

THE TRANSFORMATION PERIOD OF THE INITIAL POSITIVE AIR ION

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ABSTRACT

Time constant of transformation from initial to final positive ion. Erikson has shown that when first formed in air at atmospheric pressure the positive ion has a mobility of 1.87 cm/sec. per volt/cm, but that it quickly changes over into an ion having a mobility of 1.36. By a method essentially the same as that used by Erikson, a quantitative study was made of the rate of transformation. It was found to be dependent on the humidity of the air. At a relative humidity of 32 percent, the half-value period was found to be 0.0132 sec.; at a relative humidity of 80 percent, it is 0.0354 sec.

IT HAS been shown that in the case of air and certain other gases the products of ionization consist of a negative ion, which retains its identity for a considerable time, and an "initial" positive ion, which is quickly transformed into a less mobile structure, the "final" positive ion.^{1,2} Rough estimates of the value of the time rate of the transformation of the initial positive ion have been given by Grummann² and by Tyndall and Grindley.³ The present research was undertaken for the purpose of making a more exact evaluation of this transformation constant.

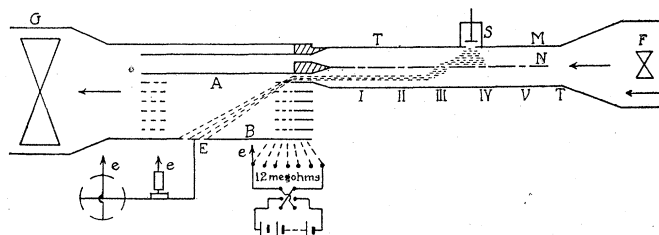


Fig. 1. Diagram of apparatus.

Measurements were made by means of an apparatus similar to that employed by Erikson.^{1,2} The ionic spectrum was obtained by passing a narrow stream of ionized air into the moving air between two plates, *A* and *B*, Fig. 1, between which was maintained a difference of potential. In the lower plate was a narrow insulated strip, *E*, connected to an electrometer. The ions, moving with the air stream in a horizontal direction and being deflected vertically by the electric field, were made to fall on *E* by proper adjustment of wind velocity and voltage. A curve showing the ionic mobility spectrum was obtained by plotting electrometer readings

¹ Erikson, Phys. Rev. **20**, 117 (1922); **24**, 622 (1924); **26**, 465; **26**, 625; **26**, 629 (1925).

² Erikson, Phys. Rev. **24**, 502 (1924).

³ Tyndall and Grindley, Proc. Roy. Soc. **A110**, 358 (1926).

against the voltage at constant wind velocity (See Fig. 2). The ions were formed in the upper half of the double tube T , Fig. 1, by alpha-rays from a polonium plate in the chamber S . Five windows were cut in the partition N dividing this tube, and S was placed so that ions entered the lower half of T through one of these windows, the others being, of course, closed. Between M and N a potential difference of 180 volts was maintained, to draw the positive ions vertically downward. Before obtaining the curves presented in this paper, a set of readings was taken at the air velocity used in this experiment, with a constant potential difference between A and B , in which the position of S was varied with respect to one of the windows. Then, in obtaining the curves of Fig. 2, the position of S with reference to a window was chosen to give the maximum possible current. It was found that with this arrangement about 97 percent of all the ions entering the lower half of the tube T were positive in charge. Hence, no correction was made for the loss of positive ions by recombination with negative ions in their passage into the measuring apparatus. Moreover, since the times

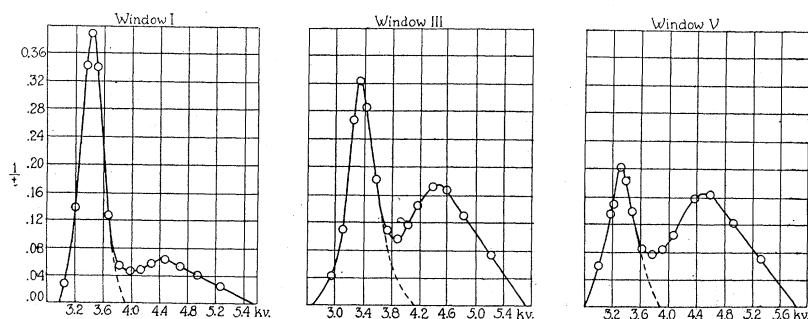


Fig. 2. Spectra of positive air ions of different ages.

here involved were very short, the number of positive ions lost by diffusion to the walls was considered negligible. To measure the current due to ions of different ages, a set of curves was obtained by placing S , successively, at each of the five windows. The relative ages of the ions from these windows were calculated from the wind velocity in T . To measure the latter, a small fan anemometer was placed at F , Fig. 1, and the velocity in T was deduced from its readings by a comparison of the cross-sectional areas of the two parts of the tube. The calibration of the anemometer was checked at the U. S. Bureau of Standards.

One may define λ , the time constant of the transformation, by the equation

$$dn/dt = -\lambda n. \quad (1)$$

Its integral is

$$n/n_0 = \exp(-\lambda t). \quad (2)$$

Here n_0 is the number of initial positive ions formed per second by the ionizing agent, and n is the number of these ions still unchanged after the

passage of a time t . Now, in Fig. 2 the ordinates are proportional to the number of ions reaching E per second. The area under the entire curve is accordingly proportional to the total number of positive ions entering the lower part of the tube T per second. Thus, the ratio n/n_0 can be taken as the ratio of the area under the first maximum of the curve to that under the entire curve. These areas were measured for all the curves with a planimeter.

In Fig. 3 are plotted as ordinates the values of $\log_{10} n/n_0$ obtained from the curves of Fig. 2. The relative "age" of the ions, plotted as abscissa in each case, is the time of passage of the ions from the window in question

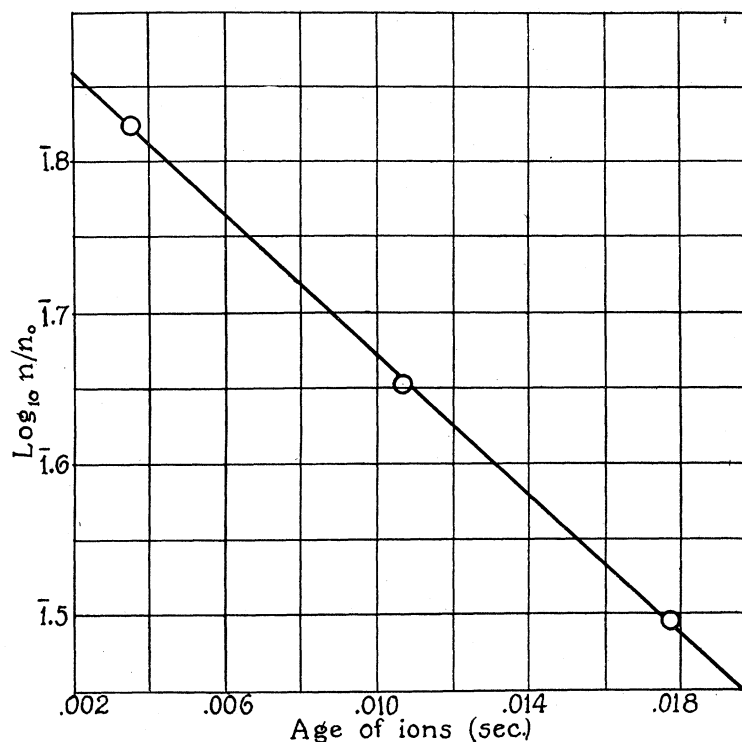


Fig. 3. Dependence of the logarithm of the relative number of initial positive ions on the age of the ions.

to a point 5 cm in front of window I. The actual time of passage to electrode E was not computed, since only the difference in times from the various windows is needed in determining λ .

In accordance with Eq. (2), λ is the product of $\log_e 10$ and the slope of the straight line of Fig. 3. The result of this calculation is

$$\lambda = 52.6 (\text{sec.})^{-1}$$

The half-value period is, accordingly,

$$\log_e 2/\lambda = 0.0132 \text{ sec.}$$

These curves were obtained at a humidity of about 32 percent.

It was found, however, that the value of λ is considerably affected by humidity conditions.³ At a relative humidity of 80 percent, for example, $\lambda = 19.6 \text{ (sec.)}^{-1}$, giving, as half-value period, 0.0354 sec. The values of the humidity here cited are those recorded at the U. S. Weather Bureau on the days on which the work was done. The windows of the room were kept open enough to assure that the humidity of the room was nearly the same as that outside. In the course of a set of readings, the humidity did not vary by more than 25 percent.

In seeking a conception of the mechanism of the humidity effect on the rate of transformation, it would seem natural to assume that the final ion has a greater tendency to load up with the water molecules than has the initial ion. For, if the curves were not carried to voltages high enough to include these heavy ions, the ratio n/n_0 would obviously be abnormally large. But this explanation can hardly be the correct one, for the results of this experiment do not in any way point to a successive decrease in the value of n_0 at the different windows. The data are, however, too meagre at present to point the way to a clear-cut picture of the action of the water molecules on those of the air.

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