Comment on "Negative-parity alpha clusters in ^{19}F"

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The suggestion by Mordechai and Fortune, that the 8.95 MeV level in ^{19}F is the "missing" $\frac{11}{2}^-$ member of the $K^\pi=\frac{1}{2}^-$ band, is not acceptable when account is taken of the intraband γ-ray transition rates. The experimental evidence suggests that there is no single $\frac{11}{2}^-$ state with a pure $p^{-1}(sd)^4$ configuration, but rather that configuration mixing takes place.

Mordechai and Fortune[1] have recently suggested that the state at $E_x=8.95$ MeV in ^{19}F is the "missing" $\frac{11}{2}^-$ member of the $K^\pi=\frac{1}{2}^-$ band in ^{19}F. Their arguments are based largely on alpha transfer data and are made without regard to the conflicting evidence from γ-ray transition rates.

The α-capture work of Symons *et al.*[2,3] has unambiguously established the spin of the 8.95 MeV state as $\frac{11}{2}^-$. However, its identification with the low-lying $K^\pi=\frac{1}{2}^-$ band in ^{19}F, which is formed by coupling a $p_{1/2}$ hole to the ground state band of ^{20}Ne, is open to question. In addition to the attributes of these apparent $p^{-1}(sd)^4$ states listed by Mordechai and Fortune,[1] enhanced $E2$ γ-ray decays within the band are also required, and, in fact, the weak coupling model suggests that the enhancement should be about the same as in the ground state band of ^{20}Ne, i.e., 15–20 Weisskopf units (W.u.).

The problem concerning the $\frac{11}{2}^-$ member of the $K^\pi=\frac{1}{2}^-$ band, which was not treated in Ref. 1, is that there are three $\frac{11}{2}^-$ levels between 7 and 10 MeV excitation. The lowest lying, at $E_x=7167$ keV, was first studied by Rogers, Dixon, and Storey,[4] who suggested that this level belonged to the $K=\frac{1}{2}^-$ band because of the strong $\frac{11}{2}^-\rightarrow(\frac{7}{2}^-)_1E2$ transition, although they pointed out that the excitation energy and small reduced alpha width were contrary to the expectation of the weak coupling model. Because of the importance of the $E2$ decay strength, we have now remeasured the branching ratios and the $\omega\gamma$ for this level, with the results shown in Table I. The $\frac{11}{2}^-\rightarrow(\frac{7}{2}^-)_1E2$ strength is found to be 12.6 ± 2.4 W.u., in agreement with our previous measurement[4] of 15 ± 5 W.u. Table I also shows branching ratios and decay strengths for the $\frac{11}{2}^-$ levels at 8953 and 9872 keV, the data being taken from the publication of Symons *et al.*,[2] which supersedes that of Fifield *et al.*[3] (Note, in particular, that the $\omega\gamma$ value originally

TABLE I. Branching ratios and γ-ray transition strengths for three $\frac{11}{2}^-$ states in ^{19}F. Uncertainties in the decay strengths are of the order of 20%.

E_x (keV)	E_f (keV)	J	B.R. (%)	Γ_γ (10^{-3} eV)	W.u.
7167[a]	3999	$\frac{7}{2}^-$	5.6 ± 0.7	9.8	$12.6E2$
	4032	$\frac{9}{2}^-$	90.9 ± 0.8	159	$0.25M1$
	4650	$\frac{13}{2}^+$	3.5 ± 0.5	6.1	$8\times10^{-4}E1$
8953[b]	2780	$\frac{9}{2}^+$	50 ± 2	71	$6.3\times10^{-4}E1$
	3999	$\frac{7}{2}^-$	26 ± 2	37	$5.1E2$
	4032	$\frac{9}{2}^-$	9 ± 1	13	$5.2\times10^{-3}M1$
	4650	$\frac{13}{2}^+$	10 ± 2	14	$3.7\times10^{-4}E1$
	5420	$\frac{7}{2}^-$	5 ± 1	7	$5.3E2$
9872[b]	2780	$\frac{9}{2}^+$	68 ± 4	408	$2.4\times10^{-3}E1$
	3999	$\frac{7}{2}^-$	5 ± 1	30	$1.8E2$
	4032	$\frac{9}{2}^-$	24 ± 3	144	$0.035M1$
	4650	$\frac{13}{2}^+$	3 ± 1	18	$2.6\times10^{-4}E1$

[a]Present results. [b]Reference 2.

given by the Oxford group[3] for the 8953 keV level, 1.37 ± 0.18 eV, was later reduced by them[2] to 0.85 ± 0.2 eV.)

Our new measurements for the $\frac{11}{2}^-$ level at 7167 keV have been made using the 4 MV van de Graaff machine at the National Research Council of Canada. Improvements over our 1972 measurements were effected in the preparation of $Ti^{15}N$ targets by the use of reactive sputtering, and in γ-ray detection by the use of Ge(Li) detectors with better resolution and efficiency. Branching ratios were measured at 0° and 55°, with corrections applied for the known angular distributions and the detector efficiency. (Advantage was taken of the fact that the $\frac{11}{2}^- \rightarrow \frac{7}{2}^-$ primary and the $\frac{11}{2}^- \rightarrow \frac{9}{2}^- \rightarrow \frac{5}{2}^-$ secondary γ rays have essentially the same angular distributions.) The value of $\omega\gamma = (\Gamma_\alpha \Gamma_\gamma / \Gamma)(2J+1)/2$ at the $E_\alpha = 4.00$ MeV resonance in the $^{15}N(\alpha,\gamma)^{19}F$ reaction, corresponding to the excitation of the $E_x = 7167$ keV level in ^{19}F, was measured relative to the $\omega\gamma$ for the $T=\frac{3}{2}$, $J=\frac{5}{2}^+$ resonance at $E_\alpha = 4.47$ MeV. Using the value[5] $\omega\gamma = 17.4 \pm 2.1$ eV for the latter, we find that the former has the value 1.05 ± 0.15 eV, in essential agreement with previous determinations.[3,4]

Table I shows that, of the three $\frac{11}{2}^-$ levels listed, the level at 7167 keV clearly has the strongest $\frac{11}{2}^- \rightarrow (\frac{7}{2}^-)_1 E2$ transition. If $E2$ strength were the only criterion, the 7167 keV level would be the best candidate for the $K=\frac{1}{2}^-$ band,[4] and the 9872 keV level the least likely. On the other hand, if one considers only the reduced alpha widths, the 8953 keV level is the most likely band member, as claimed by Mordechai and Fortune.[1]

If one assumes that any of these states is a pure $p^{-1}(sd)^4$ configuration, the above evidence is clearly contradictory. However, this problem can be resolved by recognizing the possibility of configuration mixing. Experimentally, the expected $\frac{11}{2}^- \rightarrow (\frac{7}{2}^-)_1 E2$ strength should then be spread over several $\frac{11}{2}^-$ levels; in fact, the sum of the $E2$ decay strengths for the three $\frac{11}{2}^-$ levels listed above is 19.5 ± 3 W.u., in good agreement with the $6^+ \rightarrow 4^+ E2$ strength measured in ^{20}Ne by Rogers *et al.*[6] (viz., 20 ± 3 W.u.), and with the $\frac{13}{2}^- \rightarrow (\frac{9}{2}^-)_1 E2$ strength measured in ^{19}F by Underwood *et al.*[7] (viz., 22 ± 3 W.u.). Furthermore, the relatively strong $E1$ decay of the 9872 keV level can be attributed to an $(sd)^2(pf) \rightarrow (sd)^3$ transition. The strong population of the 8953 keV level observed[8,9] in three-particle transfer is inconsistent with a pure $p^{-1}(sd)^4$ configuration, but can also be explained by an $(sd)^2(pf)$ component.

The details of the configuration mixing have not been worked out, but the existence of $p^{-1}(sd)^4$ and $(sd^2)(pf)$ components in the wave function for the $\frac{11}{2}^-$ states has been discussed, for example, by van der Borg *et al.*,[8] by Pilt *et al.*,[10] and by Fifield *et al.*[3] SU(3) shell model calculations in a pure $p^{-1}(sd)^4$ basis produce only two $\frac{11}{2}^-$ states between 8 and 10 MeV and neither[10] can be matched to the experimentally observed levels. In their discussion Pilt *et al.*[10] postulate explicitly that the $\frac{11}{2}^-$ level at 7.17 MeV is mainly $p^{-1}(sd)^4[(81)+(70)]$ with enough $(sd)^2(pf)(70)$ to reduce the alpha-spectroscopic amplitude by *destructive* interference without giving too large a triton amplitude and without reducing the $E2$ strength. The 8.95 MeV level must then contain an appreciable amount of $(sd)^2(pf)(70)$ to provide the observed triton width, and this component may interfere constructively with the smaller $p^{-1}(sd)^4 \times [(81)+(70)]$ amplitude to provide the observed alpha width.

In this Comment we have stressed the evidence from the γ-ray decay rates, because it seems to have been largely ignored by Mordechai and Fortune.[1] When these data are considered together with the evidence from transfer reactions, the only reasonable conclusion is that the $\frac{11}{2}^-$ levels of ^{19}F are strongly mixed, and that there is no single $\frac{11}{2}^-$ level with a pure "weak coupling" configuration. The correct prediction of the properties of the $\frac{11}{2}^-$ levels constitutes a challenging test of multishell calculations for the ^{19}F nucleus.

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