ON THE AGEING EFFECT IN THE MOBILITY OF POSITIVE GAS IONS.

By H. B. Wahlin.

Synopsis.

Mobility of positive ions of air immediately after formation has been found by Erikson, using a modified Zeleny method, to be much higher than the normal value. This result has been verified by the author using the alternating potential method. Ions formed in an ante-chamber by α-rays from polonium were driven by a weak auxiliary field into the measuring chamber where the mobility was determined by the use of an alternating field of 1,800 to 3,600 cycles and of variable strength. Pure dry air was used at a pressure of 30 mm. When the auxiliary potential was 1.5 volts the measured mobility was normal but when the potential was 3.0 volts or more the mobility rose to 1.80 cm./sec./volt/cm., indicating that the ions entered the measuring chamber before they were aged. The time required for the ions to age or reach the normal condition is estimated to be between 1/75 and 1/120 of a second.

At the November meeting of the American Physical Society, Professor H. A. Erikson, of the University of Minnesota, presented a paper on the variation in the mobility of positively charged gas ions with time. Using a modification of the Zeleny method for measuring mobilities Professor Erikson[1] has shown that if the determinations are made immediately after the ions are formed, the values obtained are for air, oxygen, and nitrogen much higher than the accepted values. If, however, the ions are aged for an appreciable time Erikson found this time to be of the order of 1/100 of a second (for air) before the determinations are made, the mobility falls to the normal value (1.37 cm. per sec. per volt per cm.).

In order to investigate this effect further, the writer constructed an apparatus on the principle of the Franck modification of the Rutherford alternating potential method for determining mobilities using α-particles from polonium as the ionizing source. As a source of alternating potential, an oscillating vacuum-tube circuit of the Hartley type (Fig. 1) with a telephone transformer (T) in the plate circuit was used. The voltage on the secondary of the transformer was varied by varying the potential of the plate by means of the potential dividing resistance R_2. In order to keep the frequency of the alternating potential constant with a variation in the plate voltage, a resistance (R_1) was introduced into the grid circuit of such a value that the potential could be varied over the desired range without any noticeable effect on the frequency.

[1] Erikson, Phys. Rev., 17, p. 400; 18, p. 100.

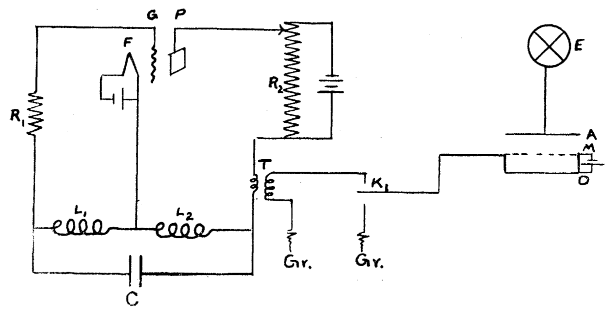

Fig. 1.

The inductances (L_1, L_2) and the capacity (C) were chosen so as to give a range of frequencies from 1,800 alternations per second to 3,600 alternations per second. One terminal of the secondary of the transformer was grounded, and the other was connected through a condenser key (K_1) to the gauze (M). On the lower side of this gauze a copper plate coated with polonium was fastened in such a manner that the radiation from the same was confined to the lower half of the region between M and D. The gauze was made by boring holes 1.3 mm. in diameter in a brass plate .5 mm. thick. The distance between centers of adjacent holes was 4 mm. The diameter of the gauze was 10 cm. This gauze was fastened to a fiber ring which rested on the brass plate (D). The distance between M and D was 1 cm. Between the gauze and the brass plate a source of potential was fastened for driving the ions through the gauze into the measuring field. A represents a collecting plate 10 cm. in diameter. The distance between A and M was varied between the limits of 6 mm. and 9 mm. The collecting plate in turn was connected through a platinum wire "bow switch" to the electrometer (E). The electrometer was of the Compton type with a gold sputtered quartz fiber as a suspension and was used at a sensibility of 4,500 scale divisions per volt with the scale at a distance of 150 cm. The amount of charge given to A in a given time was taken as a measure of the current. Then from the value of the alternating potential at which the ions cease to get across to the collecting plate the mobility may be calculated from the expression

$$K = \frac{\pi n d^2}{\sqrt{2}\, V} \frac{P}{760}, \tag{1}$$

where K is the mobility at a pressure of 760 mm., P is the pressure, n the frequency, and V is the alternating potential.

In all these determinations air was used at pressures ranging from 1 cm. to 3 cm. of mercury. A number of mobility curves were obtained at each pressure with values of the auxiliary field between M and D varying in some cases between 1.5 volts and 60 volts.

The air was purified by passing it over hot copper oxide to break up organic impurities. This would also remove the hydrogen. It next passed over potassium hydroxide to remove carbon dioxide and then through calcium chloride and phosphorous pentoxide to remove water vapor, and finally into the chamber containing the plates A, M and D. Before taking a series of readings, the chamber was washed out by exhausting to a pressure of 1 mm. or less and filling to atmospheric pressure. This was repeated three or four times, so that the residual gas left in the chamber from the previous filling was very small. In order to prevent any contamination of the gas by vapors from the walls of the chamber, the readings were taken immediately after making a filling. However, there was no noticeable difference produced in the results by allowing the gas to remain in the chamber for some time.

If the effect observed by Erikson is correct, we should expect that for low values of the auxiliary field between M and D, the ions would remain in this field long enough so that by the time they are carried through the gauze they will be aged, and that the intercept of the mobility curve on the voltage axis would give the normal value of the mobility. However, as the auxiliary field is increased ions would get through the gauze before ageing and the intercept would give values for the mobility which are abnormally high. As will be seen from Fig. 2, this is the case, for

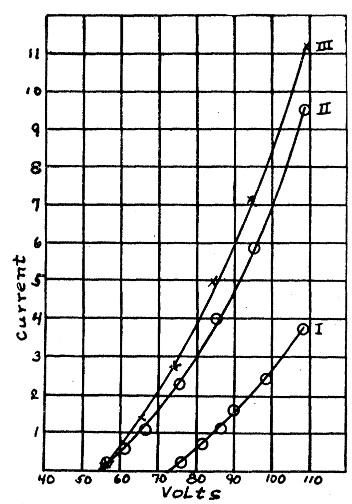

Fig. 2.

Frequency of alternating potential, 1,800 alternations per second. Plate distance d, 8 mm. Pressure of gas, 30 mm. Curve I., Auxiliary field, 1.5 volts. Curve II., Auxiliary field, 3.0 volts. Curve III., Auxiliary field, 4.5 volts.

with an auxiliary field of 1.5 volts the value for the mobility is 1.35 cm. per sec. per volt per cm., and with an auxiliary field of 3.0 volts the value rises to 1.80 cm. per sec. per volt per cm. A further increase in the auxiliary field does not change the intercept, as may be seen from the fact that the intercept for a field of 4.5 volts is the same as for 3.0 volts. The slight tendency shown by curve number 1 to be concaved upwards is probably due to the fact that the gauze and the collecting plate were not accurately parallel, for since the distance between these two is of the order of 8 mm. and since in the expression for the mobility constant (equation 1) this distance enters as the square, a small variation in this distance would produce quite an appreciable effect in altering the shape of the curve. The increased concavity of curves 2 and 3 is probably due to the fact that theions passing through the gauze are both the aged and unaged variety. The estimated time necessary for ageing is for all the curves taken somewhere between 1/75 and 1/120 of a second.

Discussion of Results.

Erikson has been unable to notice any ageing in the mobility of the negative ion. In this case, however, the effect is complicated by the fact that we have a distribution of mobilities between electronic and ionic. Determinations of the mobilities of the negative ions have shown that in most gases the mobility constant becomes abnormally high as the pressure is decreased. This would indicate that the electron does not attach itself immediately to a molecule but will travel some distance through a gas before uniting to form a negative ion. It would seem from this then that a further change after the electron once has attached itself is not very probable.

The most obvious explanation of the results given above is on the basis of a cluster theory of ion formation. On such a theory the formation of a positively charged gas ion would consist first in the detachment of an electron from the neutral molecule to form the positive ion and then the attachment of molecules to this ion to form the cluster. Then if the mobility is measured before this clustering takes place, the mean free path of the ion would be greater and as a consequence the mobility higher.

If, however, a cluster is formed, it is to be expected that it will disintegrate if the field in which the mobility is measured becomes high enough and the mobility will rise to a value limited principally by the size of the molecule or atom which forms the nucleus of the cluster. This question has been investigated by Loeb,[1] Chattock, Tyndall, and others without obtaining any evidence for an increase in the mobility.

[1] Loeb, Phys. Rev., December, 1916.

Wellisch, Franck, Franck and Meitner, and Rutherford have found that for a given gaseous medium the mobility is independent of the nature of the carrier as long as it is of atomic dimensions. On the basis of a small ion theory it is therefore to be expected that an aged ion would have the same mobility as an unaged one. However, these results can be coördinated on the basis of a cluster theory if the ions used by these observers were aged before the mobility was determined and if the size of the cluster is independent of the carrier which forms the nucleus.

In conclusion, the writer wishes to express his thanks to Mr. J. P. Foerst for his work in connection with the construction of the apparatus used in these determinations.

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