The great difficulty with the work is the fluctuating behavior of the machine, so that long observation is necessary to obtain the mean fringe deflection at each point.

Thus it appears that sharp surfaces of max. and of min. potential, respectively, surround the anode and cathode, the surfaces confronting each other and about half a mm. from the electrode plates. If the needle point of the mucronate electrodes penetrates these limiting surfaces a convection current is observed whose strength decreases rapidly as the needle protrudes further. At the surface there is usually a cuspidal maximum of current. If the needle point lies within the surface, it is inert and spark discharge, sputtering or purring may occur between any points of the electrode, while the convection current is absent. In how far these results conform with the usual equations for space charges I have yet to learn.

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* Advance note from a Report to the Carnegie Institution of Washington, D. C. See these PROCEEDINGS.

ON THE LAG OF THE KERR EFFECT

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Introduction.—Kerr discovered that certain liquids placed in an electrostatic field exhibit slight double refraction. The generally accepted explanation[1] of this phenomenon, called the Kerr effect, is that molecules possess definite optical anisotropy and that an electric field exerts an orientative influence on the molecules of the liquid, thereby giving rise to general optical anisotropy of the medium. Langevin originally assumed that the molecules are both optically and electrostatically anisotropic, the orientative action of the field arising from the couple exerted by the field on the electric moment induced along a preferential direction of the molecule. Born later took into account also the orientative couple of the electrical field due to the permanent moments of the molecules. A rather wide range of experimental facts indicate that this view of the mechanism of the Kerr effect is essentially correct. For example, Raman and Krishnan[2] have recently shown that data on the scattering of light by liquids, which are measures of the optical anisotropy of the molecules, fit in very well with estimates of molecular optical anisotropy made on the basis of the orientation theory and Kerr effect data.

Accepting the view that the orientation of the molecules by the electric field is responsible for the Kerr effect, one immediately infers that the Kerr effect is not instantaneous. That is, the molecules do not assume random positions at the same instant the electric field is relaxed because of opposing viscous and inertial forces. The orientation hypothesis leads to the conclusion that the time taken for the molecules to assume random positions, the so-called "relaxation time,"[3] varies directly as the frictional force (viscosity) exerted by the molecules on each other and inversely as the temperature of the medium. Thermal agitation is responsible for the dispersing of the array—and it is more violent at higher temperatures. Assuming the frictional force on a single molecule of water to be the same as that on a sphere of from $1/10^8$ cm. to $2/10^8$ cm. radius moving in a continuous medium having a coefficient of viscosity the same as observed macroscopically for water, it is calculated that the relaxation time is of the order of magnitude of from 10^{-10} sec. to 10^{-11} sec. It has been shown recently,[4] however, that for some liquids the observed lag of the Kerr effect (which, at first sight at least, one would expect to be of the same order of magnitude as the defined "relaxation time") is considerably greater—as much as $6(10^{-9})$ sec. for ethyl ether. The observations also indicated that the double refraction of the medium does not decay exponentially with the time after cut off the electrostatic field as the theory indicates, but that the double refraction persists for a definite length of time after cut off and then in a much shorter time interval disappears.

It is evident that experimental facts concerning characteristics of the lag in the Kerr effect would be of great value as a guide to a formulation of a satisfactory theory of the influence of electric fields on molecules in gases or liquids—leading thereby to an enhanced conception of the nature of inter-molecular forces. With this in mind we have carried through the following experiments.

The Experiments

These experiments involved measuring the differences in the lag of the Kerr effect behind the electric field for the liquids in two Kerr cells K_1 and K_2. The procedure of this measurement has been described elsewhere.[4] However, to recall it to mind, it may be remarked briefly that (referring to the diagram) the two cells K_1 and K_2 are so oriented between crossed Nicol prisms N_1 and N_2 that they produce equal and opposite ellipticity of the plane polarized light from N_1 when the electric field between the plates of the two cells are equal. Under these circumstances no light passes N_2 when the same electrostatic voltage exists across both cells simultaneously. A transformer T charges a condenser C which is discharged across the spark gap SG, the light therefrom passing through the Nicol N_1 and through the Kerr cells K_1 and K_2 and (if ellipticity of the plane polarized light is produced on passing through K_1 and K_2) through the crossed Nicol N_2 to the observer's eye or through a spectroscope S to the eye. The plates of the cells K_1 and K_2 are connected across the spark gap by leads of variable length, T_1 and T_2, so that during charging of the condenser a voltage across the plates is also impressed. On discharge of the spark, the voltage across the plates is suddenly relaxed at a time after the beginning of the spark equal to the wire paths connecting plates to the spark gap divided by the velocity of light. Because of the compensating effect of both Kerr cells no light would emerge from N_2 in case (1) the lags of the disappearance of the Kerr effects in the two cells behind the cut off of the electric field between the plates were equal and (2) the wire paths to the two cells from the spark gap were equal. In case, however, the wire paths to the two cells were the same but the lags were different there would exist a time interval during which the liquid in one of the cells only is doubly refracting. Such a situation would evidence itself by light emerging from N_2. By increasing the wire path to the cell containing the liquid having the sorter lag the effect of difference of lags could be compensated. It is clear that the difference in the time lags is equal to the differences of the wire paths to the two cells from the spark gap divided

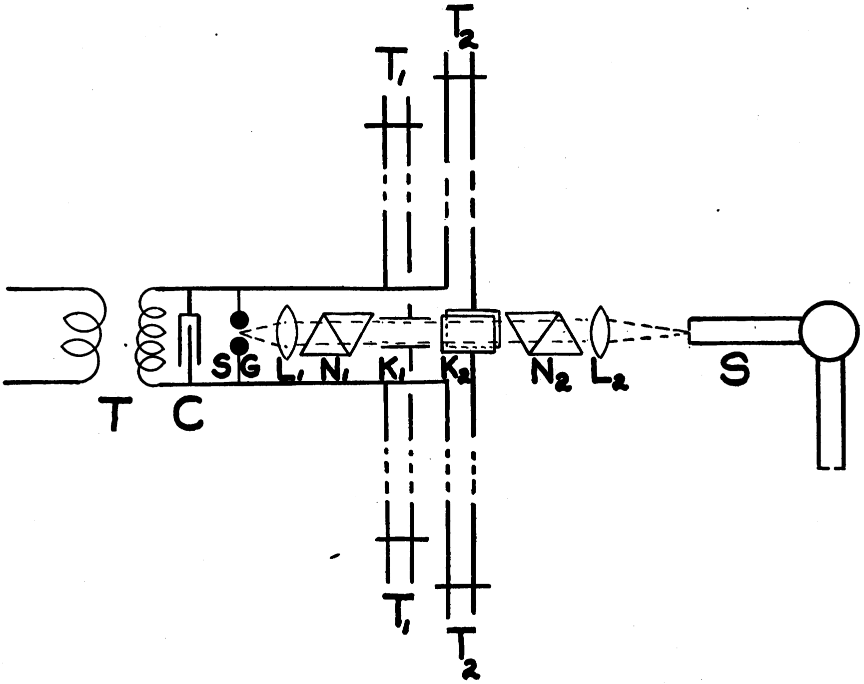

Diagram of the experimental arrangement for measuring the lag in the Kerr effect.

by the velocity of light—when the wire paths are so adjusted that no light emerges from N_2. The measurement of the lag differences, therefore, consisted in observing the wire paths differences necessarily introduced to extinguish the light as observed through N_2.

The Lag of the Kerr Effect as a Function of the Wave-Length of the Light.—The light emerging from N_2 was resolved by the spectroscope S and measurements were made on the differences between the lags of carbon bisulphide and several liquids for various wave-lengths of visible light. *It was found that for all wave-lengths the lags were the same and were as follows:*

Bromoform $3.3(10^{-9})$ sec. Chloroform $3.8(10^{-9})$ sec. Ethyl ether $6(10^{-9})$ sec., the values being the lags in excess of the lag in carbon bisulphide. A previous experiment[5] indicated that the absolute value of the lag in carbon bisulphide is very small—less than $3(10^{-9})$ sec. The values for chloroform and bromoform are probably correct to $5(10^{-10})$ sec. while the value for ethyl ether is hardly more accurate than to 10^{-9} sec. because of its low Kerr constant and attendant experimental difficulties.

The Influence of Electric Polarity of the Molecules on the Lag of the Kerr Effect.—It is known[6] that bromoform, chloroform and ethyl ether are polar while carbon bisulphide is not. The first three substances exhibit lags considerably greater than a possible lag in carbon bisulphide, the magnitude of their excess being roughly proportional to the magnitude of their permanent electric moments. This fact suggested that the lag may be directly dependent on the existence of permanent dipoles in the molecules. To substantiate this view the lag in benzene was measured relative to carbon bisulphide—as benzene likewise is known to be nonpolar. It was found that this substance exhibits no appreciable lag relative to the lag of carbon bisulphide. The measurements were especially difficult because of the small Kerr constant of benzene but it is probable that a difference in lags as great as 10^{-9} sec. would have been detected. This result makes it highly probable that *only polar molecules exhibit lags as great as* 10^{-9} *sec.*

The Influence of Temperature on the Lag of the Kerr Effect.—The theory of "relaxation times," which presumably are proportional to the "lags" here measured, leads to the conclusion that the lags are proportional to the viscosity and inversely proportional to the temperature. To test this, chloroform was placed in both Kerr cells and by a suitable cooling system the liquid in one of the cells was cooled from room temperature, 25°C. to -5°C. It was found that when the two cells were at the same temperature and the wire paths were equal no light emerged from N_2 and that when one of the cells was cooled light did pass the combination. By shortening the wire path to the cooled cell, again the light through N_2 was extinguished, indicating a greater lag in the cooled cell. Careful measurements showed the difference in the lags between room temperature and -5 °C. to be about 2 (10^{-9}) sec. Here again the measurements were difficult and the magnitude of the value cannot be trusted to within 10^{-9} sec. The important thing, however, is that a *definite increase in the lag with temperature was observed.* It was also noticed that the lag seemed to increase more rapidly than the reciprocal of the temperature indicating therefore, on the basis of the theory, that frictional forces on the molecules increased with decrease of the temperature of the liquid.

Discussion

On the orientation hypothesis it is concluded that the lag in the Kerr effect is due wholly to molecular, frictional and inertial forces which give rise to finite times of orientation and, therefore, that the lag is quite independent of the wave-length of the light. Our observations insofar as they verify this conclusion support such a theory of the Kerr effect. The fact that only polar molecules exhibit appreciable lags is not so apparent from the theory because, presumably, non-polar molecules assume definite arrays when producing a Kerr effect in a liquid, and it seems reasonable to expect that the time required for assuming random orientations would be of the same magnitude for such a non-polar array as for a group of oriented polar molecules. However, an explanation of the experimental observations is probably to be sought in the influence of the polarization of the liquid as a whole in tending to maintain the spacial array of the molecules. It is probable that the polarization due to the induced moments disappears more rapidly than the polarization arising from permanent doublets in the molecules and, therefore, that the forces tending to resist thermal disruptions of the array persist longer in polar liquids. The fact that the lag increases with decrease in temperature is emphatic in support of the hypothesis of molecular array. The theory in its present form hardly can account for the manner in which the Kerr effect decreases after cessation of the electric field. Our observations indicate that the Kerr effect persists quite undiminished for a definite time after relaxation of the field and then in a much shorter time disappears—as though a condition of instability of the molecular array is attained at a definite time after the relaxation of the electric field at which moment the array suddenly collapses. It is not at all inconceivable that this collapse of the orientation of the molecules proceeds in a manner described by the theory—decreasing to $1/e$th of its value in from 10^{-10} sec. to 10^{-11} sec.

We wish to thank Professor P. Debye for emphasizing to us the importance of determining the dependence of the lag of the Kerr effect on temperature. We also wish to thank Mr. T. H. Rider of the department of chemistry for purifying a quantity of benzene and bromoform for our experiments. Finally, we record with pleasure our indebtedness to Professor W. F. G. Swann for his interest in this work.

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[1] A good account of the subject by P. Debye is contained in Marx's *Handbuch der Radiologie*, Bd. 6, pp. 754–776.

[2] C. V. Raman and K. S. Krishnan, *Phil. Mag.*, **3**, pp. 713–735.

[3] The relaxation time is defined as the time required for the orientation of the molecules to diminish to 1/*e*th of the extent of the orientation when the field is on.

[4] Beams, *J. O. S. A. & R. S. I.*, **13**, p. 597; Beams and Allison, *Phil. Mag.* (in press).

[5] An experimental investigation of the lag in the photo-electric effect led to the conclusion that the sum of the lag of the Kerr effect in carbon bisulphide and the lag of the photo-electric effect from a potassium surface is not greater than $3(10^{-9})$ sec. We read a paper on this research at the April meeting of the American Physical Society (abstract in press) and shall publish details later.

[6] O. Blüh, *Phys. Zeit.*, No. 8, p. 226 (1926); C. P. Smyth, *J. Am. Chem. Soc.*, **46,** p. 257 (1924); R. Sänger, *Phys. Zeit.*, No. 17, p. 556 (1926).

MOBILITIES OF IONS IN ACETYLENE HYDROGEN MIXTURES

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Introduction.—In a recent paper by Erickson[1] on the variation of mobilities of gas ions with age in acetylene results of theoretical importance were obtained. The important result from the viewpoint of this work was the discovery that apparently *neither the positive nor the negative ion in acetylene showed a change in mobility with age within time intervals greater than 0.002 second, while at the same time* the mobility was *slightly greater for the negative ion than for the positive ion.* In H_2, Erickson[2] had earlier found an aging effect on the positive ion in which the mobility changed in time from a value a *little less than that of the negative* to the value normally ascribed to the positive ion, which is about 0.60 that of the negative ion. In all other gases, the positive and negative ions had the *same initial mobility within the limits of experimental error,* and the positive ions with age acquired that mobility less than that of the negative ion, which is generally observed. Gases in which the final negative ion has a mobility less than the positive ion have not been investigated although experiments on this subject are being undertaken in this laboratory.

The conclusion which Erickson draws from the aging experiments is that the initial ions, positive and negative, are monomolecular ions whose mass influences the mobility to a negligible amount, but whose mobility depends on the diameter or "apparent" diameter of the ion. The aged ion has been shown by Erickson to be generated in a unitary process, no intermediate steps being observed. This led him to the conclusion that