TABLE III. The half-width of $J=3$, $K=3$ line in the inversion spectrum of ammonia.

Pressure 10^{-2} mm Hg	A obs. Mc/sec.	A calc. Mc/sec.
5	1.27	1.15
2.5	0.57	0.58
1.5	0.34	0.34

the asymptote of relative motion of the colliding one, $P(J, K, M)$ the probability that a molecule is in J, K, M state, n the number of molecules in unit volume, and $p_i(t)$, $p_f(t)$ the perturbation energies of initial and final states of the absorption process as a function of time t; α is the function of J, K, M, V, and ρ where J, K, and M represent the rotational state of colliding molecules.

Using (1) we can calculate intermolecular potential in the usual manner, resulting in Table II. In this table $\pm$ means that the sign must be taken corresponding to that of $\epsilon_{J,K}-\epsilon_{J',K'}$, and e_m is the mth eigenvalue of a matrix whose element is[7]

$$
\begin{aligned}
(M_i, M_i'|V|M_i, M_i') = {} & \frac{d^2}{R^3}\frac{KK'}{J(J+1)J'(J'+1)} \\
& \times\{-2M_iM_i'\delta(M_i, M_j)\delta(M_i', M_j') \\
& \pm\tfrac{1}{2}[(J-M_i+1)(J+M_i)(J'-M_i')(J'+M_i'+1)]^{\frac{1}{2}} \\
& \times\delta(M_i, M_j+1)\delta(M_i', M_j'-1) \\
& \pm\tfrac{1}{2}[(J+M_i+1)(J-M_i)(J'+M_i')(J'-M_i'+1)]^{\frac{1}{2}} \\
& \times\delta(M_i, M_j-1)\delta(M_i', M_j'+1)\},
\end{aligned}
$$

R being intermolecular distance. Since an absorption line in the inversion spectrum corresponds to $\psi_{+,J,K}\rightarrow\psi_{-,J,K}$ transition, we can calculate α for it by means of the above table. Making some approximation and again resorting to (2), we can obtain values as in Table III, showing good agreement with the experiment. The half-width of other lines can be easily calculated.

In all these calculations Boltzmann distribution was assumed over rotational states from $J=0$ to $J=10$. On statistical weight of each state one may refer to Herzberg's book.[2]

[1] These results were published in The Research in Chemical Physics (in Japanese) **9**, 1 (1947); **11**, 11 (1948). Details of them will be published in the near future in J. Phys. Soc. Japan.
[2] G. Herzberg, *Infra-Red and Raman Spectra of Polyatomic Molecules* (D. Van Nostrand Company, Inc., New York, 1945), pp. 26, 221.
[3] J. H. Van Vleck, *The Theory of Electric and Magnetic Susceptibilities* (Oxford University Press, New York, 1932), p. 186.
[4] H. Schoeffers, Physik. Zeits. **41**, 89, 98 (1940).
[5] O. Stern, Zeits. f. Physik **41**, 563 (1900).
[6] W. Good, Phys. Rev. **70**, 213 (1946).
[7] H. Margenau and D. T. Warren, Phys. Rev. **51**, 748 (1935).

Erratum: Theory of High Frequency Discharges. IV

[Phys. Rev. **73**, 326 (1948)]

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IN this paper the original authorship of the similarity principle was given erroneously. I offer my apologies to Dr. R. Holm, who introduced and discussed it in Physik. Zeits. **15**, 289 (1914).

Primary and Secondary Meson Event in Photographic Emulsions

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July 29, 1948

THROUGH the courtesy of the British Overseas Airways Corporation in carrying plates for us on consecutive transatlantic flights, we have had Ilford nuclear research emulsions exposed to cosmic radiation over a period of time. Examination of these emulsions has yielded many interesting cosmic-ray events, some involving mesons.

In a total of 3.26 cc of emulsion of various types of loading so far examined and yielding just over 1000 cosmic-ray stars, we have noted one double meson event of the type first described by Lattes, Muirhead, Occhialini, and Powell[1] ($\pi-\mu$-process) in which the secondary meson lies wholly in the emulsion. This event was found in a C_2 emulsion, boron-loaded, 60 microns thick after processing. The primary meson enters through the surface and passes downward through the emulsion, ending 18 microns above the glass. The secondary meson also travels upward through the emulsion and is scattered downwards about 50 microns from the end of its range.

The ranges of the primary and secondary meson as measured in horizontal projection are 176 and 627 microns, respectively. A profile showing the vertical path of the mesons through the emulsion is given in Fig. 1. The vertical coordinates have been corrected for the shrinkage of the emulsion in processing by multiplying by a factor of 2.5. After correction for vertical travel, the primary and secondary ranges become 213 and 655 microns, respectively. The accuracy of the range measurement is believed to be ± 0.5 percent. The corrected range of the secondary is somewhat longer than the average range, 614 ± 8 microns given by Lattes, Occhialini, and Powell.[2] A mosaic of photomicrographs of the tracks is shown in Fig. 2.

Identification of the tracks as due to mesons was made by their scattering, which is greater than that of protons of comparable range, and by the grain counts as compared with that of protons. The total number of grains in the primary or π-meson track is 141, and the grain counts for the last 50, 100, and 150 microns are 46, 77, and 106. For the secondary or μ-meson the corresponding figures are 263 grains and 43, 80, and 112 grains (average grain size in the emulsion $=0.4$ micron). The distances are corrected for slant in the emulsion as deduced from the profile given above, and are thus the distances along the path of the mesons when the event took place.

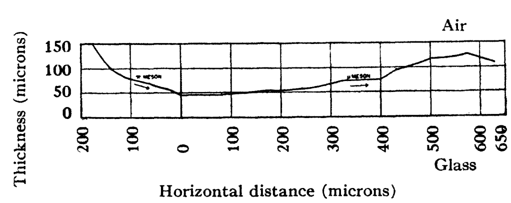

FIG. 1. Vertical profile along the tracks of the primary and secondary mesons.

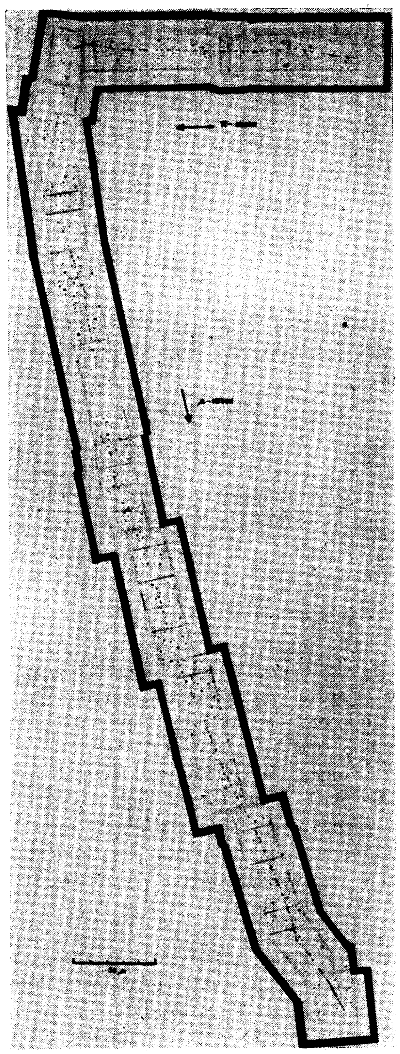

FIG. 2. Mosaic of photomicrographs of tracks of primary and secondary mesons. Leitz 114X, apochromatic objective. Observation by Joan Young.

The differences in the grain counts of the π- and μ-mesons are not great enough to give any positive indication of mass difference. In view of the shortness of the primary track and the statistical uncertainty involved because of the small number of grains, all we can say is that the possibility of a difference in mass cannot be excluded.

The plates were exposed over a six-week period, during which time they were flown 202, 187, 137, and 15 hours above 10,000, 15,000, 18,000, and 20,000 ft. respectively. They were developed for 15 minutes at 68°F in Kodak D-19 diluted with two parts of water to one of developer, with continuous agitation by mechanical means during development and fixing.

The photomicrographs were made by projecting the microscope image through a prism and mirror system onto a flat surface, each track being recorded on a strip of film in a film holder with two slides which could be moved to expose short intervals of the track, brought successively into focus on the top surface of one of the slides. The mosaic was constructed from a series of such strips.

We wish to acknowledge most gratefully the cooperation given by the British Overseas Airways Corporation in carrying the plates and in making available the time-altitude data, the painstaking work of the three observers who did most of the preliminary searching, Misses Joan Young, Shirley Young, and Berverley Mear, and the assistance of Mr. F. Morton in developing the projection scheme.

[1] Lattes, Muirhead, Occhialini, and Powell, Nature **159**, 694 (1947).
[2] Lattes, Occhialini, and Powell, Nature **160**, 453 (1947).

A Tentative Explanation of the Observed Mass of Mesons and Other Particles

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July 19, 1948

THE continued experimental discovery of elementary particles whose rest masses appear to have a wide range of values intermediate between those of the electron and the proton evidently calls for some simplifying principle.

The following suggestion, although entirely unorthodox and a reversion to pre-relativistic physics, may possibly be of some interest in this connection.

The following phenomena may be accepted as experimental facts:

(a) the mass of an elementary particle varies with velocity, and the relation $m=m_0[1-(v^2/c^2)]^{-\frac{1}{2}}$ has been verified as describing this variation, at least up to about $v=0.8c$.
(b) energy is directly convertible into mass according to the relation $W=mc^2$.

In relativistic physics, the velocity v in the mass-variation law is measured relative to the observer or, in actual practical experiments, relative to the laboratory. Suppose now that a Newtonian description of all physical phenomena is found to be possible (for example, Ritz's[1] work in electrodynamics and Dewar's tentative hypothesis of non-relativistic radiation[2]). Then velocities relative to the observer are not involved, and v in the mass-variation law (now regarded as empirical) must be measured relative to some specific inertial system.

Let us define this inertial system as the parent body from which an elementary particle is originally ejected. Then if the velocity of the parent body relative to the laboratory is small compared with that of light, there will be no appreciable difference in the mass of the ejected particle as deduced by the two theories. But if the velocity of the parent body is comparable with that of light at the moment a particle is ejected, there will be a difference.

Suppose, for example, that a nucleon (neutron or proton) of high energy, say of the order 10^{10} ev, collides with an atomic nucleus and that as a result it emits one or more electrons (+ or −) in random directions with very high

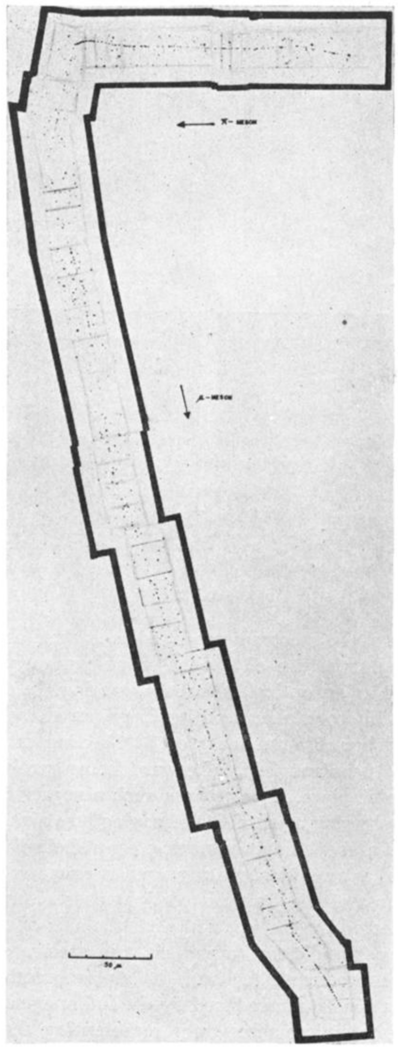

FIG. 2. Mosaic of photomicrographs of tracks of primary and secondary mesons. Leitz 114X, apochromatic objective. Observation by Joan Young.