Another NaI sample was made in vacuum in a 0.5-inch quartz tube with the result that a mass ($\sim$8.0 g) of extremely luminescent small crystals was produced. The crystals are about one or two millimeters on a side. When the quartz tube containing the crystals was placed close to a photo-multiplier, very large pulses were observed from radium gamma-rays. These pulses were larger than those observed with a clear piece of naphthalene (5.8 g) of comparable size. Of course, this NaI sample is completely unaffected by atmospheric conditions and is quite convenient for normal handling. A comparison of results is shown in Figs. 1 and 2. Figure 1 shows oscilloscope pictures of 1/30-second random exposures taken under identical circumstances with the NaI sample and with naphthalene. The source was 0.1-millicurie radium at 16 cm, filtered by 3/32-inch brass. Figure 2 shows a differential bias curve taken under identical conditions for the two materials. From the rise times of the pulses in NaI there is some evidence that the light flashes are emitted in about one microsecond or less. All work reported has been carried on at room temperature.

Further work in progress is designed to produce large single crystals of this and other alkali halides with thallium impurities. A neutron counter using a lithium halide seems to be a reasonable possibility.

In tests made by placing crystals of NaI, KI, and naphthalene on photographic plates (Eastman 103-O) much greater light output was observed from NaI and KI than from naphthalene samples of comparable size. Apparently, naphthalene is not an efficient phosphor.

A sample of NaI in a quartz tube gave measurable blackening of a photographic plate when the combination was exposed for thirty minutes to the gamma-rays of 1.8 millicuries of radium at a meter distance.

A more complete description of these results is being prepared.

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[1] J. W. Coltman and F. H. Marshall, Phys. Rev. 72, 528 (1947); H. Kallman, Natur und Technik (July 1947); M. Deutsch, Nucleonics 2, 58 (1948); G. B. Collins and Rosalie C. Hoyt, Phys. Rev. 73, 1259 (1948).
[2] P. R. Belland R. C. Davis, Bull. Am. Phys. Soc. 23, No. 3, 52 (1948). X12.
[3] R. Hilsch, Zeits. f. Physik 44, 860 (1927); W. von Meyeren, Zeits. f. Physik 61, 329 (1930).
[4] E. H. Hutten and P. Pringsheim, J. Chem. Phys. 16, 241 (1948).

An Example of the Beta-Decay of the Light Meson*

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THE photographs of Fig. 1 show two views of a large Wilson cloud chamber containing a horizontal lead plate at the top one cm thick, eight aluminum foils each 0.020 cm thick, and two lead plates at the bottom each 0.9 cm thick. The photograph at the left is taken at 21°
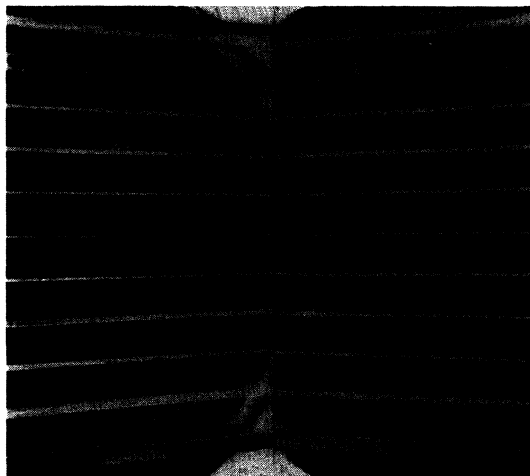

FIG. 1. A meson stops in a foil at the top of the chamber and its decay electron, after penetrating 7 foils, stops in the upper lead plate at the bottom of the chamber. The bright vertical line seen here is a thin wire used as a reference marker.

to that side of normal, while the right view is taken from a symmetrical position on the other side.

The nearly horizontal dense track which is seen between the top lead plate and the first aluminum foil, and which appears to stop in the foil, is probably that of a light meson. The density of ionization is between five and ten times the minimum for a singly charged particle. An electron with this ionization would scatter markedly and would have a range of less than two cm in the gas. Hence the observed particle cannot be an electron. A proton with this ionization has a range of more than 0.25 cm of aluminum, and so would be expected to pass through the foil. Reconstruction of the track in space shows that the point where it appears to stop in the foil is well within the region of good illumination. If the scattering of the particle inside the foil is neglected, it has a range of less than 0.10 cm of aluminum. A meson of mass $200m_e$ with this range ionizes 8 times the minimum. Therefore, it seems reasonable to assume that the stopped particle is a light meson.

From the point where the meson stops a particle ionizing less than 2 times minimum is seen to go downward. Its track appears to stop in the upper lead plate at the bottom of the chamber. The point at which the particle strikes the plate is well within the illuminated region. A proton which has a range of less than 0.9 cm of lead ionizes more than 4 times minimum; therefore the observed secondary particle cannot be a proton. In all known cases of the decay of a heavy meson to a light meson (the π-μ-decay) the light meson has an energy of 4 Mev, ionizes 5 times minimum, and has a range of 0.07 cm of aluminum.[1] The event observed here cannot be a π-μ-decay. It seems reasonable, however, to interpret this event as the beta-decay of a light meson. It is evident that the secondary particle ionizes near the minimum and that it is appreciably deflected by scattering in the aluminum foils. Taking this particle to be an electron, it is possible to estimate its

energy from the size of the deflections. The energy loss of the electron by ionization is 0.1 Mev per foil, the loss resulting from radiation may be neglected. The deflection of the particle caused by scattering in the gas is less than $\frac{1}{10}$ that caused by scattering in the foils.

The mean square average angle of deflection due to multiple scattering in a material of thickness t is[2-5]

$$(\Theta^2)_{Av} = (E_s^2 t / p^2 \beta^2),$$

where Θ is the total deflection of the incident particle due to multiple small angle scattering, t is the thickness of the scatterer in radiation lengths, E_s is 21 Mev/c, p is the momentum of the particle in Mev/c, and β is v/c, the relative speed of the particle. The deflection angle in space has been computed for the scattering at each foil from measurements on the photographic negatives. The results are tabulated below:

Foil No.	Angle
2	0.015 radian
3	0.062
4	0.059
5	0.018
6	0.047
7	0.121
8	0.033

The value of the kinetic energy corresponding to the average of the squares of these angles is 15 Mev, and the standard deviation in this result is ±3 Mev.[6] It is difficult to evaluate a possible systematic error caused by the distortions of the track by movements of the gas in the chamber. Measurements have been made on the tracks of penetrating particles which have been observed near the location of the electron track shown here. The observed angles of deflection for a typical track correspond to an energy of 110 Mev for an electron. This indicates that the distortional error in the energy determination is probably within the statistical error stated above.

This picture was made near sea level in Cambridge. The dimensions of the chamber are 18 inches in diameter by 8 inches deep, and the chamber was counter-controlled, though the event discussed could not have been selected by the counters.

1 C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Nature 160, 486 (1947).
2 E. J. Williams, Proc. Roy. Soc. A169, 531 (1939).
3 E. J. Williams, Phys. Rev. 58, 292 (1940).
4 B. Rossi and K. Greisen, Rev. Mod. Phys. 13, 240 (1941).
5 H. A. Bethe, Phys. Rev. 70, 821 (1946).
6 Two previous measurements of the energy of decay electrons, 24 and 25 Mev, have been reported by C. D. Anderson. C. D. Anderson et al., Rev. Mod. Phys. 20, 334 (1948).

On the High Energy Part of the K⁴⁰ β-Spectrum

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IN recent years some work has been performed on the subject of both the β- and γ-radiation from K⁴⁰ disintegration. Several workers have attributed the γ-rays to the excited nucleus of A⁴⁰ which would form from K⁴⁰ by K-capture. The chief argument for this attribution is that the γ-quantum would have an energy larger than the maximum energy liberated in β-disintegrations, i.e., the upper limit E_0 of the β-spectrum (and cannot be emitted "in cascade" with the β-disintegrations, as these largely outnumber the γ-emissions).

The data on the γ-quantum appear to converge on the value 1.5×10^6 e.v. Concerning E_0, O. Hirzel and H. Wäffler[1] find a value $(1.41 \pm 0.02)10^6$ ev, and Dželepov et al.[2] find $(1.35 \pm 0.05) \times 10^6$ ev. The first datum is obtained by comparison of the absorption curve with that of the Na²⁴ electrons; the second is obtained by a special magnetic spectrograph using a coincidence method of counting.

However, the writers[3] investigating the high energy part of the β-spectrum with the aid of a cloud chamber have found a substantially larger value, that is, $(1.7 \pm 0.1) \times 10^6$ ev, for the upper limit. As the substance employed (KCl) was carefully tested for radioactive impurities with negative result, this cause of error must be discarded and is, moreover, quite unlikely because of the regular shape of the spectrum and the agreement of the total activity with known data.[4]

Figure 1 shows the results in the form of a Fermi plot

TABLE I.

Energy intervals	Effect	Zero effect	Energy intervals	Effect	Zero effect
0.84			1.27		
0.95	50	7	1.37	13	2
1.05	48	0	1.48	5	0
1.16	26	2	1.58	2	0
1.27	27	7	1.68	4	2
			1.79	1	2

(energy includes rest mass). The dimensions of the rectangles give (double) average errors. The dashed line is what should be expected for a value $E_0 = 1.4 \times 10^6$ ev, in the hypothesis that the spectrum is similar to that of an "allowed" transition, at least in the high energy region. This is what is suggested by our results, if one keeps in mind that a deviation from the straight line in qualitative agreement with that observed is due to the well-known[5] distortion introduced by the thickness of the source (33 mg/cm²) and of the supporter. The same distortion prevents saying anything definite on the lower energy part of the spectrum.

The explanation of the above-mentioned lower values of E_0 is very likely to be found in the fact that the percentage of electrons beyond 1.4×10^6 ev[6] is very small (order of 1 percent) so that it easily gets lost, especially in absorption methods, if the zero effect of the revealing device is not very low. The cloud chamber has this advantage, as is shown by the values[7] in Table I taken from our work:

(The zero effect is given by the amount of tracks which would be obtained without KCl, the number of expansions being the same as for the effect.)
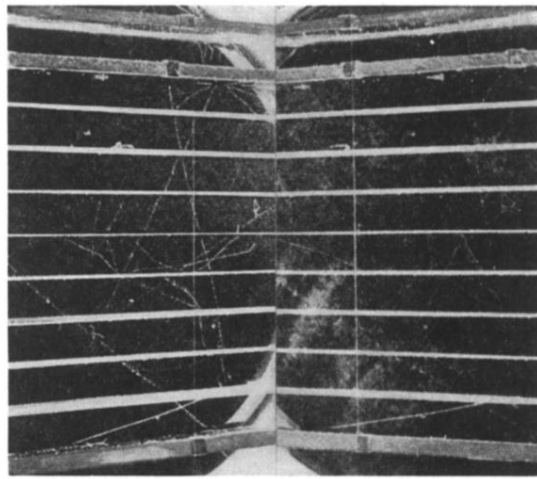
FIG. 1. A meson stops in a foil at the top of the chamber and its decay electron, after penetrating 7 foils, stops in the upper lead plate at the bottom of the chamber. The bright vertical line seen here is a thin wire used as a reference marker.