Low Excited States of F^{19}. II. Lifetime Measurements*

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The lifetimes of the 114-kev and 200-kev excited states[1] of F^{19} have been measured by the recoil technique.[2]

For the lower state the apparatus described in reference 2 was employed. A CaF_2 target ($\sim$3 kev at 1 Mev for protons) was evaporated on a thin nickel foil. The incident proton energy was chosen to give an energy of 1431 kev after passing through the nickel foil. The results are shown in Fig. 1. Curve A is obtained when an additional nickel foil is placed over the CaF_2 layer to prevent recoils from leaving the target. It will be noted that the gamma-ray counting rate drops off completely for a movement of the target, relative to the gamma-ray collimator, of 0.1 mm. The experimental points on curve B are obtained when the recoils are free to leave the target. Because of the thinness of the CaF_2 layer employed, at least 75 percent of the recoils leave the target. The theoretical curves B, C, D, were computed, taking account of the isotropic distribution[1] of the inelastically scattered protons in the center-of-mass system, and the slowing down of the recoils in leaving the CaF_2 layer. (The layer is about 1/7 of the maximum range of the F^{19} recoils.) We conclude that the mean lifetime is $(1.0\pm0.25)\times10^{-9}$ sec. This value is in good agreement with that derived from the absolute cross section for excitation of this level of F^{19} by inelastic scattering of alpha particles, if the latter process is assumed to be electric dipole Coulomb excitation.[3] The transition probability is of the order of 100 times smaller than predicted by the single-particle formula.[4]

In the case of the 200-kev state, the F^{19} recoils (at the 1092-kev resonance) were collimated in a forward cone of half-angle 30°. The recoils were stopped on a plate 8 cm in diameter which could be observed through a collimated channel by a NaI(Tl) scintillation counter. The target was a layer $\sim$8 kev thick of aluminum fluoride formed by exposing the back of a 0.2-mg/cm² Al foil to HF vapor. The distance between the target and recoil stopper was varied from 2 to 12 cm. The resultant curve, Fig. 2, indicates a mean lifetime of 0.8×10^{-7} sec with an uncertainty of about a factor 2. The large uncertainty indicated is due to the low yield and the background produced by high-energy radiation. The lifetime for this state is in satisfactory agreement with that predicted by the Coulomb excitation work[3] on the basis of an electric quadrupole assignment to the gamma ray. The observed transition probability is of the order of magnitude of that predicted by the single-particle model for an electric quadrupole transition.[4]

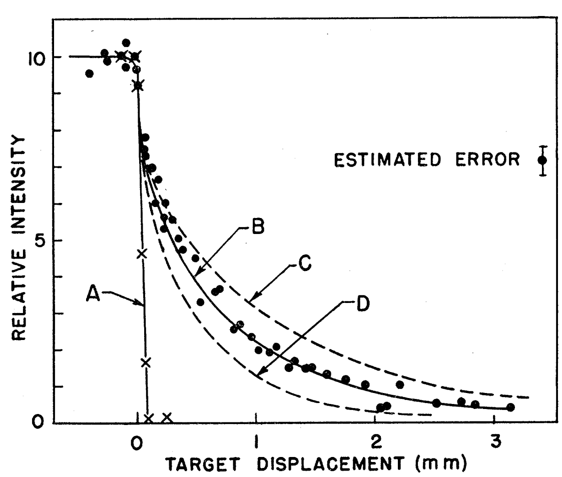

FIG. 1. Intensity of 114-kev gamma radiation as a function of the distance travelled by the fluorine recoils before radiating. Curve A is obtained by stopping all recoils at the target in an additional nickel foil. Curves B, C, and D are computed for mean lifetimes of 10^{-9} sec, 1.5×10^{-9} sec, and 0.66×10^{-9} sec, respectively.

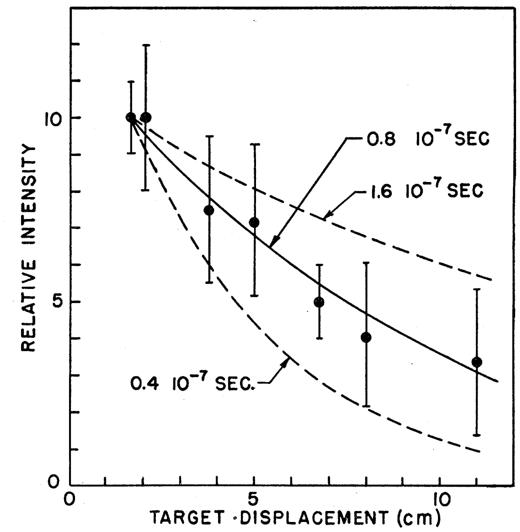

FIG. 2. Intensity of 200-kev gamma radiation as a function of the distance travelled by the fluorine recoils before radiating.

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Low Excited States of F^{19}. III. Coulomb Excitation by α Particles*

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We have investigated the yield of gamma rays resulting from the bombardment of F^{19} by α particles.[1] Up to an α-particle energy of 2.8 Mev we observed only the 1.28-Mev γ ray of the reaction $F^{19}(\alpha,p)Ne^{22*}$, and the 114-kev and 200-kev radiations from the first and second excited states of F^{19} produced by inelastic scattering of the α particles. The γ rays were detected with a $1\frac{1}{2}$ in.$\times1\frac{1}{2}$ in. sodium iodide scintillation spectrometer. The pulse spectrum was recorded with a 10-channel analyzer.

The yield of the 1.28-Mev γ ray shows a series of narrow resonances (first observable at $\sim$1.3 Mev) superimposed on a continuum. The yields of both resonances and continuum increase approximately exponentially with increasing energy. The 114- and 200-kev radiations also exhibit observable resonances above 2.0-Mev and 2.3-Mev, respectively. Below these energies the yields of the soft radiations decrease slowly as shown in Fig. 1. (The weak resonances at high energy have been omitted, their contribution to the total yield being negligible.) The absolute values of the cross sections have an estimated uncertainty of 20 percent arising chiefly from uncertainty in target thickness and stopping power. The 114-kev curve may have an additional uncertainty due to the difficulty of separating the 114-kev photopeak from the 200-kev spectrum; we may have underestimated the 114-kev yield by as much as 30 percent. On the other hand, the relative shape of each curve was reproducible to better than 10 percent for different targets and geometries.

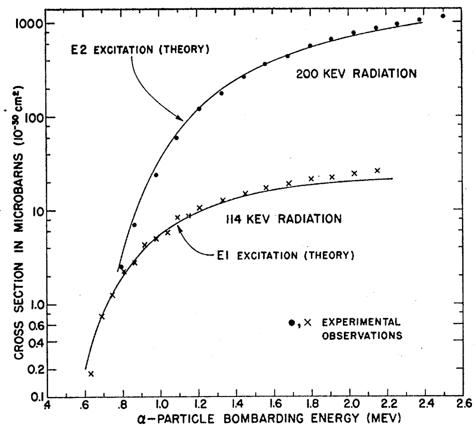

FIG. 1. Excitation of the first (114-kev) and second (200-kev) excited states of F^{19} by α particles.

The excitation curves in Fig. 1 have the general character to be expected of Coulomb excitation.[2] The curves were calculated from the theories for this process developed by Mullin and Guth,[3] Ter-Martyrosian,[4] and Alder and Winther.[5] These curves were chosen to fit the data at low energy. It is not clear whether the divergence at higher energy signifies inadequacy in the theory, or whether it is the result of an increasing contribution of compound nucleus effects. From the yield of the (α,p) reaction we infer that the cross section for formation of a compound nucleus is comparable with the excitation cross section of the 114-kev state in the neighborhood of 1.35 Mev.

The calculations for the 200-kev state assume $E2$ excitation of a $5/2^+$ state from the ground state of $F^{19}(J=1/2^+)$. To improve the calculation near the threshold, we have replaced the parameter ξ of reference 4 by

$$\xi=\frac{Z_1Z_2e}{\hbar}\left(\frac{1}{v_2}-\frac{1}{v_1}\right),$$

where v_1 and v_2 are the relative velocities of the bombarding and scattered particle. At high energy this quantity becomes identical with the expression of Alder and Winther. The absolute cross section for the excitation process is directly connected with the lifetime of the excited state. The calculated curve of Fig. 1 corresponds to a mean life $\tau=2.2\times10^{-7}$ sec, in fair agreement with the direct measurements of the lifetime by Thirion *et al.*,[6] who find $\tau\sim1\times10^{-7}$ sec. Our results support the assignment by Peterson, *et al.*[7] of $J=5/2^+$ to the second excited state of F^{19}.

The calculations for the 114-kev state assumes electric dipole excitation[3] of a $\frac{1}{2}^-$ state. The curve of Fig. 1 corresponds to a lifetime of 1.4×10^{-9} sec for electric dipole decay of this state. The agreement with the directly observed lifetime ($\tau=1.0\pm0.2\times10^{-9}$ sec)[6] is satisfactory. It should be noted, however, that in addition to the experimental uncertainties, there is an estimated uncertainty of a factor 2 in the theoretical Coulomb excitation cross sections (and consequently in the predicted lifetimes).

Measurements of the angular distributions of the 114- and 200-kev radiations were made for a thick target at a bombarding energy of 1.84 Mev. The 114-kev radiation was isotropic within 10 percent, while for the 200-kev radiation we obtained $W(0°)/W(90°)=1.22\pm0.02$. The theory for the reaction[5] predicts 1.26 for the 200-kev radiation; however, finite lifetime effects may reduce this value.[8] The isotropy of the 114-kev radiation supports the $J=\frac{1}{2}$ assignment of Peterson *et al.*[7]

The possibility that the 114-kev state is $\frac{1}{2}^+$ can be eliminated since magnetic dipole Coulomb excitation[9] would have a cross section smaller than that observed by a factor of $v^2/c^2\approx10^{-3}$ when the magnetic dipole moment is chosen to fit the observed lifetime. In addition, the possibility that the state is $\frac{3}{2}^\pm$ is eliminated by the absence of the cascade transition[7] and by the isotropy of the angular distribution in both the α-particle excitation and the proton excitation.[7] We conclude that the first excited state of F^{19} at 114 kev is $\frac{1}{2}^-$ (assuming the ground state to be $\frac{1}{2}^+$), while the second excited state at 200 kev is $5/2^+$.

The $5/2^+$ state is probably that predicted by the shell model for an odd proton in a $d_{5/2}$ state. The $\frac{1}{2}^-$ state is entirely unexpected since the shell model predicts even parities in this region from the filling of the $s_{1/2}$ and $d_{5/2}$ states. It may be related to the $\frac{1}{2}^-$ state at 3.10 Mev[10] in F^{17}, in fact the three lowest states of F^{17} are apparently $5/2^+$, $1/2^+$, and $1/2^-$. The most obvious interpretation of the $\frac{1}{2}^-$ state is in terms of a proton hole in the $p_{1/2}$ shell. The fact that it is almost accidental that this state is not the ground state is certainly in contradiction with the usual interpretations of the shell model.

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1 Investigations of the present reactions have also been carried out by N. P. Heydenburg and G. M. Temmer, and by G. A. Jones and D. H. Wilkinson (pre-publication reports).
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Low Excited States of F^{19}. IV. Angular Distributions*

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THE angular distributions[1] of inelastically scattered protons and the subsequent γ rays at resonances in Ne^{20} afford one means of establishing properties of the low excited states of F^{19}. For this purpose the 2^- resonances in Ne^{20} made by p-wave

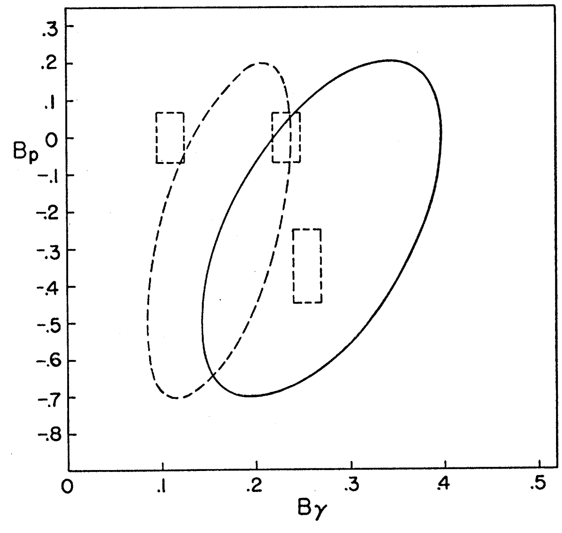

FIG. 1. The asymmetry coefficient B_p of inelastically scattered protons leading to the 200-kev state of F^{19} as related to the coefficient B_γ for the angular asymmetry of the resulting ray at 2^- resonances in Ne^{20} from $F^{19}+p$. The experimental points are plotted as dotted rectangles.