as the numbers of secondaries per cm² per sec. per unit solid angle in the vertical direction in air and lead respectively. The former value may be compared with 0.0073 as found by Street and Johnson[3] from Geiger-Mueller coincidence counts in air. This discrepancy of a little more than a factor of two may be partly ascribed to an uncertainty in the value of $I$ and partly to a tendency for a primary to be accompanied by more than one secondary at a time, these producing their share of ionization although the group is recorded as only a single coincidence. This grouping tendency has, in fact, been observed by Locher.[2] Furthermore, the fact that Rossi[4] found only a four percent difference in the number of coincidences with a 10 cm block of lead between and above a pair of counters indicates that a primary is almost always accompanied by at least one secondary, since there is but a small chance of a secondary traversing the intervening lead if $\mu_{12}$ as calculated above is correct. We must conclude, therefore, that the number of primaries is less than the number of secondaries per cm² per sec. by perhaps as much as a factor of $\frac{1}{2}$.

The absorption coefficient 0.495 of air secondaries in lead corresponds to the range which an electron of $10^7$ to $10^8$ volts energy would have on the basis of Oppenheimer's formula and this agrees in order of magnitude with the curvature of the tracks studied by Anderson.

These results also provide an explanation for the failure of Mott-Smith and Rossi to deflect the rays magnetically, since absorption in the iron magnet would have prevented the same secondary from passing through both counters. They also explain the fact that the absorption coefficient in thick shields as studied by Geiger-Mueller counters agrees roughly with that of the primary radiation.

THOMAS H. JOHNSON

The Bartol Research Foundation of the Franklin Institute,
Swarthmore, Pa.,
April 8, 1932.

[3] Bulletin of the Washington Meeting of the American Physical Soc. April, 1932.

[4] B. Rossi, Zeits. f. Physik **68,** 64 (1931).

## Note on Electron Scattering in Argon

The last paragraphs in the manuscript of our paper on "Inelastic and Elastic Electron Scattering in Argon" (Phys. Rev. **39,** 585 (1932)) did not appear in the published article; presumably they were accidentally omitted between the galley and page proofs. The missing paragraphs are as follows:

"B. In all cases hitherto investigated, the number of ejected electrons sent out at very large angles (*i.e.*, 160° or 170°) is relatively very small.

C. The total number of slow ejected electrons (say, 1 volt) is greater than the total number of faster ejected electrons (say, 8 volts) in accord with the fact that the total number of electrons which have lost a small amount of energy (say, 1 volt) above that necessary for ionization, exceeds the total number of electrons which have lost a larger amount of energy (say, 8 volts) above that necessary for ionization.

D. In general, the main peak in each curve is more accentuated the less the energy of the ejected electron and the less the energy of collision between the colliding electron and the atom.

It should be stated that the curves in any horizontal row in Fig. 13 are more strictly comparable with each other than the curves in any vertical column. The reason for this is that the focusing factor is the same for all curves in any horizontal row but changes from one row to the next. When we compare the curves for the 1-volt ejected electrons we observe that the position of the main peak moves to *smaller* angles as the energy of collision is *increased*. The same effect may also be observed for the 3-volt ejected electron. A subsidiary peak may be found in most of the curves. This tends to move to smaller angles as the energy of collision is increased. If now we consider the curves in any vertical row, we notice that in practically every case the peaks are the more accentuated the less the energy of the ejected electron. For any given collision energy, the main peak tends to move to slightly larger angles as the energy of the ejected electron under consideration is increased.

These results are to be regarded as a preliminary survey of a very promising field. On account of the number of possible variables, a complete experimental exploration will take considerable time. Just as the wave aspect of electrons has been successful in giving a general description of the characteristics of elastic scattering, it may perhaps also be invoked to account for the diffraction like patterns found for the ejected electrons."

Attention is also called to the fact that Eq. (2) in our paper is incorrect. According to Mott's article, it should be

$$\alpha'(\theta) = \frac{e^4}{m^2c^4} F^2 \frac{1+\cos^2\theta}{2}.$$

Professor Jauncey informs us, however, that the correct form of the formula is

$$\alpha'(\theta) = \left(F^2 + \frac{Z^2 - F^2}{Z}\right) \frac{e^4}{m^2c^4} \frac{1+\cos^2\theta}{2}.$$

A. L. HUGHES
J. H. MCMILLEN

Washington University,
St. Louis, Missouri,
April 8, 1932.

### Additional Experimental Verification of Fowler's Photoelectric Theory

Some time ago the writer published[1] the results of experiments on the determination of the photoelectric work functions for a series of metals, the surfaces of which were prepared in a high vacuum, but not subjected to a thorough outgassing treatment. Changes were observed in the magnitude of the photoelectric currents as a function of the time after filing the surfaces. The usual extrapolation method indicated, however, that the threshold, or work function, was *independent of the time*.

Some recent theoretical work by Fowler,[2] based upon a Fermi-Dirac distribution of free electrons, has received excellent experimental confirmation from the results of several observers working with outgassed metals. It may be of interest to know that the theory is apparently applicable to metals which are what may be called only "partially outgassed". Using the above-mentioned observations obtained by the writer, it has been found that the data make a very good fit to Fowler's theoretical curve, the deviations from the values found by the older, and doubtless more unreliable, method, being no more than could reasonably be expected.

An interesting fact determined from this new treatment of the data is that the work function does not remain constant, but *increases slightly with the time*. (Germanium is an exception in that there is a slight *decrease*.) Whereas the older extrapolation method did not make it possible to distinguish these small differences, even when the data were plotted

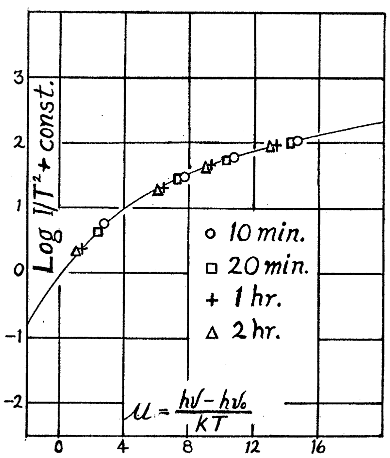


Fig. 1. Data from "partially outgassed" cobalt. The graph shows how closely the observations fit the theoretical curve and the shift of the photoelectric work function with the time.

[1] Phys. Rev. **32**, 657 (1928).
[2] Fowler, Phys. Rev. **38**, 45 (1931).

TABLE I.

| Metal | Extrapolation method | Fowler's theory 10 min. | 20 min. | 1 hr. | 2 hr. |
|---|---|---|---|---|---|
| Ca | 2.76 | 2.58 | 2.60 | 2.70 | 2.74 |
| Fe | 3.91 | 3.89 | 3.92 | 3.93 | 3.94 |
| Co | 3.90 | 3.88 | 3.39 | 3.92 | 3.92 |
| Ni | 4.06 | 4.02 | 4.04 | 4.07 | 4.08 |
| Cu | 4.18 | 3.99 | 4.04 | 4.07 | 4.09 |
| Zn | 3.89 | 3.82 | 3.84 | 3.86 | 3.86 |
| Ge | 4.29 | 4.18 | 4.17 | 4.15 | 4.14 |