Anomalous Secondary Electron Emission A New Phenomenon

Aluminum, oxidized electrolytically in a bath of borax and boric acid, is made the target of an electron gun. Caesium is introduced into the tube which is then baked at 200°C for ten minutes after which the tube is flushed with oxygen.

If a collector—electrode adjacent to the target is maintained at a positive potential with respect to the former, it is found that an electron beam from the gun impinging upon the target causes a current to the collector which, in certain cases, may be several thousand times greater than the primary beam. Over a considerable range of collector voltage and primary beam current density, it is found that

$$J_c = \alpha \epsilon^{\beta V_c} J_B^{\gamma},$$

where J_c is the collector current divided by the area of the primary beam, V_c is the collector potential, and J_B is the primary beam current density.

The collector current decays slowly after the removal of the primary beam and has been detected even after twenty-four hours. Similar time lag effects occur when the beam is first turned on, particularly if the beam has previously been permitted to fall upon the target with the collector potential reversed.

White light from a tungsten filament produces a marked drop in J_c as well as a more rapid change in the decay and building up characteristics.

Apparently, the treatment outlined above produces a surface on a resistive film which has a high emission coefficient for secondary electrons. Since the primary beam causes an emission of true secondary electrons greater in number than those in the primary beam, the surface becomes positively charged resulting in the establishment of an intense potential gradient through the resistive oxide film. This gradient is responsible for the enhanced secondary emission. This type of "secondary electron emission" is referred to as "anomalous secondary electron emission."

A complete report of this work will be published shortly.

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Cornell University,
February 24, 1936.

Can Protons Represent the Primary Cosmic Rays at Sea Level?

Analyses of the cosmic-ray intensity-altitude curves have appeared to suggest the conclusion that the primary cosmic radiation in the vicinity of the earth is composed exclusively of protons.[1] The purpose of this letter is to point out certain difficulties inherent in this view.

A charged particle is characterized by the fact that its ionization increases enormously towards the end of its range, so that, in the case of protons and alpha-particles large and measurable spurts of ionization should be produced in relatively short distances by those rays which are ending their journeys.

Let r be the distance from the end of the range to the point where the ionization per centimeter of path is σ. Then all rays producing more ions per centimeter than σ will be absorbed within the distance r; and, on a view which considers the rays as the observed entities disappearing according to an exponential law of absorption, the fraction disappearing within the distance r is $(1-e^{-\mu r})$ where μ is the observed absorption coefficient. This is the fraction of the rays which would produce at the point considered more than σ ions per centimeter of path at atmospheric pressure, and so, more than $Lp\sigma$ ions in a distance L at a pressure p. If we assign 54,000 ions as the lower limit of a spurt which is to be considered in the measurements the corresponding value of σ is $\sigma = 54{,}000/Lp$. In a vertical cylinder of length L and cross-sectional area a, the number of spurts greater than 54,000 ions should consequently be, with sufficient approximation, S, where,

$$S = (Na^2/L^2)(1-e^{-\mu r}). \quad (1)$$

N is here the number of rays per square centimeter per second per unit solid angle at the vertical and is equal to 0.013. The value of r is that corresponding to the above value of σ and must be obtained by extrapolation of the experimental data through the aid of Bethe's formula for energy loss.[2] Thus we find for a case where $L=15.2$ cm and $p=10$ atmospheres, the value $r=2700$ cm. Compton quotes $\mu=0.08$ per meter of water for proton cosmic rays, so that, with proper adjustments of units, (1) gives, for a cylinder with $L=15.2$ cm and $a=45.6$ cm^2, a value $S=1.2$ spurts per hour greater than 54,000 ions.

At my suggestion, an experiment of the above type, later to be described in detail, has been performed by C. G. and D. D. Montgomery, W. E. Ramsey, and myself. The measured value of S was found to be less than 0.11 spurt per hour. It will suffice to say that alpha-particles were eliminated by observing only coincident spurts in the upper and lower halves of the vessel, and "showers" were detected and eliminated by Geiger-counter devices.

In view of the above considerations it would seem that if protons are to be admitted at all they must function in some such manner as that implied in the writer's theory,[3] through the production of secondary rays which then become the entities actually observed by our counters.

W. F. G. SWANN

Bartol Research Foundation
of the Franklin Institute,
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[1] A. H. Compton and H. Bethe, Nature **134**, 734 (1934); also A. H. Compton, Rev. Sci. Inst. **7**, 71 (1936).
[2] H. Bethe, Zeits. f. Physik **76**, 293 (1932); see also P. M. S. Blackett, Proc. Roy. Soc. **A135**, 132 (1932). Extrapolation of the experimental results by aid of the theory is enhanced in validity by the fact that experiments have checked the theory for electrons, for the range of velocity contemplated in the calculations for protons. Ionization per centimeter of path has been obtained from energy loss on the assumption that 30 volts corresponds to one ion.
[3] W. F. G. Swann, Phys. Rev. **48**, 641 (1935).