Low Excited States of F^{19}. I. Proton Inelastic Scattering*

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The spins, parities, and other properties of the low states of F^{19} are of considerable interest in connection with the shell model and collective aspects[1] of nuclear structure. Of particular interest in this connection are the first and second excited states of F^{19} discovered in this laboratory by Mileikowsky and Whaling.[2] In this and the following notes,[3] studies of the excitation of these states in the inelastic scattering of protons and alpha particles by F^{19} are reported. This note is primarily concerned with the inelastic proton groups and the de-excitation gamma radiation accompanying the inelastic scattering.

In Fig. 1 are shown the magnetically analyzed proton groups observed at 1.431 Mev and at an angle of observation of 159° in the bombardment of a thin layer of Al_2F_6 on an evaporated Li surface. From this and similar curves the excitation energies of the first two excited states of F^{19} were found to be 113.9±0.8 kev and 199.6±0.7 kev. The corresponding values determined from scintillation counter pulse-height studies of the gamma radiation from these states were 114±1.5 kev and 198±1.5 kev.

To assign spin and parity to the compound states of Ne^{20} involved, preliminary observations have been made on the angular distributions of the protons scattered elastically by fluorine. The following tentative spin and parity assignments for resonances in $F^{19}+p$ are made: 1355 kev, 2^-; 1381 kev,[4] 2^-; 1431 kev,[5] 1^+. In addition we have confirmed[6] the following assignments: 669 kev, 1^+; 872 kev, 2^-; 935 kev, 1^+.

The inelastically scattered protons resulting from the excitation of the first excited state are isotropically distributed at the 1431-kev resonance. The elastically scattered proton groups from thin contamination layers of carbon and oxygen indicated in Fig. 1 become stronger at lower bombarding energies and smaller scattering angles. Overlapping by these groups has made it impossible, to date, to determine angular distributions at lower resonances for the first inelastic group from F^{19}. The second group is found to be isotropic at the 873-kev resonance and the 1355-kev resonance and to follow the expression $(1-0.45\cos^2\theta)$ at the 1381-kev resonance. The probable error in the measurement of the angular distribution coefficients is of the order of 10 percent.

The excitation curves of the first two excited states of F^{19} were observed by detecting the de-excitation gamma radiation in a NaI(Tl) scintillation counter and are shown in Fig. 2 as a function of incident proton energy from 650 to 1500 kev. Many of the resonances in the well-known $F^{19}+p$ reactions appear also as resonances for formation of either or both of these excited states of fluorine. The s-wave (1^+) resonances in Ne^{20} at 669-, 935-, and 1431-kev proton energy lead almost exclusively to the 114-kev states, while the p-wave (2^-) resonance at 873 kev leads almost entirely to the 200-kev state. The p-wave (2^-) resonances at 1355 and 1381 kev and the narrow resonance at 1092 kev lead in comparable quantities to the two states. Between 330 and 650 kev the yield of 114- and 200-kev gamma radiation is very small and has been omitted from Fig. 2.

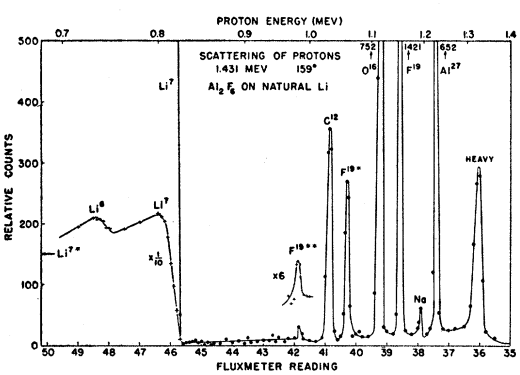

FIG. 1. Proton groups scattered at 1.431-Mev bombarding energy at a laboratory angle of 159° by a thin target of Al_2F_6 deposited on a backing layer of natural Li. Note two inelastically scattered groups from F^{19} and elastically scattered groups from contaminations of C, O, Na, and heavy elements.

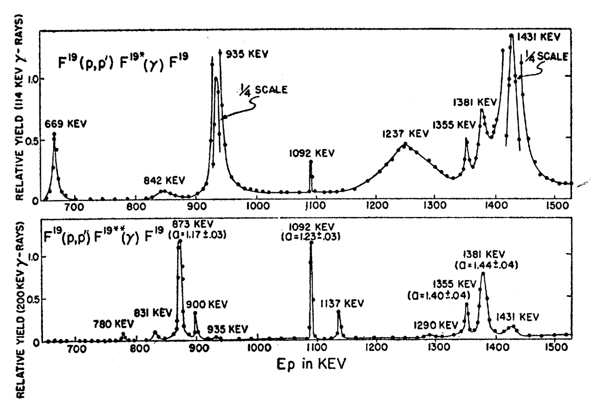

FIG. 2. Excitation of the 114- and 200-kev states of F^{19} by inelastic scattering of protons. The a appearing on the lower curve is (yield at 0°)/(yield at 90°). The cross section for the 114-kev radiation at 1431 kev is $\sim1.3\times10^{-25}$ cm², and for the 200-kev radiation is $\sim0.8\times10^{-25}$ cm² at 1381 kev.

The angular distribution of the 114-kev radiation is isotropic within the experimental error ($\frac{1}{2}$ percent to 4 percent) at all resonances investigated, and within 10 percent in the weak nonresonant yield between resonances at 750 and 1050 kev. The consistent isotropy suggests an assignment of $J=\frac{1}{2}$ for the 114-kev state. In Letter III by R. Sherr *et al.*[3] it is shown that the parity of this state is odd. The ratio of intensities of the 200-kev radiation at 0° and 90° with respect to the incident proton beam varies between 1.17 at 873 kev and 1.44 at 1381 kev. There is no evidence from 45° and 135° readings of an appreciable deviation from a $(1+A\cos^2\theta)$ distribution. The ratios obtained are consistent with an assignment of $J=5/2$, even parity for the 200-kev state, and $E2$ assignment to the gamma ray. The ratio at 873 kev suggests some attenuation (coefficient of $\cos^2\theta$ reduced to $\sim2/3$) of the anisotropy by nuclear precession in atomic electric or magnetic fields during the comparatively long lifetime of the state.

Finally, we have observed that the cascade de-excitation of the 200-kev state, through the 114-kev state, occurs with less than 1 percent of the intensity of the direct transition to the ground state. This would seem to eliminate the assignment of 3/2, 5/2, or 7/2 for the 114-kev state, since electric or magnetic dipole transitions to such states would be allowed from the upper $5/2^+$ state.

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