density of states resulting from these possibilities, the larger value tending to shift the transition toward lower temperature for a given electron concentration.

The χ_c *vs* $1/T$ curve for sample 2 (Table I) is shown in Fig. 1. In this specimen n is essentially constant over the whole temperature range. The points are experimental and the curves are calculated from Eq. (3) for both values of ω_s. In order to make the comparison, the smaller value of $\langle f^2 \rangle$ indicated in Table I made it necessary to choose $n = 6.4 \times 10^{17}$ cm^{-3} as indicated by $\langle f^2 \rangle = 54$ rather than the value obtained from the Hall coefficient (7.3×10^{17} cm^{-3}). This modification should have little effect on the analysis. It is clearly evident from Fig. 1 that fourfold degeneracy gives the better fit to the data. There is reason to believe that the bending down of the experimental curve toward the highest $1/T$ values arises from higher order corrections in the magnetic susceptibility equation.

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Streamer Theory and the Value of α/p

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The streamer theory of the breakdown in gases was proposed by Meek[1] and, independently, by Raether[2] and is known to be applicable to relatively large values of $p\delta$ (p: gas pressure, δ: gap length). In the streamer theory the values of the breakdown fields in air are usually calculated using the values of α/p obtained by Sanders[3] (α: the number of electrons produced in the path of a single electron traveling a distance of 1 cm in the direction of the field). For a uniform field gap in air at atmospheric pressure, the difference between the values calculated by this theory and the observed values becomes greater as the gap length deviates from the value of 1 cm. For gaps shorter than 1 cm the calculated fields are higher than the observed values, one reason for which is that the breakdown at the shorter gaps is more likely to occur by Townsend mechanism rather than by streamer mechanism. For longer gaps the calculated fields fall below the measured values, for which effect there has as yet been no satisfactory explanation, although it has been discussed at length by Loeb and his associates, as well as by Meek, Raether, and Hopwood. Loeb and Meek pointed out that for longer gaps, the calculated ion density in the avalanche head is less than the critical value which is necessary to form the streamer. The field must therefore be increased to produce a higher ion density if a streamer is to be formed to cause the breakdown, in which case the breakdown develops through the formation of the mid-gap streamer.

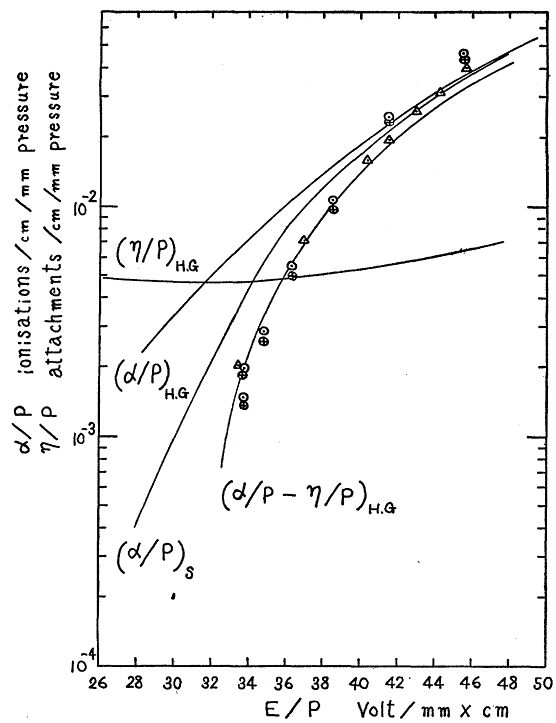

FIG. 1. Relations between E/p and the values of (α/p, η/p, $\alpha/p - \eta/p$) in air. $(\alpha/p)_{\mathrm{HG}}$: the measured curve of Harrison and Geballe. $(\alpha/p)_{\mathrm{S}}$: the measured curve of Sanders. △: the measured values of Paavola. $(\alpha/p)_{\mathrm{P}}$. ⊙: the values of α/p obtained so as to give agreement between the measured fields and the calculated values of Meek's equation in air at atmospheric pressure [$E_r = E = 5.27 \times 10^{-7} \alpha e^{\alpha x} (x/p)^{-\frac{1}{2}}$]. ⊕: the values of α/p obtained so as to give agreement between the measured fields and the values calculated by Raether's equation in air at atmospheric pressure ($\alpha\delta = 17.7 + \ln\delta$).

Raether suggested that the conditions governing the propagation of the streamer may necessitate a higher field than is required to cause the avalanche-streamer transition.

In such discussions on the reason for the deviations, we entertain a doubt concerning the values of α/p used in the calculation. Sanders' data of α/p have been considered to be reliable, as they coincided with Masch's[4] data which were obtained by more accurate apparatus.

At that time, there were no adequate investigations on the effect of attachment upon the value of α/p.

Recently Harrison and Geballe[5] measured the values of α/p for air and other gases; they separated η/p from the real α/p, where η is the number of negative ions produced by the attachment to neutral molecules in the path of a single electron traveling a distance of 1 cm in the direction of the field. Former measured values of α/p for electronegative gases, such as air, may possibly have included the values of η/p.

Figure 1 shows $(\alpha/p)_{\mathrm{HG}}$ and $(\eta/p)_{\mathrm{HG}}$ obtained by Harrison and Geballe, compared with the formerly measured values of $(\alpha/p)_{\mathrm{S}}$ by Sanders and $(\alpha/p)_{\mathrm{P}}$ by Paavola.[6] Paavola's values are of great importance because they were measured at atmospheric pressure. Also shown is the difference between $(\alpha/p)_{\mathrm{HG}}$ and $(\eta/p)_{\mathrm{HG}}$ computed by the authors. The figure includes the values of α/p which must be used to give good agreement between the measured breakdown fields and the values calculated with Meek's or Raether's criterion. These values coincide with the curve of $(\alpha/p-\eta/p)_{\mathrm{HG}}$ or the values of $(\alpha/p)_{\mathrm{P}}$ in the region where the streamer theory is applicable (E/p is less than 38.5 v/cm-mm Hg or δ is greater than 2.5 cm at atmospheric pressure). In other words, if the values of $(\alpha/p-\eta/p)_{\mathrm{HG}}$ or $(\alpha/p)_{\mathrm{P}}$ are used in Meek's or Raether's equation, the calculated breakdown fields closely approach the measured values.

Because the values of α/p for air as measured by many investigators differ, more exact values of α/p, especially at low E/p are desired for this problem. The authors have recently developed a single avalanche theory as well as a theory of modified multiple avalanche. In the single avalanche theory, the very best results are obtainable by using the values of $(\alpha/p-\eta/p)_{\mathrm{HG}}$ or $(\alpha/p)_{\mathrm{P}}$. A description of these theories will be published.

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Dependence of Light Amplification in Phosphors on Light Intensity

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Cusano[1] has shown that ultraviolet excited luminescence in a ZnS:Mn, Cl phosphor film can be enhanced by the application of an electric field. This is interpreted[2,3] as a radiation-controlled electroluminescence ("photoelectroluminescence"[3]) inasmuch as the electrons excited by the radiation supply the electrons for impact excitation of the luminescence centers. Under the conditions of the experiment, the amplification depends on the radiation intensity such that the ratio $\rho=I/I_0$ (I=luminescence intensity with field, I_0=luminescence intensity without field) varies, for constant field, inversely as the square root of the excitation intensity. It will be shown that this square root law can be derived by an appropriate modification of a previous treatment[4] of the simultaneous effects of radiation and electric fields on phosphors.

In analogy to Eq. (2) of the paper mentioned,[4] we write

$$dN/dt=\eta-A_1Nm-A_2N(n-m+N)+\epsilon(m-N)+\gamma N, \tag{1}$$

$$dm/dt=\eta-A_1Nm+\gamma N. \tag{2}$$

Here N=number of conduction electrons; m=number of holes and empty centers; n=number of traps; η=number of electrons excited to the conduction band by incident ultraviolet radiation, used also as a measure of this radiation; A_1, A_2="transition probabilities" for recombinations and trappings respectively; ϵ and γ are constants for a given field strength, that disappear for zero field. The ϵ term describes emptying of traps by the field ($m-N$=number of filled traps). This is the essential process of "electrophotoluminescence" effects.[4] The γ term is added to take into account the excitation of electrons by impact with accelerated conduction electrons, which is the essential process of photoelectroluminescence. Quenching processes are neglected as immaterial for the present case, and the equations are written for dc fields.

The luminescence intensity is assumed to be $I=A_1Nm$. In equilibrium,

$$dN/dt=0,\quad dm/dt=0. \tag{3}$$

Then $I=\eta+\gamma N$, $I_0=\eta$ and

$$\rho=1+\gamma N/\eta. \tag{4}$$

N can be determined from Eq. (3) after elimination of m. This model is, of course, simplified (no separation of empty centers and holes; "bimolecular" recombination; thermal transitions left out). But the success of similar models in other respects justifies trying it for the present problem, although we cannot expect rigorous quantitative results.

For N a cubic equation is obtained, which reduces to a quadratic equation for certain approximative assumptions, for instance, if the ϵ effect can be neglected. In this case,

$$N=\tfrac{1}{2}(\gamma/A_1-n)+[\eta/A_1+\tfrac{1}{4}(\gamma/A_1-n)^2]^{\frac{1}{2}}. \tag{5}$$

This leads to the observed square root law if the conditions

$$(\gamma-A_1n)^2\ll 4\eta A_1\ll 4\gamma^2 \tag{6}$$