Proton and alpha spectroscopic factors for states at 6.4–7.5 MeV in ^{19}Ne

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We have computed single-particle alpha and proton widths for states at 6.4–7.5 MeV in ^{19}Ne and compared them with measured widths to extract spectroscopic factors. The state at 7.42 MeV appears to have either an incorrectly-assigned J^{π} or an incorrect proton width, or both.

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In ^{19}Ne, in the excitation energy range 6.4–7.5 MeV (which is important for astrophysical reactions involving ^{18}F + p), alpha-particle widths have been measured for four states [1,2]. For eight others for which a mirror correspondence to states in ^{19}F has been suggested [1–3] alpha widths have been estimated under the (probably reasonable) assumption that the reduced widths θ_{α}^{2} are equal in the two nuclei. These alpha widths are needed for calculations of reaction rates. Some workers have questioned the validity of estimating ^{19}Ne widths using mirror symmetry and widths from ^{19}F. For the four states with measured α widths, we have computed single-particle widths for $\alpha + {}^{15}$N and $\alpha + {}^{15}$O in order to compare the spectroscopic factors $S_{\alpha} = \Gamma_{\text{exp}}/\Gamma_{\text{sp}}$. Whenever Γ_p is also known in ^{19}Ne we have computed the proton sp widths and hence S_p. Our α-particle well had $R = 3.45$ fm, $a = 0.60$ fm. For the proton, we used $R = 1.25(18)^{1/3}$, $a = 0.65$ fm. The potential depth was adjusted to put a resonance at the observed energy, and the sp width was computed from the expression $2/\Gamma_{\text{sp}} = d\delta/dE$, where δ is the phase shift.

The relevant pairs of states [1–4] are listed in Table I. Many of the widths and J^{π} assignments in this region of ^{19}F came from ^{15}N + α elastic scattering and an R-matrix analysis [5]. It has been pointed out [6,7] that almost half of the J^{π} assignments of Ref. [5] were incorrect, but nearly all the L_{α} values were correct. A reanalysis by Ref. [7] has resulted in new energies and widths for some states. Some data at the high end of the energy range of Ref. [5] were analyzed by Mo and Weller [8]. In the region 6.4–7.5 MeV, J^{π} values for all the states observed in (α, α) are as listed in the compilation [4] except for the state at 7.118 MeV, whose J^{π} is given as 7/2^{+} in Ref. [4]. It has $L_{\alpha} = 3$, implying $J^{\pi} = 5/2^{+}$ or $7/2^{+}$, and $\ell_p = 2$ in ^{18}O(d, n) [9], implying $J^{\pi} = 3/2^{+}$ or $5/2^{+}$. Hence, if it is a single state, it is 5/2^{+} (as initially suggested by Ref. [10]), and that value was used in the reanalysis of Ref. [7].

Utku *et al.* [1] first suggested the mirror correspondence for the 1/2^{-} states, and [7] modified the ^{19}F energy [from 6.429 to 6.536(5) MeV] and width [from 280 to 245(6) keV], as listed in Table I. Several excitation energies in the region 6.4–7.5 MeV in ^{19}Ne were supplied by Ref. [1]. Others are from later work. Several mirror-pair identifications were suggested by Ref. [1], but only the 1/2^{-} of the four pairs of states listed in Table I. Reference [1] and others [6] have pointed out the difficulty of the missing ^{19}F level that is the mirror of ^{19}Ne (7.076). The possibility that ^{19}F (7.26) might be the missing mirror is supported by the large $\ell = 0$ strength in ^{18}F (d, p) [11].

The level at 7.42 MeV in ^{19}Ne was discovered by Ref. [2] and assigned $J^{\pi} = 7/2^{+}$. They suggest it is the mirror of the 7.56-MeV state in ^{19}F [4], seen only via (α, α) and assigned 7/2^{+} by Ref. [8], who analyzed the structure as a doublet, one member having $\Gamma \approx 85$ keV.

The identification ^{19}F (7.59) $\leftrightarrow$ ^{19}Ne (7.533) was suggested by Ref. [2], even though other possibilities have been given [3]. In the compilation [4], the ^{19}F state has a tentative (5/2^{-}) assignment.

Most of the proton and alpha widths of the ^{19}Ne states in Tables I and II are from Ref. [1] except as noted above. Mirror identifications (not always the same ones) were recently summarized by Refs. [2] and [3].

We note that the corresponding α sp widths in ^{19}F and ^{19}Ne are nearly equal for these cases, suggesting similar alpha widths if the mirror spectroscopic factors are equal and the mirror identifications are correct. At this region of excitation, the alpha sp widths vary reasonably slowly with energy. Of the four pairs of states, two have reasonably large S_{α}'s and they agree in the mirrors. Two states have quite small S_{α}'s in ^{19}Ne, but here the mirror state in ^{19}F is either unknown or merely suggested [^{19}Ne (7.07) and ^{19}Ne (7.53)]. For both these states the proton S factor (Table II) is large enough that the mirror in ^{19}F should be visible in ^{18}F (d, p) [11].

Uncertainties tabulated for S_{α} come only from experimental uncertainties in measured widths. There is also a model uncertainty in S_{α} arising from an uncertainty in single-particle width. If considerably different geometrical parameters had been used for the alpha-particle well, then the sp widths (and hence the spectroscopic factors) would have been significantly different. But, if the same parameters are used in ^{19}F and ^{19}Ne, then the ^{19}Ne widths computed from the experimental ^{19}F widths are nearly unchanged. And it is the widths that are of interest for astrophysics calculations, not the spectroscopic factors. For the states considered here, we list in the last column of Table I the ^{19}Ne widths computed from the ^{19}F widths, assuming mirror symmetry. At least for this set of states, the assumption of mirror symmetry works well. We think widths calculated in this manner are acceptable for computing reaction rates.

TABLE I. Alpha widths (experimental and calculated) for suggested mirror levels in ^{19}F and ^{19}Ne.

Nucl.	E_x (MeV)	J^π	E_α (MeV)	L	N	Γ_{sp} (MeV)	Γ_{exp} (keV)	S_α	Γ_{calc}(^{19}Ne) (keV)[a]
^{19}F	6.536	1/2$^-$	2.520	0	4	0.67	245(6)	0.37(1)	
^{19}Ne	6.437	1/2$^-$	2.908	0	4	0.57	215(19)	0.38(3)	248(6)
^{19}F	unkn	3/2$^+$	3.2–3.5	1	4	1.6–2.5	25–40[b]	—	
^{19}Ne	7.076	3/2$^+$	3.547	1	4	1.5	23.8(12)	0.016(1)	[b]
^{19}F	7.56	7/2$^+$	3.55	3	3	0.275	≈85	≈0.31	
^{19}Ne	7.42	7/2$^+$	3.89	3	3	0.290	71(11)	0.24(4)	≈85
^{19}F	(7.59)	(5/2$^-$)	3.57	2	3	0.95	(40)	(0.04)	
^{19}Ne	7.533	5/2$^-$	4.00	2	3	0.98	21(11)	0.021(11)	(38)

[a]Using ^{19}F experimental widths and mirror symmetry.
[b]^{19}Ne alpha width of 23.8(12) keV, together with ^{19}F Γ_{sp} of 1.6–2.5 MeV, leads to expected alpha width of 25–40 keV for mirror in ^{19}F.

Four states in this region of ^{19}Ne have measured proton widths [1,2,12,13] (as opposed to upper limits). These are listed in Table II. Three of them are the same as the states with measured alpha widths in Table I. The large S_p, together with the small S_α, should aid in the identification in ^{19}F of the mirror of ^{19}Ne (7.07). This state has eluded discovery up to now. (But see the discussion in Ref. [11].) For the supposed 7/2$^+$ state [2] at 7.42 MeV the results are very strange, viz. $S_p = 8$, significantly larger than the theoretical upper limit. Thus, we conclude that at least one of the J^π or proton width in Ref. [2] is incorrect for this state. The experimental width is such that this state would have a large S_p even if the proton has $\ell = 1(\Gamma_{sp} = 60$ keV). For $\ell = 0$, the sp width is 170 keV, providing $S_p = 0.16(2)$ (if the proton width is as quoted). In that case J^π would be 1/2$^+$ or 3/2$^+$ and the mirror level in ^{19}F would be unknown. However, if J is smaller than 7/2, the value of Γ_{exp} extracted from the data will be larger than 27 keV—producing a larger S_p.

TABLE II. Experimental and sp proton widths for ^{19}Ne → ^{18}F (g.s.) + p.

E_x (MeV)	J^π	E_p (MeV)	Config	Γ_{sp} (keV)	Γ_{exp} (keV)	S
6.741	3/2$^-$	0.331	2p	0.11	$2.22(69) \times 10^{-3}$ [a]	0.020(7)
7.076	3/2$^+$	0.665	2s	31	15.2(1.0)[b]	0.49(3)
7.420	7/2$^+$	1.009	1d	3.3	27(4)[c]	8.2(12)
7.533	5/2$^-$	1.122	2p	95	10(6)[c]	0.11(6)

[a]Reference [12].
[b]Reference [13].
[c]Reference [2].

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