THE ELECTRICAL CONDUCTIVITY OF FLUORESCENT ANTHRACENE VAPOR.

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THE following paper is an account of an attempt to determine whether fluorescence has any effect on the electrical conductivity of anthracene vapor. Although the results of the experiment were negative, it being impossible to detect any conductivity of the vapor either unilluminated or fluorescent, the accuracy of the work was such as to set a rather definite upper limit for any effect that may be present, and the results are presented with the hope that some experimenter may be able to apply an improvement of the method to the same substance or, preferably, to others that might be expected to show the effect sought for.

The idea of testing the effect of fluorescence on the conductivity of a vapor was suggested to the writer by the paper of Nichols and Merritt¹ in which they reported an increase of 1.1 per cent. in the conductivity of an alcoholic solution of eosin and smaller changes for solutions of fluorescein, rhodamin, cyanin and naphthalin roth, the effect being ascribed to a dissociation of the X-ray type. The final form of the experiment, which was the result of several preliminary attempts, was carried out under the guidance of Professors Nichols and Merritt, and the writer wishes to thank them here for their many very useful suggestions and for their patient encouragement in the face of difficulties.

The expectation of a change in conductivity during fluorescence is based on the theory that fluorescence is a dissociation phenomenon. Whether this dissociation is such as to produce any such effect is as yet undetermined. Some of the theories and experiments that are for or against the assumption of a change will be briefly mentioned.

In the work of Nichols and Merritt with solutions, a Wheatstone-

¹ Nichols and Merritt, *PHYS. REV.*, Vol. 19, p. 296, 1904.

bridge method was used and difficulties were encountered due to heating on illumination and to the difficulty of eliminating disturbances due to polarization. Since the appearance of their paper the experiment has been repeated by Camichel,¹ who found no effect that could not be accounted for by heating. Regner² set 0.1 per cent. as the upper limit of change for solutions of eosin and fluorescein. More recently Hodge³ and Goldman⁴ have shown separately that the effect found by Nichols and Merritt was due to an electromotive force produced by light at the electrodes of the cell, and that no measurable change of conductivity was present.

Little work has been done on vapors. Henry⁵ could find no conduction of iodine vapor due to light. On the other hand, J. J. Thomson⁶ states, without giving reference, that light increases the conductivity of sodium vapor. Wiedemann and Schmidt,⁷ in their paper in which they propose the dissociation theory, say that this does not call for any ionization in the case of fluorescent vapors.

The desirability of anthracene vapor for this experiment is seen from the following considerations:

1. The vapor is strongly fluorescent.
2. It has banded absorption and fluorescent spectra⁸ lying in the region 320–400 μ , light of these wave-lengths being transmitted by the glass used in this experiment. Stark,⁹ in his work on band spectra, has concluded that fluorescence and photoelectric properties are intimately associated with absorption in bands shaded toward the red, and that the “carriers” of the band spectra are the negative electrons, which are pulled out of their normal position by the incident light, and upon their return to the position of equilibrium liberate the energy of the fluorescent light.
3. If the separation of the electron is complete, photoelectric properties would be exhibited. It is thus that Stark and Steubing

¹ Camichel, *Jour. de Phys.*, 4, p. 873, 1905.

² Regner, *Phys. Zeit.*, 4, p. 862, 1903.

³ Hodge, *PHYS. REV.*, 28, p. 25, 1908.

⁴ Goldman, *Ann. der Phys.*, 27, p. 332, 1908.

⁵ Henry, *Proc. Camb. Soc.*, 9, p. 319, 1897.

⁶ Thomson, *Cond. through Gases*, p. 213.

⁷ Wiedemann and Schmidt, *Ann. der Phys.*, 56, p. 201, 1895.

⁸ Elston, *Astr. Jour.*, 25, p. 155, 1907.

⁹ Stark, *Phys. Zeit.*, 8, p. 81, 1907.

explain the fluorescence of solid anthracene.¹ After investigating a number of substances, they say: "It is highly probable that for organic substances, at least, the photoelectric effect and fluorescence are intimately connected with each other." Hence it would seem that the vapor of anthracene would be as likely as any vapor to possess photoelectric properties.

APPARATUS.

The glass tube used to contain the anthracene is shown in Fig. 1. The larger part of the tube was 15 cm. long and 2.5 cm. in diameter. The electrodes between which the current passes consisted of an outer

Fig. 1.

aluminum cylinder, to which connection was made by sealing a platinum wire through the glass at *M*, and an inner brass wire supported by a quartz tube *Q* and visible through the slit in the outer electrode.

The quartz tube served as insulation for the brass wire electrode. Further protection was afforded by a deposit of silver on the inside of the glass tube around the quartz, this silver layer extending around to the outside of the open end where it was wrapped with tinfoil and grounded to form a guard-ring. Thus no charge could leak over the glass surface from the outer electrode.

The openings at the outer end of the quartz tube were sealed with de Kochtinsky cement. This would not stand heating, and the furnace was arranged to enclose only the large part of the tube (see dotted outline in Fig. 2). It was necessary to have the quartz tube fit snugly in place and to provide a tight-fitting cap *C* at the inner end in order to prevent the sublimation of the anthracene to the colder parts of the tube.

The tube, after being charged with anthracene, was exhausted to

¹ Stark and Steubing, *Phys. Zeit.*, 9, p. 481, 1908. Also, Pochettino, *Nuo. Cim.*, 15, p. 171, 1906.

a pressure of a few tenths of a millimeter, sealed off, and heated electrically. Light from a carbon arc *A* was converged by the lens *L*, and could be passed into the furnace through a mica window or could be cut off by the screen *S*. When the light was on, a bright cone of violet fluorescence could be seen in the center of the tube.

The outer electrode was charged from a storage battery *B*, and the rate at which the inner electrode acquired a charge was measured by means of a sensitive Dolezalek electrometer, which was enclosed

Fig. 2.

in a wire cage to protect it from the electrostatic disturbances. The end of the anthracene tube projected through a hole in this cage, making the protection of the inner electrode practically perfect.

The electrometer needle was charged to a constant potential (in most of the work this was 60 volts), one pair of quadrants was grounded and the other pair connected to the wire electrode. This pair could be grounded or insulated at will by means of the key *K*. When *K* is raised the motion of the needle is noted by observing on a ground-glass scale the image of a lamp filament formed by the small concave electrometer mirror. The current can be calculated from the known constants of the electrometer.

If V_q be the potential of the charging quadrants;

K be the deflection when V_q is one volt;

C be the capacity of the charging system;

Q , the charge; D , the deflection; I , the current; then

$$D = K \times V_q \text{ and } Q = C V_q.$$

$$I = dQ/dt = C \times dV/dt = K \times C \times dD/dt$$

on the assumptions that K is the same for the moving needle as for the needle at rest and that C does not change with the position of the needle. Such assumptions are allowable for slow motion and small deflections.

OBSERVATIONS AND RESULTS.

$K = 375$ mm. on a scale one meter distant, when the potential of the needle was 60 volts.

C was determined by dividing the charge with a coaxial cylinder condenser of 30 cm. capacity, and was found to be 45 cm. or 5×10^{-5} microfarads.

A charging rate of 1 division per second could easily be observed if definite. This would mean a current 1.3×10^{-13} amperes. The insulation was such that the rate of leak when charged to 50 div. deflection was about 10 div. per minute, or one sixth the rate mentioned as easily measurable for charging.

At the low pressure used, anthracene vaporizes sufficiently to show fluorescence between 200° and 250° C. "90 per cent. sublimed" anthracene was used without attempt at purification as it was easily obtainable and the presence of impurities in the material does not seem to affect the fluorescence of the vapor. No attempt was made to shield the electrodes from the light scattered by the end of the tube, nor to use monochromatic light.

In liquids there is an electrode photoelectric effect, dependent upon which of the electrodes is illuminated. The possibility of the existence of such an effect in the vapor was not considered in this experiment.

In most of the work, the outer electrode was charged to 120 volts from an ordinary storage battery. K was raised and the rate of motion noted for the unilluminated tube. This was repeated with the light on.

When the tube was newly made up the electrometer remained quiet under all conditions, except for an occasional drift of not more than 1 division in 5 seconds. In the earlier work, after a few heatings, the electrometer began showing a tendency to rise rather quickly to a more or less definite deflection, regardless of conditions of potential or illumination. This peculiar effect varied from run to run and became very great in a case or two when the cement

with which the tube was sealed cracked and admitted air. A brown deposit was then left in the tube, apparently the result of a combination of the oxygen of the air with the anthracene.

A possible explanation of this attainment of a steady deflection even when the outer electrode was earthed is that the product of the decomposition of the anthracene is deposited on the quartz tube separating the silver guard-ring from the inner electrode and forms with these two metals a sort of voltaic cell. This "cell" had a very high temperature coefficient and in some cases the E.M.F. was so great as to throw the spot of light off the scale.

After several trials it was found possible, by taking great care to prevent the entrance of air, to get almost entirely rid of this effect. When this was possible the electrometer behaved normally.

No ordinary conduction was found. If the light had any effect it was too small to be detected. Thinking that the vapor under the action of the light might be almost ionized, an attempt was made to help out the ionization by exposing the vapor to the action of a small sample of radium bromide. The ionizing rays from this substance did not pass through the glass sufficiently to be of any use.

Higher potential was obtained by making up a set of small lead-sulphuric acid storage cells in test-tubes. This battery, when put in series with the one already at hand, gave from 360 to 540 volts, depending upon the condition of the small cells. The sensibility was increased by charging the electrometer needle to 120 volts. With the greater sensitiveness and the unsteady potential furnished by the cells, the electrometer wandered more or less in the neighborhood of the zero, but still did not indicate any steady rate of charging such as would have been evident had there been any considerable conductivity.

In the freshly exhausted tube the pressure was so low that the application of 400 volts caused a continuous luminous discharge through the tube, but this soon disappeared as the pressure rose due to the vaporization of the anthracene.

The number of trials was great enough to leave no doubt as to the behavior of the vapor under the various conditions mentioned.

CONCLUSIONS.

1. The conductivity of anthracene vapor at the temperature and density used in this experiment is too small to measure in the manner described.

2. The effect of fluorescence, if any exists, is too small to be found in this way.

The rate of leak of the electrometer system, while small, might mask a very slight effect. This matter, as well as the effect of pressure and temperature and of screening off the white light from the carbons of the arc, might be made the subject of any further investigation with this or another fluorescent vapor.

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