LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the twentieth of the preceding month; for the second issue, the fifth of the month. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

The Variation with Altitude of the Production of Bursts of Cosmic-Ray Ionization

The frequency distribution of large cosmic-ray showers has been found[1] to be represented satisfactorily by a relation of the form $R=A/N^s$, where N is the number of rays in the shower, RdN the rate of occurrence of showers having sizes between N and $N+dN$, and A and s are parameters. Distribution curves, taken from several observers, for showers from lead are shown, in Fig. 1, to be well represented by this relation when the rates of occurrence of the smaller showers, which values are uncertain because of the statistical fluctuations in the ionization, are disregarded. The sizes of the bursts of ionization have been reduced to numbers of rays by somewhat arbitrary assumptions, since sufficient information for the proper reduction was not, in all cases, available. The factors used do not influence the values of s, but cause proportional errors in A. Table I gives values of s and the sources of the data plotted. The value of R for 100-ray showers is of the order of 10^{-5} per hour per cc of lead at sea level for thicknesses of the order of one centimeter.

TABLE I.

CURVE	OBSERVER	REFERENCE	s	REMARKS
1	J. C. Street and R. T. Young	Phys. Rev. **47**, 572 (1935)	3.4	Computed to the basis of 60 ions/cm/ray
2	E. G. Steinke and H. Schindler	Zeits. f. Physik **75**, 115 (1932)	3.1	Assumed 4.8×10^3 ions per ray
3	R. Bennett, G. Brown, and H. A. Rahmel	Phys. Rev. **47**, 435 (1935)	3.1	Mt. Evans data, assumed 2×10^5 ions per ray
4	W. Messerschmidt	G. Hoffmann, Papers & Discussions, Int. Conf. on Physics, London, 1934, I, p. 226	3.1	Assumed 9×10^4 ions/ray
5	C. G. Montgomery and D. D. Montgomery	Phys. Rev. **47**, 429 (1935)	3.3	2×10^5 ions/ray
		mean	3.2	

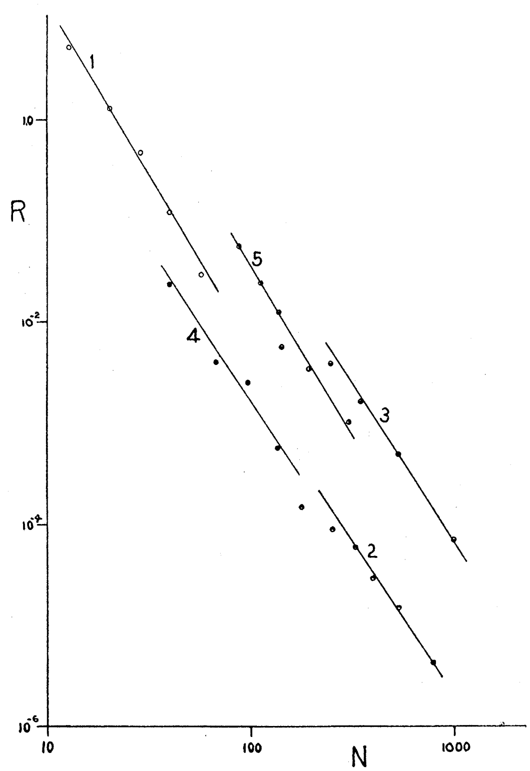

FIG. 1.

The assumption of a distribution curve of this form has interesting consequences when applied to measurements of burst production at different elevations. Fig. 2 shows measurements, previously reported,[2] for bursts from lead and magnesium at sea level and at an elevation of 4300 meters. It appears from this that the value of s, although characteristic of the material, is independent of elevation. Although the ratio of the frequencies of occurrence of bursts of a given size at different altitudes is very different for the two substances, the ratio of the sizes of bursts which occur at a given rate at the two elevations is very nearly the same. This is also true for the observations at the

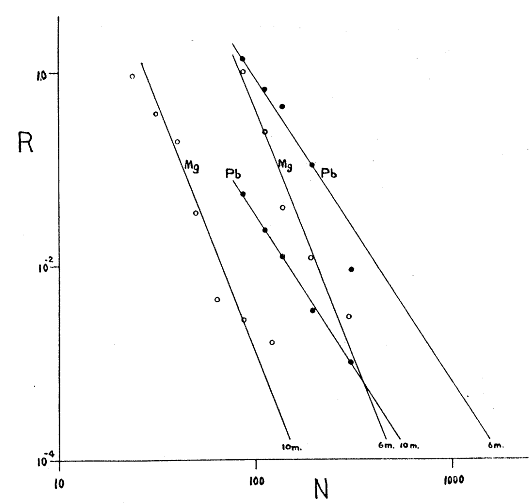

FIG. 2.

intermediate elevations where measurements were made. This suggests that the process which produces a shower of a given size at sea level would occur at the same rate at a high elevation, but would there produce a shower of a larger size, and that this increase is independent of the shower producing material.

If we make this assumption, it can be stated mathematically that the quantity

$$\left[\frac{A(h_1, Z)}{A(h_2, Z)}\right]^{1/s(Z)}$$

is independent of Z, where h_1 and h_2 are two elevations, and Z the atomic number.

This is equivalent to the differential relation

$$\frac{\partial}{\partial Z}\left(\frac{1}{s}\frac{1}{A}\frac{\partial A}{\partial h}\right)=0,$$

whose solution is

$$A=A_0(Z)[F(h)]^{s(Z)}.$$

This immediately suggests the expression postulated by Professor W. F. G. Swann:[3]

$$A=A_0E^{\alpha},$$

where E is the energy of the primary cosmic rays, and A_0 and α are functions of Z only. Since Swann's theory is consistent with the observed variation with altitude for the bursts from lead and magnesium, it appears that the shape of the frequency distribution curve is determined by the exponent α in such a way that s is proportional to α. It is to be noted that the fact that the observed variations with altitude of the frequency of occurrence of bursts from lead and magnesium are different is entirely inconsistent with the hypothesis that bursts are produced by a soft component of the cosmic radiation.

The authors wish to thank Professor Swann for helpful discussions of this matter.

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Swarthmore, Pennsylvania,
November 22, 1935.

[1] C. G. Montgomery and D. D. Montgomery, Phys. Rev. **48**, 786 (1935).
[2] C. G. Montgomery and D. D. Montgomery, Phys. Rev. **47**, 429 (1935).
[3] W. F. G. Swann, Phys. Rev. **48**, 641 (1935).

Determination of the Saturation Ionization Current from High Speed Electrons in Air

Last year we reported a study[1,2] of the ionization produced in liquid carbon disulphide by x-rays produced at moderate voltage. Jaffe's[3] theory of columnar ionization furnishes the relationship

$$\frac{I_\infty}{I_x}=\frac{\alpha N}{kudXf(X)}+1,$$

where I_∞/I_x is the fraction of the ions drawn from a column of diameter d by a field X. For high field strengths $f(x)$ approaches 1 so that a plot of $1/I_x$ against $1/X$ gives a straight line which can be extrapolated to $1/X=0$ thus furnishing a calculated value for the ionization current at infinite field. The agreement between values derived from this equation for the energy of ionization per ion pair for CS_2 in the liquid and gaseous state respectively have proved its applicability for x-ray ionization. Subsequently, it has been found that this method for determining saturation current in liquids could be applied well to the ionization produced in CS_2 by gamma-rays.[4]

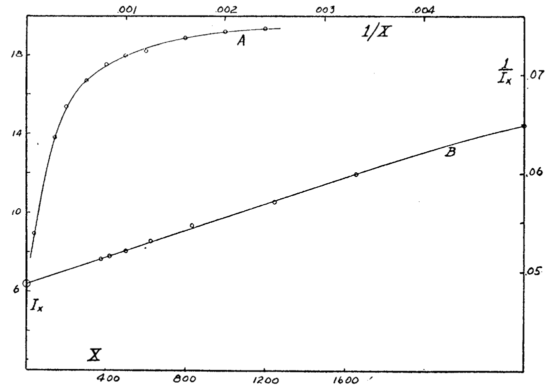

Fig. 1.

The method of plotting has now been extended to determine the ionization produced in air at normal pressure by a heterogeneous beam of electrons having a maximum energy of 150 electron kilovolts. The electron beam produced by a Lenard tube, entered ionization chambers of various forms placed near the tube window (distance 3–10 cm). By using a parallel plate ionization chamber (metal gauze plates 1 cm apart, placed at right angles to the beam), at potentials up to 1300 volts, where the air began to break down by collision ionization, curve A (with coordinates at bottom and left of plot) was obtained for the ionization current as a function of the voltage. Curve B shows the same data plotted reciprocally and extrapolated to $1/X=0$, giving the derived current at infinite field. Air breakdown began when the ratio I_x/I_∞ reached about 0.93.

Jaffe's theory of columnar ionization is presumed to be invalid under the conditions here used, since in air there is an extensive overlapping of the columns and hence strong intercolumnar recombination. It is interesting, therefore, that these empirical results are apparently so similar to those of liquids. The linear relationship between $1/X$ and $1/I_x$ held for values of I_x/I_∞ from about 0.36 to 0.96.

Recent work by Clay and Van Tijn[5] for the ionization produced by gamma-rays in gases under high pressure, gives curves closely similar to those above, but are based on Jaffe's theory of columnar ionization.

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Washington, D. C.,
November 25, 1935.

[1] F. L. Mohler and L. S. Taylor, Phys. Rev. **45**, 762 (1934).
[2] F. L. Mohler and L. S. Taylor, Bur. Standards J. Research **13**, 659 (1934).
[3] A. Jaffe's, Ann. d. Physik **42**, 303 (1913).
[4] L. S. Taylor and F. L. Mohler, Science **81**, 318 (1935).
[5] J. Clay and M. A. Van Tijn, Physica **2**, 825 (1935).