Additional 1^+ states in ^{20}F†

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Observation of a dominant $L=0$ component in the $^{18}O(^3He,p)$ ^{20}F angular distribution to the 3.97-MeV state, when combined with previous restrictions, assigns $J^\pi=1^+$. An apparent $L=0$ component for the 3.17-MeV state gives a tentative (1^+) assignment for that state. Both these states appear to consist largely of core excitation.

[NUCLEAR REACTIONS $^{18}O(^3He,p)$ $E=19.0$ MeV, measured angular distributions for 1^+ states; assigned $L=0+2$ and hence $J^\pi=1^+$ for 3.175-, 3.966-MeV states.]

I. INTRODUCTION

1^+ states are known[1] in ^{20}F at excitation energies of 1.057, 3.488, and 4.082 MeV. On the basis of shell-model calculations and systematics of core excitation in this region of nuclei, several additional 1^+ states are expected. A spherical shell-model calculation[2] in an $(sd)^4$ basis predicts 1^+ states at $E_x=0.92$, 2.47, 3.75, and 4.31 MeV. The correspondence between the 0.92-MeV theoretical state and the 1.06-MeV experimental state is obvious. The theoretical state at 2.47 MeV is undoubtedly to be identified with the experimental state at 3.49 MeV, on the basis of its large $l=0$ spectroscopic factor in $^{19}F(d,p)^{20}F$.[3,4] A later calculation[5] that more nearly reproduces the energy of this 1^+ state produces additional 1^+ states at 4.42 and 5.16 MeV.

Based on the systematics of excitation energies of core-excited states in this mass region, other 1^+ states should exist at reasonably low energies. For example, the six-particle–two-hole (6p-2h) 1^+ state that has the six particles coupled to $J^\pi=0^+$, $T=1$ and the two holes to $J^\pi=1^+$, $T=0$ [in weak-coupling parlance, this state has the description $^{22}Ne(g.s.)\otimes{}^{14}N(g.s.)$] is expected near 3 MeV. Coupling the first-excited 2^+ state of ^{22}Ne (at $E_x=1.27$ MeV) to the $^{14}N(g.s.)$ produces a triplet of states, one of which is 1^+. The 6p-2h states with $T_p=0$, $T_h=1$ should lie only slightly higher.

In the reaction $^{19}F(d,p)^{20}F$[3,4,6] the only state (apart from those at 1.06, 3.49, and 4.08 MeV) that was populated with a measurable $l=0$ component is at 4.31 MeV. It thus is a candidate for being a 1^+ state.

States (with no assigned J^π) at 3.18, 3.59, 3.68, and 3.97 MeV were populated with $l=2$ in $^{19}F(d,p)^{20}F$,[4] implying $J^\pi=(1,2,3)^+$. A subsequent study of the $^{18}O(^3He,p)^{20}F$ reaction[7] ruled out $J^\pi=1^+$ for the 3.59- and 3.68-MeV states if they are single states and not unresolved doublets. In that work, the region of the 3.18-MeV state and the region above $E_x=3.76$ MeV were obscured by target impurities. We have reinvestigated the $^{18}O(^3He,p)^{20}F$ reaction with a different target. This reaction provides an ideal way of searching for 1^+ states because $L=0$ transfer is strongly

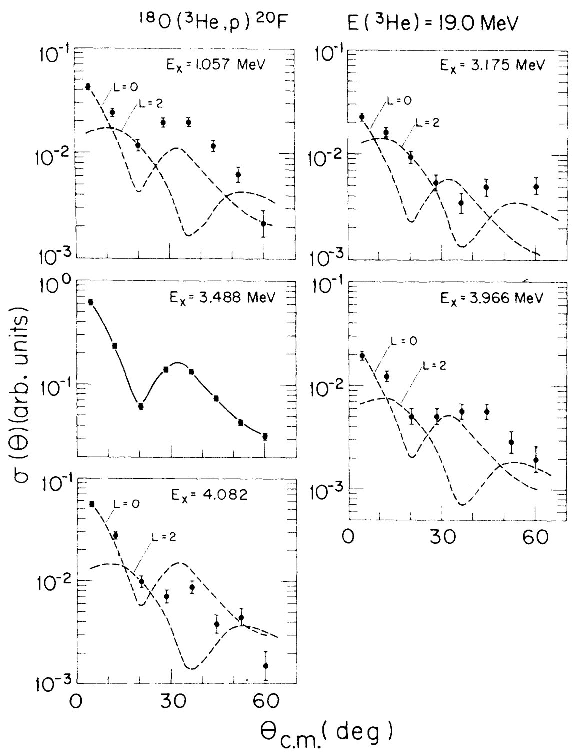

FIG. 1. Angular distributions of the states at excitation energies of 1.057, 3.488, 4.082, 3.175, and 3.966 MeV, together with empirical $L=0$ and $L=2$ curves.

TABLE I. Summary of information on 1^+ states in ^{20}F.

E_x [a] (MeV)	l	(d,p) [b] $(2J+1)S$	$(^3He,p)$ [c] L	γ decay [d]
1.057	0	0.013	0+2	100% to 2^+ g.s.
	2	0.022		
3.175	2	0.019	0+2	>95% to 1^- state at 0.98 MeV
3.488	0	1.20	0(+2)	$68\pm4\%$ to 2^+ g.s.
				$7\pm1\%$ to 1^- 0.98-MeV state
				$7\pm1\%$ to 1^+ 1.06-MeV state
				$10\pm2\%$ to 2^- 1.31-MeV state
				$8\pm2\%$ to 2^- 1.84-MeV state
3.966	2	0.036	0+2	77% to 2^+ g.s.
				6% to 1^- 0.98-MeV state
				17% to 2^- 1.31-MeV state
4.082	0	0.13	0+2	$35\pm7\%$ to 2^+ g.s.
	2	0.083		$65\pm13\%$ to 3^+ 2.19-MeV state

[a] Excitation energies from Ref. 1.
[b] Reference 4.
[c] Present work and Ref. 7.
[d] Summarized in Ref. 1.

favored kinematically in (^{3}He,p). Of course, a 1^+ state may lack any measurable $L=0$ strength for structural reasons, but the observation of $L=0$ requires $J^\pi=0^+$ or 1^+. If $J^\pi=0^+$ is ruled out from other evidence, $L=0$ in (^{3}He,p) uniquely assigns $J^\pi=1^+$.

II. EXPERIMENTAL PROCEDURE AND RESULTS

A beam of 19.0-MeV ^{3}He ions from the Penn tandem bombarded a gold-backed foil of an oxide of tungsten. The target was prepared by heating a tungsten filament in oxygen gas that was enriched to 98% in ^{18}O. However, the target as used contained a significant amount of ^{16}O. Because of this fact, plus uncertainties in target thickness and in the relative proportions of the different oxides of tungsten (e.g., WO_3, W_2O_5, etc.) we have not measured absolute cross sections. The yield is given in arbitrary units. Outgoing protons were momentum analyzed in a multiangle spectrograph and detected in K5 nuclear emulsion plates. Mylar foil prevented charged particles other than protons from striking the emulsions.

Angular distributions for the states at 1.057, 3.488, 4.082, 3.175, and 3.966 MeV are displayed in Fig. 1. The states on the left-hand side of the figure are already known to have $J^\pi=1^+$. The curves in the figure are empirical $L=0$ and $L=2$ shapes. The $L=0$ curve is obtained from the strong 3.488-MeV state, whose angular distribution has no discernible $L=2$ contribution.[7] The $L=2$ shape is obtained from the strong 2^+ state at 2.044 MeV. The angular distribution of the 3.966-MeV state is seen to be dominated by $L=0$. This result, coupled with the ^{19}F$(d,p)^{20}$F results,[4] yields an unambiguous J^π assignment of 1^+ for the 3.966-MeV state. For the 3.175-MeV state, the $L=0$ component is less dominant but nevertheless appears to be present. $L=0$ is the only L value that continues to rise at extreme forward angles, as do the data. We thus make the assignment of (1^+) to this state a tentative one.

These assignments are consistent with total cross sections measured in the ^{14}N(^{7}Li,p)^{20}F reaction[8] and with less restrictive information on γ decays. (See Table I.) The only observed decay of the 3.18-MeV state is to a 1^- state at 0.98 MeV. The 3.97-MeV state decays predominantly to the 2^+ ground state and weakly to 1^- and 2^- states at 0.98 and 1.31 MeV, respectively.

The absence of $l=0$ and the weak cross section $(2J+1)S(3.18)=0.02$ and $(2J+1)S(3.97)=0.04$ observed[4] for these two states in ^{19}F$(d,p)^{20}$F makes it likely that they are dominantly core-excited states. However, the third shell-model state is predicted[2] to have virtually no $l=0$ component in (d,p) and a relatively small spectroscopic factor for $l=2$ $[(2J+1)S=0.2]$. If the 3.18-MeV state is dominantly ^{22}Ne(g.s.)$\otimes$^{14}N(g.s.) and the 3.97-MeV state dominantly ^{22}Ne$(2^+)\otimes$^{14}N(g.s.), then 2^+ and 3^+ states from the latter coupling should also exist near 4 MeV. Finally, if the 3.18-MeV state is of the proposed configuration, it might be strongly populated in two-particle pickup on ^{22}Ne.

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[1] F. Ajzenberg-Selove, Nucl. Phys. A190, 1 (1972).
[2] E. C. Halbert, J. B. McGrory, B. H. Wildenthal, and S. P. Pandya, in *Advances in Nuclear Physics,* edited by M. Baranger and E. Vogt (Plenum, New York, 1971), Vol. 4.
[3] H. T. Fortune, G. C. Morrison, R. C. Bearse, J. L. Yntema, and B. H. Wildenthal, Phys. Rev. C 6, 21 (1972).
[4] H. T. Fortune and R. R. Betts, Phys. Rev. C 10, 1292 (1974).
[5] B. H. Wildenthal (private communication).
[6] F. A. El Bedewi, Proc. Phys. Soc. London A69, 221 (1956).
[7] D. J. Crozier and H. T. Fortune, Phys. Rev. C 10, 1697 (1974).
[8] J. N. Bishop and H. T. Fortune, Bull. Am. Phys. Soc. 18, 678 (1973); and (unpublished).