TABLE II. Measurements on the scattering event.

Measurement \ Particle	Incident K-particle	Scattered K-particle (K')	Recoil proton (p)
Dip angle	$+4.78°\pm0.33°$	$-3.85°\pm0.27°$	$-1.04°\pm0.07°$
Projected angle	0°	$38.9°\ \pm0.18°$	$59.1°\ \pm0.34°$
Range	···	$32.07\ \pm0.54$ mm	2.427 ± 0.034 mm
Range (corrected for dip)	···	$32.21\ \pm0.54$ mm	2.427 ± 0.034 mm
Space angles (computed)	0°	$38.80°\pm0.2°$	$59.12°\pm0.35°$

measurements. The actual mass determination was carried out by two independent methods.

a. *From the scattered K-particle range and conservation of transverse momentum.*—In this method two sets of the quantity $\beta_{K'}\gamma_{K'}$ are obtained for assumed K-particle mass values. (1) The quantity $R_{K'}/M_K$ is a function of the velocity of the K-particle only. Thus from the measured value of $R_{K'}$ we have obtained a set of values of $\beta_{K'}\gamma_{K'}$ as a function of the mass of the K-particle. (Curve A, Fig. 2.) (2) The momentum of the scattered K-particle ($P_{K'}=289.15\pm1.85$ Mev/c) is determined by transverse momentum balance from the proton momentum ($P_p=211.08\pm0.91$ Mev/c) which has been obtained from the proton range. Using this momentum for the K-particle, another set of values of $\beta_{K'}\gamma_{K'}(=P_{K'}/M_Kc)$ as a function of K-particle mass is calculated. (Curve B, Fig. 2.) The intersection of the bands formed by curves A and B, together with their resoective errors, gives the K-particle mass as $972\pm12\ m_e$.

In passing from ranges to momenta we have used the tables of Barkas and Young[6] which are based on Vigneron's calculations.[7] This method utilizes the range and space angles of both outcoming particles and is principally sensitive to the errors in the range measurements. As two range measurements are used, uncertainties in the range-energy relation and emulsion composition tend to cancel out.

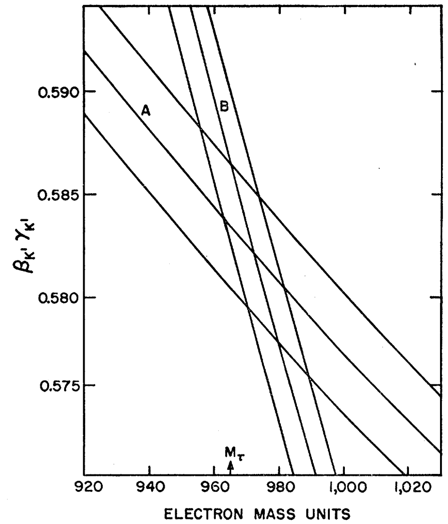

FIG. 2. A plot of $\beta_{K'}\gamma_{K'}$ as a function of K-particle mass. Curve A is based on the scattered K-particle range $R_{K'}=32.21$ mm. Curve B is based on the scattered K-particle momentum $P_{K'}=289.15$ Mev/c which is obtained from the recoil proton range. The intersection of curves A and B together with their error limits defines the K-particle mass as $972\pm12\ m_e$. The mass of the τ meson M_τ is shown for comparison.

b. *From the conservation of energy and momentum in the scattering event.*—In this method the K-particle mass was expressed analytically in terms of the recoil proton energy (from proton range) and the two space angles only. The resulting mass is $984\pm79\ m_e$. The much larger error inherent in this method is mainly due to the very strong dependence on the error in the angular measurement. The agreement between the two mass determinations together with the coplanarity check and the absence of a recoil or electron at the scattering center (Fig. 1) leads us to believe that our interpretation of the event as a K-hydrogen scattering is correct.

We wish to thank Professor E. Segrè for many helpful discussions.

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[*] This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] See for instance the summary by B. Rossi of the papers presented on this topic in the Proceedings of the Fifth Annual Rochester Conference on High-Energy Physics (University of Rochester Press, Rochester, to be published).

[2] Kerth, Stork, Birge, Haddock, and Whitehead, Bull. Am. Phys. Soc. **30**, No. 3, 41 (1955).

[3] A comparison between the momentum of the incoming particle as obtained from the magnetic momentum selection and from the kinematics of the scattering event affords an additional check on its identity as a K-particle. The incoming particle has a momentum of 411 ± 12 Mev/c as defined by its $H\rho$. After 5.16 cm of travel in the emulsion this momentum is reduced to 316 ± 24 Mev/c in agreement with $P_K=333.71\pm2.1$ Mev/c as obtained from the kinematics of the collision.

[4] R. M. Sternheimer, Phys. Rev. **91**, 256 (1953).

[5] J. R. Fleming and J. J. Lord, Phys. Rev. **92**, 511 (1953). Also J. R. Fleming, M.S. thesis, University of Washington, 1954 (unpublished).

[6] W. H. Barkas and B. M. Young, University of California Radiation Laboratory Report UCRL-2579 (revised) (unpublished).

[7] L. Vigneron, J. physiol. (Paris) **14**, 145 (1952).

Mass Measurement and Excited States of F^{21}†

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NEW masses of the isotopes of light nuclei have been of interest particularly to those working with systematic studies. We wish to report that we have experimentally determined that F^{21} is heavy-particle-stable and has a mass defect of 6.125 ± 0.030 Mev or an atomic mass of 21.005703 ± 0.000025 amu. Alpha particles from the reaction $O^{16}(t,\alpha)N^{15}$ were used for the energy calibration. Excited states of F^{21} are indicated at 0.33, 1.11, 1.84, and 2.16 Mev. Masses used in the calculations were taken from the review article of Ajzenberg and Lauritsen.[1]

This information was obtained from an experiment designed to measure the energy levels of O^{18} by observing alpha particle groups from the reaction $F^{19}(t,\alpha)O^{18}$. Narrow proton groups, presumably from the reaction $F^{19}(t,p)F^{21}$, were observed that did not correspond to any level possible from any of the common contaminants (O, C, N, etc.) or to any level observed in any background run. The groups were obtained by bombarding thin evaporated targets of CaF_2 or PbF_2 with a 1.82-Mev triton beam from one of our 2.5-Mev Van de Graaff accelerators and analyzing the reaction products at 90° with a Cal-Tech type 16-inch double-focusing magnetic spectrometer.

If one plots the masses and half-lives of nuclei differing from F^{21} by one or more alpha particles against the mass number as the abscissa, one gets rough curves with which one might empirically predict the characteristics of F^{21} and other such nuclei. It is of interest that the measured mass of F^{21} is consistent with this curve. The predicted value of the half-life of F^{21} from such considerations is 100 to 200 sec.

A detailed report of this work, verification, and more accurate values of the excited states, and information on O^{18} will be published in the future.

† Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. 27, 157 (1955).

Elastic Scattering of 48.2-Mev Alpha Particles*

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In view of the recent interest in the elastic scattering of alpha particles by heavy nuclei,[1–5] it seems desirable to report the results of investigations that have been under way here for some time.

The angular distributions of 48.2-Mev alpha particles (from the 60-inch cyclotron at Crocker Laboratory in Berkeley) elastically scattered by Au and Ag nuclei have been investigated in considerable detail for angles between 7° and 135° in the laboratory system (Figs. 1 and 2).

The 36-inch scattering chamber[6] was used, and the scattered particles detected by a proportional counter telescope. The long-time reproducibility of data was excellent, so there was no difficulty in normalizing from run to run. The angular resolution is estimated to be ±0.75 degree. No background difficulties were encountered below 90 degrees. At the wider angles the low yields made it difficult to accumulate statistics, but we feel sure that there is no appreciable rise in the cross sections.

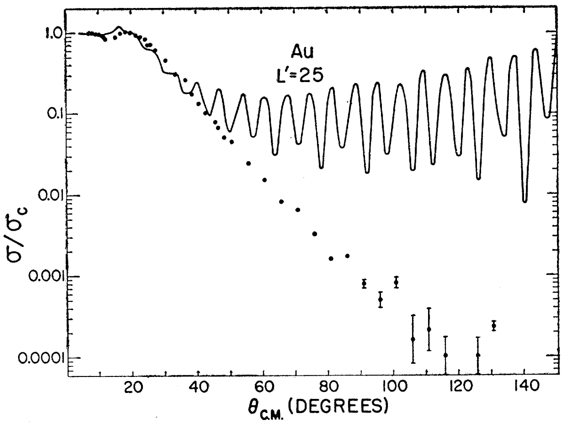

Fig. 1. Angular distribution (relative to Coulomb scattering) of elastically scattered alpha particles from Au. The curve represents the distribution predicted by Blair's sharp cut-off model.

The most striking features in these distributions are the departure from Coulomb scattering by factors of 10^3 to 10^4 at angles beyond 25°, and the structure exhibited in the silver curve between 20° and 60°. According to Blair's model[2] these may be attributed to the effect of collisions by the incident alpha particle with the nucleus. At these energies the incident particles interact strongly with the nucleus in spite of the Coulomb barrier, and it is reasonable to expect that a satisfactory theoretical explanation of these detailed distributions may shed light on the form of the interaction potential. As the figures show, the sharp cut-off model reproduces the general features for forward angles. Attempts are being made to find a satisfactory fit to the data by modifying Blair's theory to include a gradual cutoff of the interaction radius, following the suggestions of Wall *et al.*[4] In addition, an approach is being made using an optical model with a potential

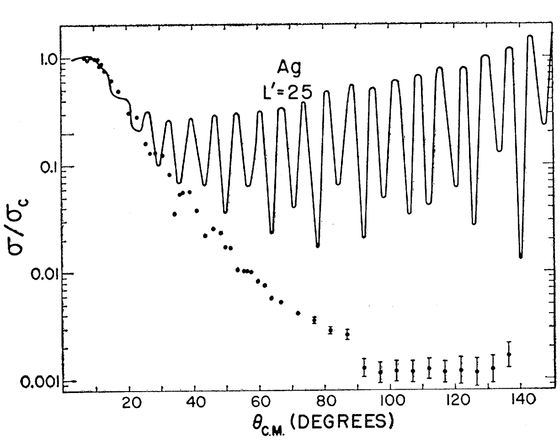

Fig. 2. Angular distribution of (relative to Coulomb scattering) elastically scattered alpha particles from Ag. The curve represents the distribution predicted by Blair's sharp cut-off model.