(2) The elastic scattering of mesons and protons can be calculated from the known emulsion constitution, using Williams's formula[2] for the mean square angle of multiple scattering, and is shown plotted against range in Fig. 2. Bearing in mind the fact that the single scattering will introduce large fluctuations, the experimental points appear to be consistent with a meson mass between 100 $m_e$ and 300 $m_e$, $m_e$ being the electron mass. Only the horizontal projection of the scattering along the track can actually be measured; on the average, multiplying this by a factor $\sqrt{2}$ will give the true value. The scattering of fast electrons cannot be found from any simple formula, but it is certainly much greater than the observed values.

(3) A value of the meson mass can also be arrived at from the energy required in the nuclear disintegration. In this process, the emitted particles must have sufficient energy to surmount the potential barrier, so that the disintegrating nucleus in this case cannot be that of silver or bromine, and must, therefore, be either carbon, oxygen or nitrogen (in the gelatin).

An approximate calculation of the momentum of the recoil nucleus indicates that at least one neutron must be postulated to conserve momentum; the kinetic energy of this neutron must be around 4 MeV. If we assume that a negative meson is captured by a nucleus nearly at the end of its range and is annihilated, so that the rest energy of the meson becomes nuclear excitation energy, we could have disintegration schemes such as

$$Y^- + O_8^{16} \rightarrow N_7^{16*} \rightarrow H_1^3 + 2H_1^1 + n_0^1 + Be_4^{10*}$$
$$(\text{or } 2n_0^1 + Be_4^9)$$
$$Y^- + N_7^{14} \rightarrow C_6^{14*} \rightarrow H_1^3 + 2H_1^1 + n_0^1 + Li_3^{8*}$$
$$Y^- + C_6^{12} \rightarrow B_5^{12*} \rightarrow H_1^3 + 2H_1^1 + n_0^1 + He_2^{6*}$$

As the recoil nucleus would be expected to have a fairly high excitation energy (5–10 MeV.) above the ground-state, it must be relatively stable against further disintegration into charged particles. With this limitation, there are still a large number of possible reactions (considering all isotopes of carbon, oxygen and nitrogen), but it appears that in general the mass excess of the recoil nucleus $\sim$ 15 MeV., whereas that of the initial one $\sim$ 5 MeV. or less. The negative $Q$ value of the reaction, allowing for excitation energy, is then found to be $\sim$ 60 MeV., and the total kinetic energy of the ejected particles $\sim$ 20 MeV. The total excitation energy of the original nucleus would then be $\sim$ 80 MeV., probably with an error of $\pm$ 20 MeV. (to allow for the various numbers of neutrons emitted, etc.).

On the above hypothesis, the meson should, therefore, have a rest energy of 60–100 MeV., that is, a mass of between 120 $m_e$ and 200 $m_e$.

Near the end of the meson track, a small number of grains are observed slightly off the main track. If these are due to fast secondary electrons, their ranges appear to be considerably greater than would be expected from the energy of the primary.

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[1] Powell, Occhialini, Livesey and Chilton, *J. Sci. Instr.*, **23**, 102 (1946).
[2] Williams, *Proc. Roy. Soc.*, A, **169**, 531 (1938).

## Angular Distribution of Protons Ejected in the Disintegration of Nitrogen by α-Particles

USING a powerful polonium source and an especially well-defined geometry, we have recently obtained 850 expansion-chamber photographs showing 90 proton tracks produced on the disintegration of nitrogen by α-particle bombardment. Our arrangement, therefore, gave on the average one disintegration for every ten photographs, thus greatly reducing both the expense of the photographic materials used and the labour of the examination of the photographs.

The number of disintegrations decreases rapidly as the energy of the α-particles is reduced, but the photographs show that disintegrations occur quite definitely for energies less than 1·7 MeV., and probably at energies less than 1 MeV.

The angular distribution shows a marked change with energy. For α-particles of energy less than 3 MeV., the distribution is almost uniform in numbers between 30° and 120°, while at 3·5 MeV. there is a marked preponderance at about 90° with proportionately smaller numbers of protons ejected symmetrically at angles greater and less than this value. It is interesting to recall that the well-known disintegrations recorded by Blackett and Lees[1] for 3–4 MeV. α-particles in nitrogen both show the ejection of the proton in the neighbourhood of 90°.

A full report of the experiment, together with selected photographs, will be published elsewhere.

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[1] Blackett, P. M. S., and Lees, D. S., *Proc. Roy. Soc.*, A, **136**, 325 (1932).

## A Revised Estimate of the Age of the Earth

SINCE the publication of my preliminary account of a new method of estimating the age of the earth[1], based on Nier's isotopic analyses of samples of lead from galena and other lead minerals of known geological age, I have revised the calculations, using Glaisher's Exponential Tables[2], and greatly increased the number of solutions. 1,419 solutions for $t_0$ (the time since the isotopic constitution of the earth's primeval lead began to be modified by additions of lead isotopes generated from uranium I, actinium U and thorium) and for $x$ and $y$ (the respective isotopic abundances of $Pb^{206}$ and $Pb^{207}$ in primeval lead) have been obtained from the following combinations of data (Table 1). The numbers are those of the lead samples as listed in the original article[1], and the italicized figures in brackets are the approximate ages in millions of years ($t_m$) of the parental lead minerals.

TABLE 1

| Number of lead sample | Combined with Nos. | and also with Nos. |
|---|---|---|
| 25 (Great Bear Lake, *1330*) | 1, 2, 3, 5, 6 (*25*) | 19 and 21 |
| 23 (Broken Hill, N.S.W., *1200*) | 7 (*60*) | 19 and 21 |
| 22 (Broken Hill, N.S.W., *1200*) | 9 and 11 | 19 and 21 |
| 21 (Quebec, *800*) | (Joplin, *100*) | 19 |
| 19 (Ivigtut, *600*) | 13–18 (*220*) | — |

together with combinations of each of the above five sets with the others.

The data for six samples have not been used: either because the ages of the parent minerals are unknown or because the constitutions of the leads are so abnormal as to give highly discordant and mutually divergent results.