ing $\Gamma = 0.1$ and the remaining parameters the same as for curve 3, we obtain curve 4 which reproduces the data very well. We do not want, however, to stress the importance of this fit, since the last modification introduces an additional parameter.

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HOLE-PARTICLE STATES IN ^{18}F†

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Using the reaction ^{14}N(Li^7, t)^{18}F we have assigned hole-particle configurations to ten states of ^{18}F. The results support a model which assumes weak coupling between holes and particles. It has also been found that the reaction obeys a $\Delta T = 0$ selection rule.

Recently there has been considerable interest[1-3] in the possible hole-particle nature of many of the low-lying states of ^{18}F. In particular, it has been proposed that the positive-parity states at 1.70 and 2.52 MeV have $(1p_{1/2})^{-2}(2s, 1d)^4$ configurations and the known or suspected negative-parity states at 1.08, 2.10, and 3.13 MeV have $(1p_{1/2})^{-1}(2s, 1d)^3$ configurations. It is clear that such states cannot be reached with the previously studied double-stripping reaction ^{16}O(^{3}He, p)^{18}F or single-stripping reaction ^{17}O(^{3}He, d)^{18}F, but many of them can in principle be excited with the four-nucleon-transfer (^{7}Li, t) reaction.

This Letter reports confirmation of the configurations of these states and the identification of other hole-particle states in ^{18}F with the reaction ^{14}N(^{7}Li, t)^{18}F. We have also ascertained that the $T=1$ states in ^{18}F are not excited by the reaction although $\Delta T = 1$ excitations are not forbidden in principle.

The experiment was performed with a 15-MeV ^{7}Li^{+++} beam from the University of Pennsylvania tandem accelerator,[4] and reaction products were detected with nuclear emulsions in the multiangle magnetic spectrograph. Solid targets containing ^{14}N were found to be unsatisfactory because of either premature failure or inadequate energy resolution, and to avoid these difficulties, a gas cell without an entrance window was designed. Beam entered the cell through six tantalum apertures 1 mm in diameter spaced 2 mm apart. This geometry permitted ~90% of the available beam (0.15-0.30 μA) to enter the cell and gave a high impedance to gas flow, allowing the internal pressure to be kept at 12 Torr while the pressure in the spectrograph vacuum tank was 1.2×10^{-3} Torr. Reaction products left the cell through a 0.15-mil Mylar window, and the primary beam through a 0.5-mil nickel foil. Spectra were recorded simultaneously at 7.5° intervals from 15° to 152.5°.

A typical spectrum is shown in Fig. 1 and absolute differential cross sections obtained at two angles are given in Table I. A striking feature of the data is the relative strength with

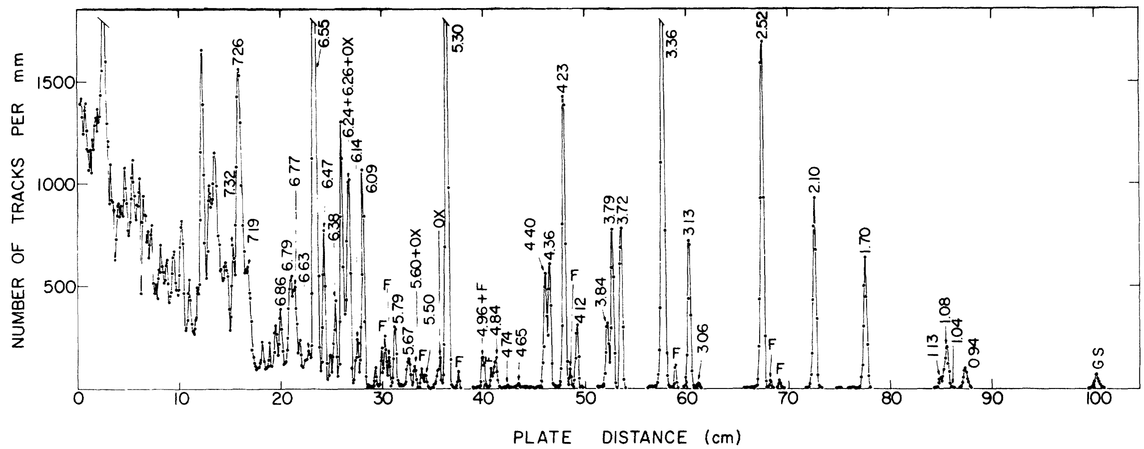

FIG. 1. Spectrum of the reaction $^{14}N(^7Li, t)^{18}F$ recorded at a lab angle of 15° and $E_{Li} = 15.0$ MeV. Deuteron and alpha groups arising from the reactions $^{14}N(^7Li, d)^{19}F$ and $^{14}N(^7Li, \alpha)^{17}O$ are labeled F and Ox, respectively.

Table I. Existing information on ^{18}F states below 7.4 MeV and absolute differential cross sections for their excitation with the reaction $^{14}N(^7Li, t)^{18}F$. Excitation energies are taken from Refs. 6 and 7 with the exception of the 6.30-MeV level which has not been previously reported. Spins, parities, and isospins for levels below 5 MeV are taken from Refs. 5 and 7; the assignment to the 5.30-MeV level is taken from Ref. 8, and all other assignments are those quoted in Ref. 6. New assignments to hole-particle states, consistent with the existing values and the weak-coupling model, are shown in square brackets.

E_x (MeV)	J^π	$\sigma(15°)_{lab}$ (mb/sr)	E_x (MeV)	J^π	$\sigma(15°)_{lab}$ (mb/sr)
g.s.	1^+	.11	4.964	2^+;T=1	a
.937	3^+	.14	5.295	1^+,2,3[3^+]	2.21
1.043	0^+;T=1	<.002	5.502		.043
1.081	0^-	.28	5.603	$0^-,1^-,2^-$	<.084
1.131	5^+	.047	5.668	$0^-,1^-,2^-$	.14
1.701	1^+	.68	5.786		.25
2.101	2^-	.99	6.092	$2^-,3^-,4^-$	.77
2.524	2^+	1.71	6.139		.20
3.060	2^+;T=1	~.020	6.235	$2^-,3^-,4^-$ }	<.88
3.134	$1^{(-)}$[1^-]	.71	6.264	1^+ }	
3.358	$2^+,3^+$[3^+]	2.75	6.30[b]		1.05
3.724	$1^{(+)}$	.68	6.376		.30
3.790	1,2,3[3^-]	.64	6.472		.55
3.839	2^+	.30	6.548	$3^+,4^+,5^+$[$4^+,5^+$]	3.37
4.115	3^+	.24	6.634		.11
4.231	1,2[1^+]	1.24	6.765		.44
4.361	≤ 3	.45	6.790	2^-	.59
4.400	≥ 2	.48	6.859		.35
4.651	4^+;T=1	~.018	7.19		.58
4.741	0^+;T=1	~.009	7.26		2.25
4.844	1	.15	7.32		.55

[a]Obscured by deuteron group; for 4.964-MeV level $\sigma(22.5°)_{lab} \simeq 0.014$ mb/sr.

[b]New level; given energy is ±20 keV.

which certain states are excited. Specifically, the transitions to the six states at 1.70, 2.52, 3.36, 4.23, 5.30, and 6.55 MeV account for more than one-half of the summed cross section observed at 15° for transitions to all states below 7-MeV excitation. It is also significant that these same six states are, at most, only weakly excited by the reactions $^{16}O(^3He, p)^{18}F$ and $^{17}O(He, d)^{18}F$.[5]

Consideration of the above in light of the existing information[5-8] on the spins and parities of ^{18}F levels has led us to propose that the six strongly excited states are predominantly of a four-particle, two-hole nature and are excited by the transfer of four nucleons into the $(2s, 1d)$ shell. If the hole-particle coupling is weak, as suggested by Arima, Horiuchi, and Sebe,[1] then the particle wave functions are substantially the same as the eigenfunctions of the ^{20}Ne ground-state rotational band, and the hole wave function is like that of the ^{14}N ground state.

The first three states in the ^{20}Ne ground-state band have $J^\Pi = 0^+$, 2^+, and 4^+,[9] and, when weakly coupled to the $(1p_{1/2})_{1+}{}^{-2}$ hole configuration, give rise to seven hole-particle states in ^{18}F as shown in Fig. 2. The figure also shows the proposed correspondence between the observed and expected levels made on the basis of consistency with the existing spin and parity assignments. An immediate result is that we further restrict the previous spin and parity assignments to $J^\Pi = 3^+$ for the 3.36-MeV level, 1^+ for the 4.23-MeV level, and 3^+ for the 5.30-MeV level. The 6.55 MeV level can have either $J^\Pi = 4^+$ or 5^+. We are unable to locate the third level with parentage in

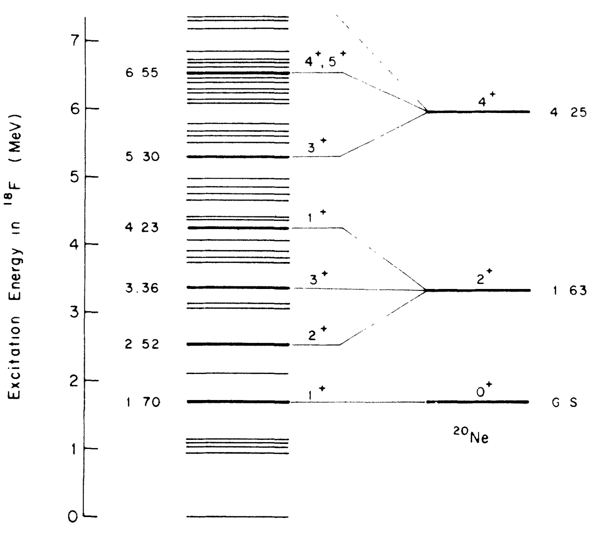

FIG. 2. Proposed association between the two-hole, four-particle states in ^{18}F and states in ^{20}Ne. The ^{20}Ne level diagram has been shifted to align the ground state with the 1.70-MeV level in ^{18}F.

the 4^+ state of ^{20}Ne, but there are several candidates among the strongly excited states above 7-MeV excitation.

If the slightly different kinematical situations are disregarded, it follows that the cross sections for the ^{20}Ne 0^+, 2^+, and 4^+ rotational bands measured from the reaction[10] ^{16}O(Li^7, t)^{20}Ne should be similar to those observed from the reaction ^{14}N(^{7}Li, t)^{18}F to the proposed four-particle, two-hole states of ^{18}F. A comparison of the present differential cross sections measured at 15° with those from Ref. 10 bears this out within an accuracy of about ±30%. It would also be expected that the ratio of intensities of the groups corresponding to the 1^+ state 4.23 MeV, the 2^+ state at 2.524 MeV, and the 3^+ state at 3.358 MeV of ^{18}F, all of which arise from the coupling of the ^{14}N core with the 2^+ state in ^{20}Ne, should follow the $2J+1$ rule. The observed differential cross sections at 15° are in the ratio 3:4.14:6.65, which is in reasonably good agreement with the predicted ratio of 3:5:7.

The situation with respect to the low-lying negative-parity states is only slightly less clear. Poletti[11] has proposed that their configurations are obtained by promoting a particle from the $1p_{1/2}$ shell to the $(2s, 1d)$ shell to form $(1p_{1/2})^{-1}\times(2s, 1d)^3$ configurations. That is, they are thought to arise from the coupling of a $p_{1/2}$ hole to the lowest positive-parity states of ^{19}F. Since there are two such states with $J^\Pi = \frac{1}{2}^+$ and $\frac{5}{2}^+$, four odd-parity states can be formed with spins 0, 1, 2, and 3. The 0^- and 2^- states have been identified[11] as the 1.08- and 2.10-MeV levels in ^{18}F, and there is evidence[12] that the spin-1 level at 3.13 MeV also has negative parity. Following the suggestion of Warburton, Olness, and Poletti[13] we propose the 3.79-MeV level as the expected 3^- state with the justifications that (a) it is excited with moderate strength by the (^{7}Li, t) reaction, (b) it is only weakly excited by the reactions ^{16}O(^{3}He, p)^{18}F and ^{17}O(^{3}He, d)^{18}F, and (c) it is the only state below 4.4 MeV which has a γ decay[13] consistent with a 3^- assignment.

It is notable that the transitions to the $(1p_{1/2})^{-1}\times(2s, 1d)^3$ states are, with only one exception, markedly weaker than transitions to the $(1p_{1/2})^{-2}\times(2s, 1d)^4$ states but are stronger than the transitions to states thought to have $(2s, 1d)^2$ configurations. This observation suggests that the (^{7}Li, t) reaction preferentially excites states formed by transferring all four nucleons into the same shell, that cross sections are reduced somewhat when one of the four nucleons is transferred into a different shell, and that the cross sections are further reduced when the transferred nucleons are equally distributed between two shells.

The weakest transitions in the spectrum (by about an order of magnitude or more at 15°) are those to the five known[5,14] $T=1$ states at 1.04, 3.06, 4.65, 4.74, and 4.96 MeV. Both ^{7}Li and the triton have $T=T_3=\frac{1}{2}$ and the elementary coupling rules therefore allow either $\Delta T=0$ or $\Delta T=1$ excitations by the (^{7}Li, t) reaction. The apparent $\Delta T=0$ selection rule is evidence for a direct alpha-transfer mechanism for the reaction and an alpha-triton cluster model for ^{7}Li.

The direct character of the reaction is further supported by the pronounced forward peaking seen in the angular distributions. Additional evidence is the fact that the deuteron groups arising from the reaction ^{14}N(^{7}Li, d)^{19}F are very weak (see Fig. 1) compared with the average triton strength. If the reaction mechanism were dominantly compound, one would expect the deuteron groups to be stronger because of their higher probability of evaporation from a compound nucleus.

Data on the reaction ^{14}N(^{6}Li, d)^{18}F have also been obtained and preliminary analysis indicates substantial agreement with our conclusions concerning the hole-particle states in ^{18}F. A more detailed analysis including the (^{6}Li, d) results and angular distributions for both reactions is being prepared.

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REPORT ON THE INVESTIGATION OF MACH'S PRINCIPLE IN THE SCALAR-TENSOR THEORY OF GRAVITY

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Most statements of Mach's principle demand that the mass of a solitary object be zero. The results of self-energy calculations in the canonical formalism of the scalar-tensor theory for solitary neutral point particles and the solitary charged point particle are reported here. The results show that from the viewpoint of Mach's principle, the scalar-tensor theory offers no substantial improvement over general relativity.

In 1961, Brans and Dicke[1] proposed a new theory of gravitation, apparently compatible with Mach's principle. The need for a new theory was pointed out because of the difficulties encountered in attempting to incorporate Mach's principle into general relativity.

That some Machian effects do exist in general relativity has been demonstrated by Brill and Cohen.[2] Here, the Machian effects are of a kinematic nature and refer to the "dragging" of inertial frames by distant matter in the universe. A thin, spherical, mass shell, whose radius equals its Schwarzschild radius, is capable of perfectly "dragging" along with it an interior inertial frame if the shell is slowly rotating relative to an inertial frame at infinity. Thus the mass shell appears at rest relative to the interior inertial frame and observers therein. In fact, this offers an explanation for the observational fact that the distant stars of the universe are, in the large, rotationally at rest relative to a local inertial frame.

There are other Machian effects which apparently are not in general relativity. Of the many statements of Mach's principle, not a few imply that the inertia of a body depends upon its interaction with the other bodies in the universe and that, in the absence of these bodies, the inertia of the body is zero. That this does not occur in general relativity is, perhaps, obvious, but will be shown in a review of the self-energy calculations of Arnowitt, Deser, and Misner[3] (ADM) to follow shortly.

The statement of Mach's principle in the scalar-tensor theory is more general than the above.[4] Local physical laws are assumed influenced by distant matter in the universe through the fundamental constants appearing in the laws, a partial