are proton densities from the same Woods-Saxon calculation, in which the parameters were adjusted to fit $\langle r^2\rangle$ measured for the charge distribution.

Such densities should be used in calculations of K^- or antiproton absorption. These rely critically on densities at large radii, and any estimates that do not take the asymptotic separation energy into account are likely to be seriously in error, particularly for heavy nuclei.

A comparison between our results and those of Negele,[15] who has done perhaps the most realistic neclear-matter calculations to date, are not very meaningful because he does not reproduce the absolute binding energies of neutron-hole states *exactly*. Deviations of the order of an MeV become crucial in determining the asymptotic cross sections. The Bethe-Siemens model[16] for K^- capture emphasizes the importance of the neutron tail but tends to overestimate its absolute magnitude by about a factor of 2 at 10 fm.

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New High-Spin States in ^{19}F and a Possible $K=\frac{3}{2}^+$ Band

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New levels in ^{19}F with spins of $\frac{9}{2}^+$ and $\frac{11}{2}$ have been discovered at energies of 6592±2 and 7937±3 keV, respectively. It is suggested that these levels, together with the known 3907-keV ($\frac{3}{2}^+$), 4549-keV ($\frac{5}{2}^+$), and 5464-keV ($\frac{7}{2}^+$) levels, form a $K=\frac{3}{2}^+$ rotational band.

Members of the ground-state rotational band in ^{19}F up to the $(2s, 1d)^3$ limit have now been identified with the discovery of levels of spin $\frac{11}{2}^+$ at 6.50 MeV[1] and spin $\frac{13}{2}^+$ at 4.65 MeV.[2] This band is reasonably well explained by a shell-model calculation with three nucleons outside an inert ^{16}O core. Similarly, the second $\frac{3}{2}^+$ level at 3.91 MeV, the second $\frac{5}{2}^+$ level at 4.55 MeV,[3] and the second $\frac{7}{2}^+$ level at 5.46 MeV[4] seem to comprise a $K=\frac{3}{2}^+$ band, but these levels are not so easily explained in terms of three-particle configurations. In particular, three-particle shell-model calculations generally predict the second $\frac{3}{2}^+$ state to lie above 6 MeV. In order to further our understanding of these states we have searched for and found levels of spin $\frac{9}{2}^+$ at 6592 ± 2 keV and spin $\frac{11}{2}$ at 7937 ± 3 keV which seem to be the higher members of a $K = \frac{3}{2}^+$ band based on the 3.91-MeV level.

The two new levels reported here have been observed as resonances at $E_\alpha = 3.27$ and 4.97 MeV, respectively, in the reaction $^{15}N(\alpha, \gamma)^{19}F$ using singly and doubly charged α-particle beams from the 4-MV National Research Council Van de Graaff accelerator. Targets were made by nitriding titanium on a tantalum backing (>99% ^{15}N). γ-ray spectra and angular distributions were studied with Ge(Li) detectors of 30 and 40 cm^3. For both resonances reasonable fits to the angular distributions were found for several spin hypotheses but unique spins were assigned by eliminating those hypotheses which required unreasonably large quadrupole or octupole transition strengths. Radiative widths $\omega\gamma = \frac{1}{2}(2J+1) \times \Gamma_\alpha \Gamma_\gamma / \Gamma$ were measured by a comparison with the yield of the resonance at $E_\alpha = 1.68$ MeV, which has been measured by Dixon and Storey[5] to have $\omega\gamma = 1.64 \pm 0.16$ eV. Transition strengths were obtained from the radiative widths by assuming $\Gamma_\alpha \gg \Gamma_\gamma$.

The decay scheme for the level corresponding to the resonance at 3.27 MeV is shown in Fig. 1(a). The radiative width was found to be $\omega\gamma = 1.6 \pm 0.2$ eV. Of the possible spins of $\frac{5}{2}$, $\frac{7}{2}$, and $\frac{9}{2}$ for the resonance, $\frac{5}{2}$ is ruled out by the large quadrupole strength required for the transition to the first $\frac{9}{2}^+$ level at 2.78 MeV $[|M|^2 > 150$ Weisskopf units (W.u.)$]$, $\frac{7}{2}$ is ruled out by the large quadrupole strength required for the transition to the $\frac{7}{2}^+$ level at 4.38 MeV ($|M|^2 > 55$ W.u.), and $\frac{9}{2}^-$ is ruled out by the large $M2$ strength implied by the transition to the $\frac{5}{2}^+$ level at 197 keV ($|M|^2 > 30$ W.u.). Hence the level at 6.59 MeV is assigned $J^\pi = \frac{9}{2}^+$.

The level of interest in the $E_\alpha = 4.97$-MeV resonance is actually the upper member of a doublet, separated by about 9 keV in excitation from another level which has $J^\pi = \frac{7}{2}^+$ or $\frac{9}{2}^\pm$. The decay schemes of both resonances are shown in Fig. 1(b). The radiative width of the upper resonance is $\omega\gamma = 3.1 \pm 0.5$ eV. Of the possible spins of $\frac{13}{2}$, $\frac{11}{2}$, and $\frac{9}{2}$ for this level, $\frac{13}{2}$ and $\frac{9}{2}$ are both ruled out by the large quadrupole strengths required for the transitions to the $\frac{13}{2}^+$ level at 4.65 MeV ($|M|^2 > 90$ and $|M|^2 > 600$ W.u., respectively). From the angular distribution it was not possible to establish the parity of the resonance although positive parity is strongly suggested by the decay scheme.

The first three members of the suggested $K = \frac{3}{2}^+$ band in ^{19}F have been studied previously. Positive parity is assumed for the 3907-keV ($\frac{3}{2}$) level because the apparent analog of this state in ^{19}Ne at 4.04 MeV has been shown to have positive parity on the basis of the $L = 0$ pattern observed for the feed to this level in the reaction $^{21}Ne(p, t)^{19}Ne$.[6] This indicates that $K = \frac{3}{2}^+$ for this state since the two neutrons picked up carry off no angular momentum, leaving K unchanged from its value for the ^{21}Ne ground state, viz., $K = \frac{3}{2}^+$. This also indicates that the analog state in ^{19}F at 3907 keV has $K = \frac{3}{2}^+$. The level at 4549 keV has

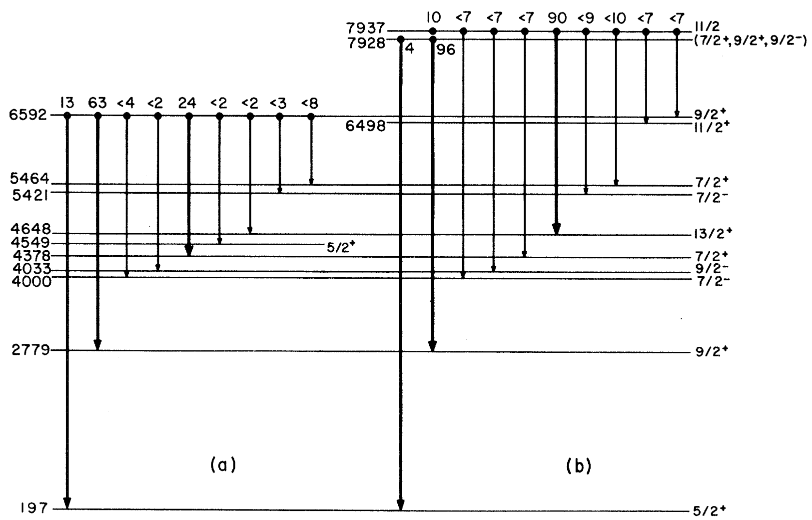

FIG. 1. γ-ray decay of the resonances in ^{19}F at (a) $E_\alpha = 3.27$ MeV, and (b) $E_\alpha = 4.97$ MeV.

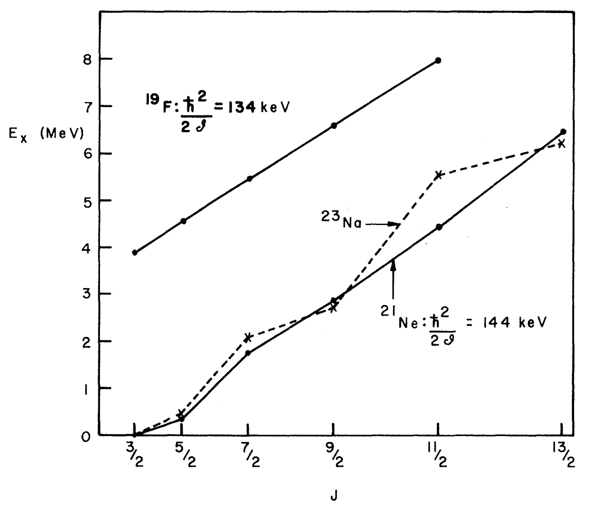

FIG. 2. Plots of excitation energy versus $J(J+1)$ for $K=\frac{3}{2}^+$ bands in ^{19}F, ^{21}Ne, and ^{23}Na.

a spin[3,7] of $\frac{5}{2}^+$. We have confirmed the spin assignment by a study of a resonance at $E_\alpha = 3.18$ MeV in ^{15}N$(\alpha,\gamma)^{19}$F which feeds this level. The $\frac{7}{2}^+$ level has been studied by Tolbert[4] at the $E_\alpha = 1.84$-MeV resonance in ^{15}N$(\alpha,\gamma)^{19}$F. We have confirmed Tolbert's spin-parity assignment but find the excitation energy to be 5464 ± 2 keV. We have also remeasured the radiative width to be $\omega\gamma = 2.5 \pm 0.4$ eV.

It is still an open question which $\frac{7}{2}^+$ state—the 4378-keV or the 5464-keV state—belongs to the ground-state rotational band. We have assigned the 4378-keV state to the $K=\frac{1}{2}^+$ band primarily because the first $T=\frac{3}{2}$ state in ^{19}F, with a predominantly $(d_{5/2})^3$ configuration, decays to the 4378-keV but not to the 5464-keV state,[8] and because ^{19}O decays by β emission to the 4378-keV state[9] with $\log ft = 3.54 \pm 0.06$. On the other hand Bingham *et al.*[10] see a strong peak corresponding to a level at 5.47 MeV in the three-nucleon transfer reaction ^{16}O(^{6}Li, ^{3}He)^{19}F.

Figure 2 shows that the five levels in ^{19}F which we are considering for a $K=\frac{3}{2}^+$ band are fitted remarkably well by the $J(J+1)$ prediction of the rotational model. However, it has not been possible to confirm a rotational-like structure by the observation of in-band $E2$ transitions, since even a 20-W.u. in-band $E2$ transition would correspond to a decay branch of less than 1% for any of the possible cases reported here, well below the assigned limits on these transitions. If however, for purposes of discussion, we assume the simple rotational model, then the moment-of-inertia parameter $\hbar^2/2\mathcal{J}$ is found to have the value

TABLE I. Observed γ-ray branching ratios and transition strengths in Weisskopf units. The subscripts i and f refer to the initial and final states, respectively.

E_i (keV)	J_i	E_f (keV)	J_f	Branching Ratio (%)	Transition strengths in W.u. M1	E2
5464	$\frac{7}{2}^+$	2779	$\frac{9}{2}^+$	59	0.9±0.2	3±2
		1554	$\frac{3}{2}^+$	5		14±4
		1346	$\frac{5}{2}^-$	32	$(6\pm1)\times10^{-3}$(E1)	<8(M2)
		197	$\frac{5}{2}^+$	4	$(1.5\pm0.5)\times10^{-3}$	2.0±0.5
					or $(8\pm2)\times10^{-3}$	<0.2
6592	$\frac{9}{2}^+$	4378	$\frac{7}{2}^+$	24	0.35±0.08	<6
		2779	$\frac{9}{2}^+$	63	0.17±0.05	<20
		197	$\frac{5}{2}^+$	13		1.6±0.4
7937	$\frac{11}{2}^+$	4648	$\frac{13}{2}^+$	90	0.63±0.12	<3
		2779	$\frac{9}{2}^+$	10	0.02[a]	

[a]Assumed pure M1.

134 keV, significantly lower than the values for the $K=\frac{1}{2}^+$ and $\frac{1}{2}^-$ bands in ^{19}F (about 190 and 220 keV, respectively). This implies a higher moment of inertia or a more deformed shape for the $K=\frac{3}{2}^+$ band. The parameter is similar to that obtained for the ground-state rotational bands[11,12] in ^{21}Ne and in ^{23}Na, suggesting that the ^{19}F band may have 5p-2h (five-particle, two-hole) configurations based on the removal of two particles from the ^{21}Ne core, or 7p-4h configurations based on the removal of an α particle from the ^{23}Na core. The latter suggestion is in keeping with the view of Engeland and Ellis[13] that the 3.91-MeV state may have a 7p-4h configuration, and with the shell-model calculation of McGrory[14] for seven particles outside a ^{12}C core.

Table I shows observed transition strengths for the γ-ray decays of the $\frac{7}{2}^+$, $\frac{9}{2}^+$, and $\frac{11}{2}^+$ levels. The out-of-band $M1$ strengths are surprisingly large if these represent particle-hole to three-particle transitions. In fact Rogers[15] has shown that except for the decay of the 3.91-MeV level and certain other transitions (e.g., the $E2$ strength from the second $\frac{9}{2}^+$ level to the 197-keV level is about 200 times the calculated value), decays from members of the proposed $K=\frac{3}{2}^+$ band can be reasonably well explained in terms of three-particle configurations. We conclude that these states probably contain a large three-particle component to account for the observed $M1$ strengths, but also a sizable admixture of particle-hole configurations to account for the relatively high moment of inertia and low energies in the band, as well as to explain certain details of the decay schemes, and perhaps to explain the unusual properties of the $\frac{7}{2}^+$ states.

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Evidence for a $K^\pi = 5^+$ Ground-State Rotational Band in ^{26}Al†

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Measurement of γ-ray distributions from the reaction $^{23}Na(\alpha, n\gamma)^{26}Al$ confirms spin $J=5$ for the 3404-keV level and gives an unambiguous spin assignment of $J=6$ for the 3508-keV level. Measurement of lifetimes and mixing ratios show that both states have positive parity. The excitation energy and the enhanced $E2$ strength of >11 Weisskopf units for the 6^+ to 5^+ ground-state transition identify the level at 3508 keV as the 6^+ member of a $K=5^+$ rotational band based on the ground state.

The change in the sign of the deformation of nuclei in the middle of the s-d shell has been of considerable interest in the last few years. The nuclei ^{24}Mg, ^{25}Mg, and ^{25}Al have well-known rotational bands corresponding to strong prolate deformations, and ^{28}Si, ^{29}Si, and ^{29}P are found to be oblate. Definite rotational structure in nuclei with $A=26$ and 27 has not been established. It has been suggested that these nuclei, being in a transitional region, should have very small deformations and have mainly spherical states corresponding to reasonably simple shell-model configurations. However, shell-model calculations for ^{26}Al by Wildenthal *et al.*[1] produced much worse agreement between theory and experiment than similar calculations for other neighboring nuclei.

The present knowledge[2] of decays, spins, and parities of levels in ^{26}Al below 3.6 MeV is summarized in Fig. 1. On the unified model the ground state is assumed[3] to be formed by two particles outside a deformed ^{24}Mg core, both in Nilsson orbit 5 with $\Omega=\frac{5}{2}$ and coupled to give $J=K=5$. The antiparallel coupling of these two particles is assumed to give rise to $K=0$ levels at 228 keV (0^+), 1058 keV (1^+), and 2069.5 keV (2^+). Other levels can be formed by coupling one particle in orbit 5 ($\Omega=\frac{5}{2}$) to a particle in orbits 9, 11, and 8 ($\Omega=\frac{1}{2}$, $\frac{1}{2}$, and $\frac{3}{2}$), but calculations[3] using only these configurations do not successfully reproduce the measured single-particle spectroscopic factors in ^{26}Al. If, however, ^{26}Al has any