spectroscopic factor. This procedure involves the experimental width for decay by proton emission and a single-particle (sp) width computed in a potential model. The relationship is $C^2S = \Gamma_{p\,\rm exp}/\Gamma_{p\,\rm sp}$. Generally, the computed sp width depends somewhat on the geometrical parameters of the potential well, but that dependence is usually about the same as in the DWBA cross section, so that any uncertainty caused by this sensitivity affects both evaluations of S in the same way. If values of S obtained from decay widths are to be compared with those from transfer, care must be exercised in the DWBA calculations for cross sections leading to unbound states. One standard procedure [1] is usually used for such calculations.

It might be thought that spectroscopic factors determined by the two methods should approximately agree only if S is large. The intent here is to examine such a comparison for cases in which S is small. In ^{19}F, just above proton decay threshold, several states exist that serve as good examples for such a comparison [2]. I consider all such states from 8.1 to 10.9 MeV, provided a spectroscopic factor was obtained in the ^{18}O(d, n) reaction [3], the proton width is known, and J^π is known (so that values of $(2J+1)C^2S$ from [3] can be used to compute C^2S). Six $T = 1/2$ states satisfy these criteria, corresponding to three ℓ values and four different J^π. (The $1/2^+$, $T = 3/2$ state is treated separately (see Table I). They are listed in Table II. Experimental proton widths have been taken from the compilation [2]. Many of these originated with Wiescher *et al.* [4]. In some cases, the only listing of proton width is in a footnote to a table [2], as I have indicated. The spectroscopic factors for these states cover a range of about a factor of 4.4, whereas the proton widths span a range of about 6.8×10^5.

II. ANALYSIS AND RESULTS

I have calculated the sp widths using a Woods-Saxon potential plus the Coulomb potential of a uniform sphere, with geometric parameters r_0, a, $r_{0c} = 1.26$, 0.60, 1.40 fm. These sp widths are also listed in Tables I and II. The values of $(2J+1)C^2S$ from [3] have been converted to C^2S and are listed in the tables. These authors state that they used the established procedure for unbound states. The last column of the tables lists the ratios $\Gamma_{p\ \rm exp}/\Gamma_{p\ \rm sp}$.

Information [2,5–8] for the $1/2^+$, $T = 3/2$ state is listed in Table I. This state has $C^2S = 0.25$ in ^{18}O(d, n) [3], 0.30 in ^{18}O(α, t) [7], and 0.16 in (^{3}He, d) [8]. The first two are slightly larger than the $\Gamma_{p\ \rm exp}/\Gamma_{p\ \rm sp}$ ratio of 0.18(2). In this case C^2 is 1/3, so that the width ratio corresponds to $S = 0.54(6)$. For comparison, the parent state at 1.47 MeV in ^{19}O has $S = 1.00$ [9] or 0.50 [10]. The variation in these numbers remains a minor mystery.

For the $T = 1/2$ states, except for one case, the $\Gamma_{p\ \rm exp}/\Gamma_{p\ \rm sp}$ ratios are comparable to the C^2S values from the (d, n) reaction, but the latter are generally slightly larger than the former. This might indicate the presence of another reaction mechanism.

In Fig. 1, I have plotted the (d, n) spectroscopic factors vs $\Gamma_{p\ \rm exp}/\Gamma_{p\ \rm sp}$. The solid line indicates equality of the two. Ratios of the two are plotted in Fig. 2. The overall level of agreement is reasonable. The largest deviation is for $3/2^+$ states. This may be due to the fact that [3] used the

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TABLE I. Properties of $1/2^+$, $T = 3/2$ state at $E_x = 8.793$ MeV in ^{19}F.

$\Gamma_{\rm exp}$ (keV)		C^2S					$S(^{19}O(1/2^+))$	
Total[a]	Proton[b]	(d,n)[c]	(α,t)[d]	$(^3He,d)$[e]	$\Gamma_{p\,\rm sp}$ (keV)[f]	$\Gamma_{p\,\rm exp}/\Gamma_{p\,\rm sp}$	[9]	[10]
46(2)	26(2)	0.25	0.30	0.16	142	0.18(2)	1.0	0.50[g]

[a]Reference [2].
[b]References [5,6].
[c]Reference [4].
[d]Reference [7].
[e]Reference [8].
[f]Present.
[g]Plane-wave analysis, normalized to $S = 1$ for ^{17}O$(1/2^+)$.

$\lambda_{\rm so} = 25$ ($\lambda_{\rm so} = 180.3\, V_{\rm so}/V_0$) prescription for the proton spin-orbit potential. Because this spin-orbit term is destructive for $j_<$ states, this usage causes an unnaturally deep central potential in those cases, increasing the interior wave function at the expense of the wave function at the nuclear surface, thereby decreasing the theoretical cross section and increasing the extracted spectroscopic factor. It would be interesting to repeat the (d,n) analysis with $V_{\rm so} = 6$ MeV, rather than $\lambda_{\rm so} = 25$. I estimate that the reduction in C^2S would be a factor of about 0.7.

One oddity concerns the two $5/2^+$ states, which have nearly identical $C^2S(d,n)$, but whose values of $\Gamma_{p\,\rm exp}/\Gamma_{p\,\rm sp}$ differ by an order of magnitude. It might be useful to reexamine the proton widths of these two states. The uncertainty on the width of the 8.31-MeV state is about 50%, so this disagreement is only a 1.8σ effect. A new paper [11] concerning ^{19}F states in this region of excitation offers little assistance regarding proton widths. Of the states treated here, only the one at 9.668 MeV has a proton width in [11], viz., 173 keV, compared with 2.1 keV in the compilation [2].

III. SUMMARY

To summarize, states in ^{19}F from 8.1 to 10.9 MeV have proton widths that cover a range of greater than a factor of 10^5, involve three ℓ values and four J^π values. Yet, spectroscopic factors from the reaction ^{18}O(d,n) and those computed from the proton widths agree to within about a factor of 2.

TABLE II. Energies (MeV), widths, and spectroscopic factors for states in ^{19}F, $E_x = 8.1-10.9$ MeV.

E_x	J^π	C^2S	Width[a]			
Ref. [2]		Ref. [3]	Total[b]	Proton[b]	Proton sp[c]	$\Gamma_{p\,\rm exp}/\Gamma_{p\,\rm sp}$
8.138	$1/2^+$	0.11	<0.3	0.17 eV[d]	2 eV	0.085
8.310	$5/2^+$	0.023	47(19) eV	0.019(9) eV[e]	5.4 eV	0.0035
8.592	$3/2^-$	0.038	2.0(1)	224(43) eV[f]	10	0.0224
9.668	$3/2^+$	0.095	3.6(4)	2.1[g]	48	0.044
10.308	$3/2^+$	0.095	9.2	5.2[g]	162	0.032
10.86	$5/2^+$	0.025	240(2)	13[g]	350	0.037

[a]Widths in keV, unless otherwise noted.
[b]Reference [2].
[c]Present.
[d]Reference [4] and footnote e in Table 19.18 [2].
[e]Reference [4] and footnote f in Table 19.18 [2].
[f]Reference [4] and footnote g in Table 19.18 [2].
[g]Table 19.20 [2].

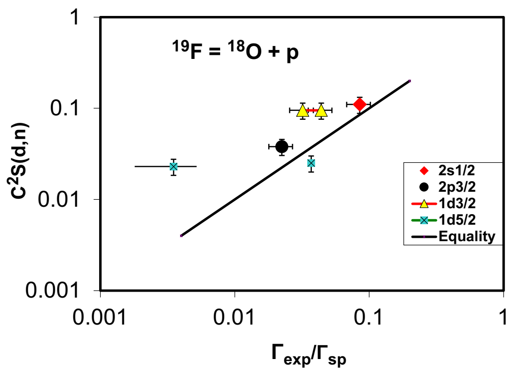

FIG. 1. The quantities C^2S from the reaction ^{18}O(d, n) are plotted vs $\Gamma_{p\ \mathrm{exp}}/\Gamma_{p\ \mathrm{sp}}$. The solid line indicates equality of the two quantities.

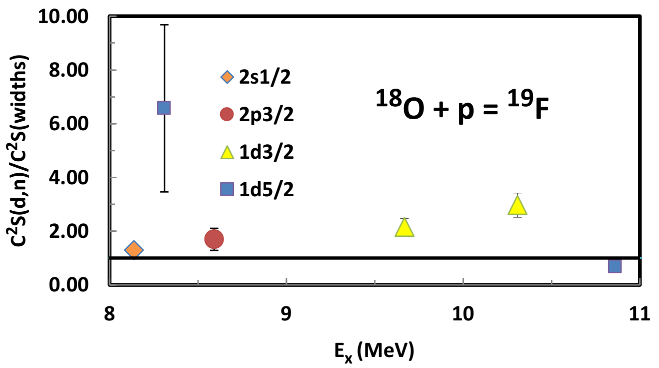

FIG. 2. Ratios $C^2S(d, n)/(\Gamma_{p\ \mathrm{exp}}/\Gamma_{p\ \mathrm{sp}})$ are plotted vs excitation energy.

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