producing materials were water and iron-filing located above the counter arrangement (equal masses in equal volumes). In experiment A the upper counters of the telescopes had an area of 400 cm² each and the lower ones an area of 250 cm². In experiment B all counters had an area of 600 cm² each. The resolving time of the circuit was 10^{-6} sec. The results are given in the table below.

TABLE I. Frequencies of penetrating showers in h^{-1}.

	Exp. A	Exp. B
No material	0.412 ± 0.045	1.06 ± 0.08
H_2O (57 g cm^{-2})	0.783 ± 0.074	2.07 ± 0.12
Fe (57 g cm^{-2})	0.592 ± 0.049	1.37 ± 0.14
H_2O (120 g cm^{-2})		2.02 ± 0.11
Fe (120 g cm^{-2})		1.34 ± 0.12

We see from these data that (a) the registered cross section per nucleon is larger in the case of water than in the case of iron, indicating that either the absorption coefficient of primaries or the constitution and multiplicity of the produced showers depends on the nuclear structure;[3] (b) with 57 g cm^{-2} of water or iron we observed saturation; (c) the existence of a difference between the frequencies at saturation in the case of water and iron suggests that the constitution, multiplicity, or angular divergence of the produced showers are different in the two cases. (d) The intensity of the shower-producing radiation is reduced by a factor $\gtrsim 1/e$ in a thickness of 57 g cm^{-2} in both H_2O and Fe. We conclude that the lower limit of the cross sections of this radiation is in both cases of the order of the geometrical cross sections of the nuclei.[4]

We thank Prof. G. Wataghin for the suggestion of this problem and for his kind, constant help during the performance of the measurements.

[1] A preliminary account of this work was presented at the meeting on July 13 of the Academia Brasileira de Ciencias.
[2] G. Wataghin, Phys. Rev. **71**, 453 (1947).
[3] Similar conclusions can be drawn from a recent work of Cocconi and Greisen, Phys. Rev. **74**, 62 (1948).
[4] For further work on the production of penetrating showers we refer to: V. Regener, Phys. Rev. **64**, 250 (1943); W. Hasen, Phys. Rev. **64**, 257 (1943); L. Janossy and Rochester, Proc. Roy. Soc. **A183**, 183 (1944); L. Janossy and D. Broadbent, Proc. Roy. Soc. **A190**, 497 (1947); O. Sala and G. Wataghin, Phys. Rev. **70**, 430 (1946); E. George and A. Jason, Nature **161**, 248 (1948). We finally mention experiments on the production of penetrating showers in paraffin and lead made by Professor Clay (private communication to Professor Wataghin).

The Beta-Spectrum of S^{35}

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August 19, 1948

RECENTLY Cook, Langer,[1] and Price[2] have published results on S^{35} negatrons and both positrons and negatrons from Cu^{64} which show an increase in number over that predicted by the Fermi theory at low energies. Because it is difficult to understand theoretically why such deviations should occur at low energy after the Coulomb correction has been made, an attempt was made to check these results with thinner sources. The Columbia University solenoid β-ray spectrometer[3,4] was used with eight different S^{35} sources. These measurements all show straight-line Fermi plots for the upper half of the energy spectrum. Some show straight-line plots from the upper energy limit down to 16 kev, while others showed deviations from the straight line at much higher energies, similar to the curve given by Cook and Langer.[2] The solenoid spectrometer possesses advantages over the other type instruments in that it has a high geometric efficiency ($\sim$1 percent) and can use a large effective source area. This permits the use of extremely thin sources with as low as $\sim$1 microcurie of total activity and a resolution of 1.25 percent.

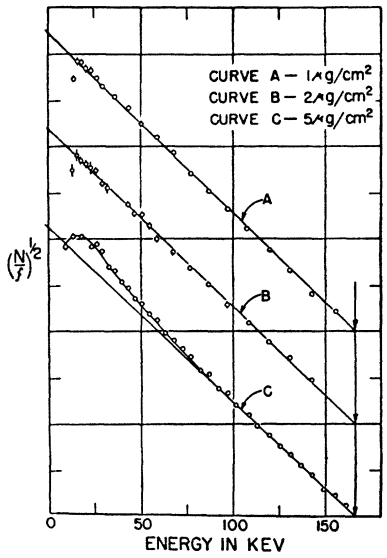

FIG. 1.

Figure 1, curves A and B, show the results for two of the best sources prepared. Curve C shows the results for a somewhat thicker source. These Fermi plots are corrected for the Coulomb effect, using the non-relativistic correction factor which agrees within $\sim$2 percent or better with the relativistic correction for S^{35}. The best straight line in each case was made to meet the axis at 166 kev; this value was obtained on each of several runs when the high energy region was investigated. The points of curves A and B do not deviate significantly from the straight-line plot above 16 kev. The drop at lower energies is probably instrumental and will be investigated further.

The counter windows consist of four thicknesses of collodion films prepared by spreading one drop of collodion solution (one part collodion, two parts amylacetate) over a pan of water in the usual manner. The total thickness is probably <30 micrograms/cm² and will transmit electrons down to 4 kev. The source backings were also collodion about 3 micrograms/cm². The sources were prepared by placing a drop of solution of carrier free S^{35} (from Oak Ridge) on the backing and drying in such a manner that it spread over a suitable area. The deposit did not form a perfectly uniform layer, so that the maximum local thicknesses were hard to estimate. Assuming uniform spreading, the sources for Fig. 1A, B, C were

about 1, 2, and 5 micrograms/cm² in addition to the backing film.

These are considerably thinner than the sources previously reported. It is important to note that a source as thin as that used for Fig. 1C gives such large deviations from the straight-line Fermi plot, and these results emphasize the importance of using extremely thin sources for low energy measurements. Rough data also indicate that additional source backing (a collodion film of ~10 micrograms/cm²) noticeably distorts the low energy portion of the spectrum. This effect is being investigated further.

We wish to thank Professors L. J. Rainwater, W. W. Havens, Jr., and J. R. Dunning for the constant encouragement and valuable discussion. The document is based on work performed under Contract AT-30-1-Gen 72 with the Atomic Energy Commission and Columbia University.

* This letter is based on work performed under Contract AT-30-1-Gen-72, and the information covered therein will appear in the Manhattan Project Technical Series, as part of the contribution of Columbia University.

[1] C. S. Cook and L. M. Langer, Phys. Rev. **73**, 601 (1948).
[2] C. S. Cook, L. M. Langer, and H. C. Price, Jr., Phys. Rev. **73**, 1395 (1948).
[3] C. M. Witcher, Phys. Rev. **60**, 32 (1941).
[4] C. S. Wu, W. W. Havens, Jr., R. Albert, and G. Grimm, Phys. Rev. **73**, 1259 (A) (1948).

Secondary Electron Emission by Fast Neutral Molecules and Neutralization of Positive Ions*

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WHEN a beam of positive ions passes through a gas at rest there occurs a weakening of the beam by a charge exchange with the gas atoms.[1] For most of these charge collisions the now fast atom undergoes little deviation. As a result there is little transfer of kinetic energy and we have, on removing any unneutralized ions, a beam of fast atoms with an energy equivalent to that of the original ion beam. One method of detection of such a neutral beam is to allow the atoms to strike a metal surface and measure the secondary electrons emitted under this bombardment.[2] The investigation here reported concerns the measurement of the number of these secondary

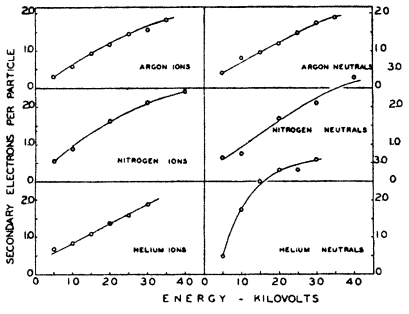

FIG. 1. Number of secondary electrons emitted from a tantalum surface per particle as a function of the energy of the particle in electron volts.

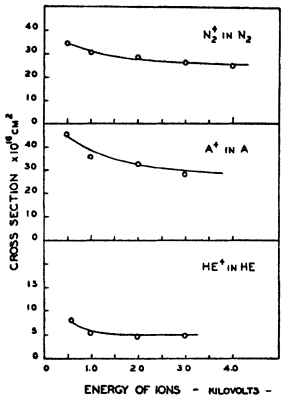

FIG. 2. Cross section for neutralization of ions in their own gas as a function of the ion energy in electron volts.

electrons removed from a tantalum surface by argon, helium, and nitrogen ions and molecules with energies ranging from 500 to 4000 electron volts.

A beam of positive ions of the desired energy is directed into a region where the same gas as that from which the positive ions are formed is present at a pressure of 10^{-4} to 10^{-3} mm of Hg. If in this neutralizing chamber a charge exchange collision should occur, the fast ion now becomes a neutral atom and a gas atom an ion. Most of these charge exchange collisions will be glancing, as is indicated by the much larger cross section for collisions obtained from various kinetic theory measurements. Hence most of the ions resulting from this charge exchange will be slow. These slow ions can be collected on an electrode by a small potential difference between the ends of the neutralizing chamber. In confirmation of this, it is found that as the potential difference between the electrodes at the ends of the neutralizing chamber is increased, the slow positive ion current collected by the electrodes increases rapidly with the voltage up to 40 or 50 volts. From 50 to 80 volts the current remains practically constant but beyond 80 volts rises again. The now neutralized fast atom may continue through a hole in the end of the neutralizing chamber and strike the tantalum surface from which the secondary electron emission occurs.

If E_+ = the ion current to the tantalum surface when it is positive, thus holding secondary electrons, E_- = the current to the tantalum surface (positives arriving, electrons leaving) when the surface is negative, and A = the slow positive ion current collected in the neutralizing chamber; then $E_- - E_+$ = the number of secondary electrons removed from the tantalum surface.

$$E_- - E_+ = k_+ E_+ + k_0 A,$$

where k_+ = number of electrons removed per positive ion striking the surface and k_0 = number of electrons removed per neutral atom striking the surface; so

$$(E_- - E_+)/E_+ = k_+ + k_0(A/E_+).$$

Now if the pressure in the neutralizing chamber is increased the slow positive ion current A will increase; since more ions are neutralized and since there are now,