Quantitative Determination of Nickel in the Presence of Chromium. When alpha benzildioxime is added to the ammoniacal solution of a nickel salt, the nickel is precipitated quantitatively as the nickel derivative of the dioxime. However, if chromic salts are also present, they contaminate the precipitate even when tartrates or citrates have been added to the solution. FREDERICK G. GERMUTH of the Department of Public Works of Baltimore (*Chemist Analyst*, 1928, *17*, No. 2, pages 3, 7) finds that the addition of a minute quantity of cupric ammonium chloride to the solution prior to precipitation of the nickel prevents occlusion of chromium in the nickel precipitate, and thus increases the accuracy of the determination. J. S. H.

Hydrogen Peroxide. A. C. CUTHBERTSON, G. L. MATHESON AND O. MAASS of McGill University (*Jour. Am. Chem. Soc.*, 1928, *50*, 1120–1121) find that pure hydrogen peroxide has a melting point of — 0.89° C., and a density of 1.4649 at 0° C. J. S. H.

ON RELAXATION OF ELECTRIC FIELDS IN KERR CELLS AND APPARENT LAGS OF THE KERR EFFECT.

BY

J. W. BEAMS, PH.D. AND ERNEST O. LAWRENCE, PH.D.

INTRODUCTION.

WHEN an electric field is impressed between parallel plates immersed in carbon bisulphide it is found that the liquid becomes doubly refracting. This phenomenon, called the Kerr Effect, has been known for a long time and has been used in various ways in optical investigations involving very short time intervals. Recently one of the authors [1] made use of a modification of the method of Abraham and Lemoine [2] in a study of the relative times of appearance of spectrum lines in spark discharges and later [3] carried out some experiments which indicated that in some liquids the Kerr effect lags behind a rapidly changing electric field. During the past year the authors [4] studied the photo-electric effects produced by short flashes of light and also investigated in further detail the apparent lags of the Kerr effect in various liquids. The present work is a continuation of these experiments.

EXPERIMENTAL ARRANGEMENT AND THEORY OF THE METHOD.

The experimental arrangement for the study of lags in the Kerr effect and for the production of short light flashes centers around two Kerr cells, K_1 and K_2, placed between crossed Nicol prisms, N_1 and N_2. The normals to the surfaces of the plates of one cell are at right angles to the normals to the surfaces of the other pair of plates and both sets of normals make angles of forty-five degrees with the electric vector of the plane polarized light passing between the plates from N_1.

[1] Beams, *Phys. Rev.*, Vol. 28, p. 475, 1926.

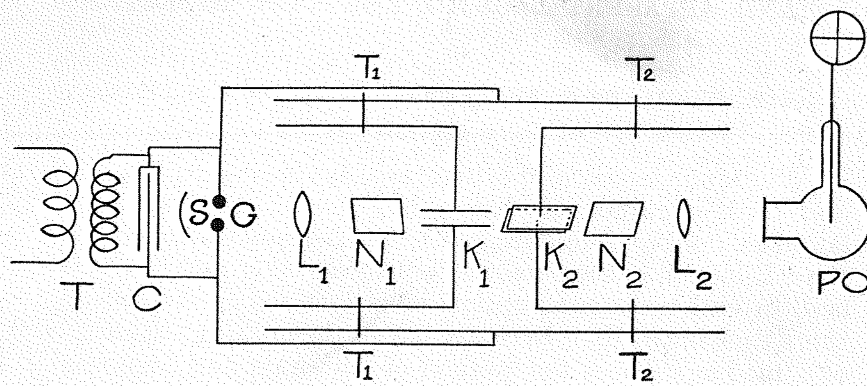
[2] Abraham and Lemoine, *Comp. Rend.*, Vol. 130, p. 245 (1900).

[3] Beams and Allison, *Phil. Mag.*, Vol. 3, p. 1199, 1927.

[4] Lawrence and Beams, *Proc. Nat'l. Acad.*, Vol. 13, p. 207 (1927). Beams and Lawrence, *Proc. Nat'l. Acad.*, Vol. 13, p. 505 (1927).

As the diagram indicates, (Fig. 1), the plates are attached to the spark gap SG by wires of variable length T_1T_2, the spark gap being also the source of light for the Nicol prism-Kerr cell optical system.

FIG. 1.



Prior to the discharge of the spark the potential difference applied across the spark gap by the transformer T and condenser C is also impressed across K_1 and K_2. Being at right angles to each other, however, the ellipticity of the light produced by the double refraction in K_1 is compensated by the opposite double refraction in K_2 and therefore the light emerges from K_2 plane polarized and unable to pass through N_2. On discharge of the spark a steep discharge wave is propagated along the wires and at a time after the beginning of the spark discharge equal to the wire path divided by the velocity of light the cells begin their discharge. Thus, for example, if the leads to K_2 are longer than the leads to K_1, K_1 will begin discharging before K_2 and during the period when the fields between the plates are unequal the light will be elliptically polarized and a portion of the light from N_1 will emerge from N_2.

The intensity of the light emerging from the Nicol N_2 is a function of the differences of the birefringence in the two cells and, indeed, because of the small values actually operative in the present experiments, the intensity of the light is proportional to the square of the differences in the retardations of the electric vector. The double refraction being

proportional to the square of the electric field between the cell plates, it follows that the intensity of the light I is

$$I = I_0(V_1^2 - V_2^2)^2,$$

where V_1 and V_2 are the voltages across K_1 and K_2 at any time t and I_0 is the proportionality constant which of course depends on such factors as the Kerr constant of the liquids, the size of the Kerr cells, the intensity of the light entering N_1, etc.

In order to obtain a qualitative theory of the action of the electro-optical arrangement it is assumed that the electric field between the Kerr cell plates disappears exponentially in time after the discharge wave strikes the cell. Thus, if the leads to the Kerr cells differ in length by l cms. such that K_1 begins its relaxation of the electric field at time t_1 and K_2 at a corresponding time $t_2 + t_l$, where $t_l = l/c$, c being the velocity of light, the intensity of the light emerging from N_2 at any time prior to t_1 will be zero (for the cells are arranged so that each shall compensate the effects of the other when both are charged to the same voltage) and in the time interval t_1 to $t_1 + t_l$ the intensity will be

$$I_{t_1}^{t_1+t_l} = I_0 V^4(1 - e^{-2\alpha_1 t})^2,$$

and for all values of t greater than $t_1 + t_l$ the intensity of the transmitted light will be proportional to

$$I_{t_1+t_l}^{\infty} = I_0 V_0^4(e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2,$$

where of course α_1 and α_2 are the exponential time constants which determine the rapidity of relaxation of the electric field in K_1 and K_2, respectively.

The total flux of light energy through N_2 consequently is

$$E = E_0 \int_{t_1}^{t_1+t_l} (1 - e^{-2\alpha_1 t})^2 dt + E_0 \int_{t_1+t_l}^{\infty} (e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2 dt,$$

which reduces on integration to

$$E = E_0 \left[t_l + \frac{\alpha_2}{(\alpha_1 + \alpha_2)\alpha_1} e^{-2\alpha_1 t_l} + \frac{\alpha_1 - 3\alpha_2}{4\alpha_1\alpha_2} \right]. \qquad (1)$$

If the Kerr cells are identical in shape and are placed symmetrically with respect to other parts of the electrical circuit their time rates of discharge are equal, i.e.,

$$\alpha_1 = \alpha_2 = \alpha.$$

For such a special case, equ. (1) reduces to

$$E = E_0\left[t_l + \frac{1}{2\alpha}(e^{-2\alpha t_l} - 1)\right]. \tag{2}$$

Clearly for $t_l = 0$, that is, when the wires connecting the cells to the spark gap are of the same length the birefringence in the two cells compensate for all time and the flux of light from N_2 is zero.

It is equally evident from equation (1) that in case $\alpha_1 > \alpha_2$ the flux of energy from N_2 is not zero when $t_l = 0$ and indeed the energy flux is not even a minimum. The value of t_l for which E is a minimum is of course the value which satisfies the condition,

$$\frac{dE}{dt_l} = 0$$

and is

$$t_m = \frac{1}{2\alpha_1}\log\left(\frac{2\alpha_2}{\alpha_2 + \alpha_2}\right). \tag{3}$$

Thus, if the voltages across the plates of the Kerr cells decrease exponentially at different rates typified by the constants α_1 and α_2, the maximum extinction of the light is attained when the wire paths to the two cells are unequal by the amount l cms. where

$$l = ct_m.$$

Substituting this value of t_m in equ. (1) we have an expression for the magnitude of the flux of energy through the shutter when the wire paths are arranged to give greatest extinction, viz.,

$$E_m = \frac{1}{2\alpha_1}\left[\log\left(\frac{2\alpha_2}{\alpha_1 + \alpha_2}\right) + \frac{\alpha_1 - 3\alpha_2}{2\alpha_2} + 1\right]. \tag{4}$$

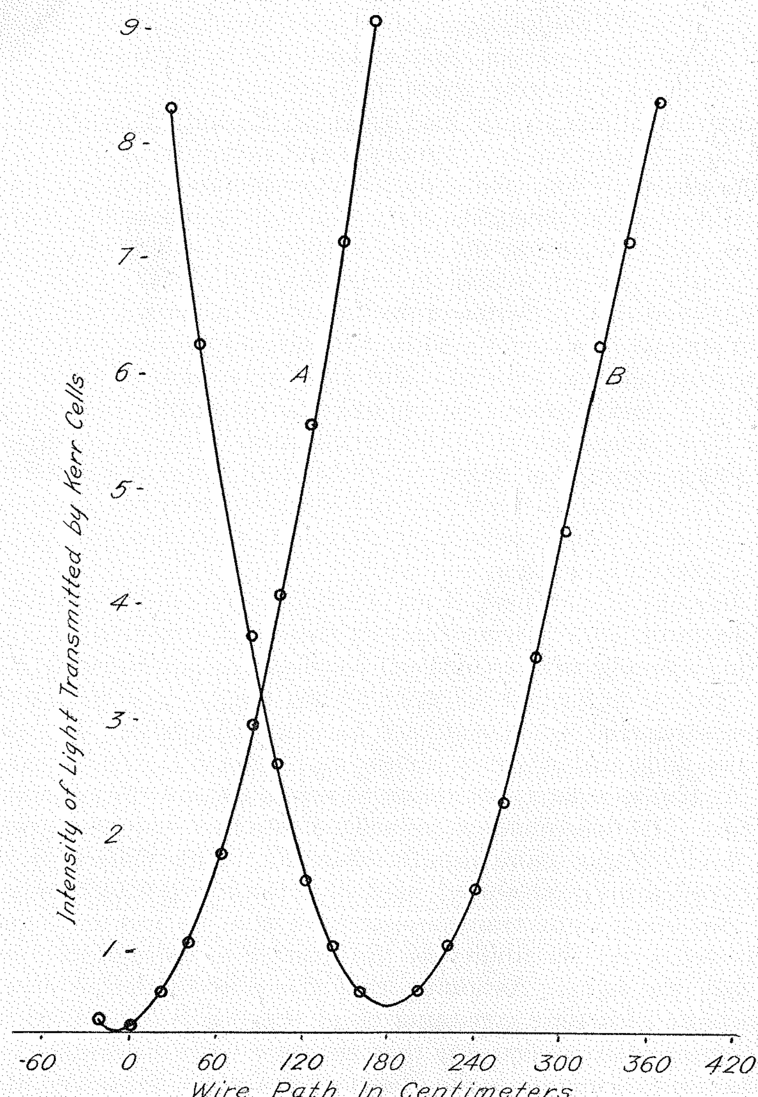
It is easy to see, moreover, that different rates of discharge of the Kerr cells irrespective of the mode of discharge, would always be in evidence by such lack of complete extinction of the light through the optical system.

EXPERIMENTAL OBSERVATIONS.

Fig. 2 exhibits results which are typical. Curve A is a plot of the photo-electric current produced in a photo-cell PC due to light emerging from N_2 corresponding to various differences of lengths of lead wires to K_1 and K_2 when K_1 and K_2 are identical in dimensions and symmetrically placed in the circuit. The photo-electric current, and therefore the amount of light emerging from N_2, is zero when the wires to the two cells are of the same length, the extinction of the light being perfect within the experimental error. Curve A is the theoretical variation of the flux of radiation as calculated from equ. (2) assuming α to be 10^8; the circles represent the experimental observations. The close agreement of the data with the curve cannot be regarded as definitely indicating that the voltage across the Kerr cell plates drops in an exponential manner; an appreciably different type of discharge would give rise to very similar data. It may be inferred with considerable confidence, however, that the discharge takes place in less than 10^{-8} sec.

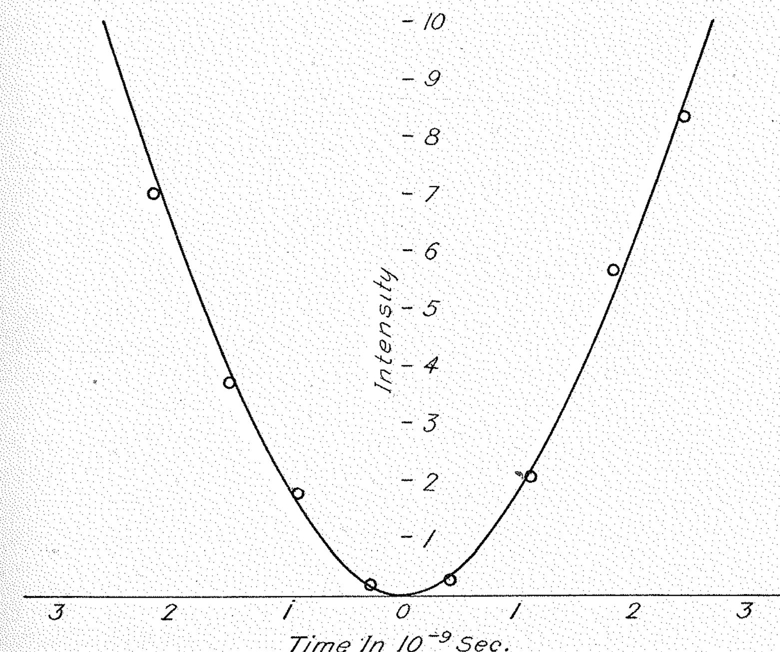
The circles of Curve B are a similar plot of the observed amounts of light passing through the optical system for the same Kerr cells with a third cell K_3 placed in parallel with K_2. The plates of K_1 and K_2 were 8 cms. long, 1 cm. wide and were separated by 0.5 cm. of carbon bisulphide. K_3 was 15 cms. long and otherwise similar to K_1 and K_2. The system K_2 K_3 had a capacity therefore of about 3 times the capacity of K_1. The differences of capacity of the two systems caused K_1 to discharge more rapidly than K_2. This difference of rates of discharge produced the shift of the wire path difference for minimum light transmission from zero to 180 cms. and also destroyed the ability of the shutter to extinguish completely the light. Assuming that the cells discharge exponentially with time constants of $\alpha_1 = 10^8$ and $\alpha_2 = \frac{1}{3}\cdot 10^8$ it is computed from equ. (3) that the wire path differences for maximum extinction is the observed 180 cms. However, the variation of the flux of light through the optical system with different relative wire paths to K_1 and K_2 is very much different from the variation to be expected from equation (1). Indeed, the minimum flux of light is less than a tenth of the

FIG. 2.



amount predicted by equ. (4). It appears therefore that an exponential discharge cannot account quantitatively for the action of the Kerr cells. The fact that there are very marked shifts of relative wire paths for maximum extinction of the light, the light extinction nevertheless being so nearly complete, indicates that the discharge is less rapid initially and more rapid in its later stages.

FIG. 3.



The dependence of the rate of discharge on the capacity of the cells suggested that cells of smaller capacities would yield much more rapid relaxations of the birefringence. Cells having plates 2 cms. long with otherwise similar dimensions to the 8 cms. cells gave the data of Fig. 3 where the curve is the theoretical curve, [equ. (2)] with $\alpha = 2 \cdot 10^8$ and the circles represent the experimental observations. Also, inserting correspondingly small capacities in parallel with the cells gave rise to differences of wire paths to the two cells for extinction of the light which interpreted by equ. (3) indicated such larger values of α and therefore more rapid decay of the double refraction. However, the change in α with change in capacity was not linear and seemed to approach a limiting value for cells of these dimensions.

DISCUSSION.

The way in which the Kerr cells discharge clearly depends not only on their capacities and the inductance and resistance (resistance being negligible) of the connecting wires but also on the rate of fall of voltage across the spark gap and the steepness of the discharge wave which travels along the wires from the spark gap to the Kerr cells. A very interesting research having an important bearing on these considerations has recently been carried out by Rogowski, Flegler and Tamm.[5] They have studied the form of wave fronts traveling along parallel wires 60 meters long resulting from suddenly impressing a voltage at one end by closing a switch, a Braun tube oscillograph being attached at the other end. Their photographs show in most cases wave fronts steeper than they were able to detect, although slopes of $3 \cdot 10^{-8}$ sec. should have been quite evident. On increasing the speed of the time axis such as easily to resolve less than 10^{-8} sec. they found that the wave fronts were even steeper than 10^{-8} sec., although a slight slope was in evidence. The small slope which they observed was probably largely due to the finite rate of charging of the deflecting plates of the oscillograph having capacities of about 6 cms. They concluded that the capacity of the plates was negligible because it was observed that placing a capacity of 10 cms. in parallel with the deflecting plates produced no appreciable change in observed effects. However, this test was carried out using a slower time axis which was incapable of resolving effects of 10^{-8} sec. duration. Even with the slower time axis a very marked effect was produced when plates of 20 cms. capacity were inserted in parallel with the deflecting plates, the magnitude of the effect being such as to make it quite evident that the capacity of the oscillograph determined the steepest observed slopes. Their very fine technique led also to a study of the time of break down of spark gaps. They found that the voltage across a spark gap drops to a small value in less than 10^{-8} sec. even when the platinum points of the spark gap were 6 cms. apart.

[5] Rogowski, Flegler and Tamm, *Archiv. für Elektrotechnik*, Vol. 18, p. 479 (1927).

The general conclusion to be gained from their research therefore is that the wave fronts traveling down the wires in the present experiments had slopes extending over less than 10^{-8} sec. and consequently that the inductance of the lead wires and the capacity of the Kerr cells determined largely the nature of the fall of voltage across the plates. If the effect of resistance of the lead wires were large compared to the effect of their inductance the voltage would have dropped exponentially as has been assumed above in the theory of the action of the optical system. A simple computation shows, however, that the resistance of the wires was negligible and therefore the discharge, instead of falling off exponentially, because of the inductance, was less rapid initially and more rapid in its later stage. As pointed out in an earlier paragraph this estimate of the nature of the discharge is in accord with a reasonable interpretation of the experimental data of curve *B*, Fig. 2.

In a study of the photo-electric effects produced by flashes of light emerging from the electro-optical shutter corresponding to various differences of wire paths to the two cells, it was concluded that flashes as short as 10^{-10} sec. duration were produced. In view of the present definite evidence for the very appreciable discharge rates the former conclusion must be modified. The shortest flashes produced were more probably of the order of magnitude of 10^{-9} sec. duration.

Experimental observations in the past which have been interpreted as evidence of a lag of the Kerr effect behind the electric field are, on the basis of the present work, more probably due merely to the different capacities of cells containing dissimilar liquids having various dielectric constants.

In 1913 Gutton[6] carried out some experiments which were interpreted as indicative of very considerable lags of the Kerr effect in various liquids. He arranged two Kerr cells with their plates at right angles to each other between crossed

[6] Gutton, *Jour. d. Phys.*, Vol. 3, p. 445 (1913).

nicols and adjusted the distance apart of one of the pairs of plates so that the Kerr effects produced in each cell were compensated, thereby extinguishing the light observed through the crossed nicol. He found that, with different liquids in the two cells, although their Kerr effects compensated for equal applied static voltages, extinction of the light was not attained when sufficiently high frequency alternating voltages were used. He found it necessary to increase the field in one of the cells by a readjustment of the separation of the plates in order to regain extinction. This was interpreted as indicating that the Kerr effect in one of the liquids was unable to build up as rapidly as the changing electric field and therefore required a larger capacity, i.e., greater electric field to produce sufficient birefringence to compensate the double refraction in the other cell. It is more probable that the cell of larger capacity did not charge up to the same potential as the smaller cell and for this reason alone compensation was not attained at high frequencies.

The two cells containing different liquids when adjusted to compensate each other with equal static potential differences across the pairs of plates will have capacities proportional to the ratio of the dielectric constant to the Kerr constant of the liquids. This is true because a large Kerr constant requires a small cell to produce a given birefringence and for given dimensions of the plates the capacity of course is proportional to the dielectric constant. It is to be expected therefore that a cell containing a liquid having a large value for this ratio would have a relatively slow charging and discharging rate and would apparently exhibit a lag of the Kerr effect relative to the Kerr effect in the other cell containing a liquid having a smaller value for this ratio. This is really what Gutton observed as the table below indicates.

Pairs of Liquids.	Ratio $\frac{\text{Dielectric constant}}{\text{Kerr constant}}$.	Lag of Kerr Effect.
Nitrobenzene	.0046	0.6 (10^{-8} sec.)
Bromonapthalene	.016	
Nitrobenzene	.0046	1.4 (10^{-8} sec.)
Carbonbisulphide	.026	
Carbonbisulphide	.026	1.7 (10^{-8} sec.)
Toluene	.10	

The first column lists the pairs of liquids examined, the second column records the ratios of the dielectric constant to the Kerr constants (which are proportional to the capacity of the cells containing the liquids) for the various liquids and the third column contains the observed apparent excess lag of the Kerr effect in the second liquid relative to a lag in the first. It is seen that in all cases the cell having the larger capacity contained the liquid exhibiting the larger apparent lag of the Kerr effect. Consequently, it is to be concluded that his observations cannot be regarded as measures of lags in the Kerr effect but are the results of capacity effects.

The observations in the past [3] using the technique involved in the present experiments which were interpreted as observations of lags of the Kerr effect are quite evidently also due to capacity effects. The extinction of the light passing through the optical system was so nearly perfect in experiments of this sort—although the rates of discharge were sufficiently different to require very marked differences in wire paths to the cells to obtain extinction—that a relative lag of the Kerr effect in one of the liquids presented itself as the most reasonable interpretation of the phenomenon. However, the present work makes such a view quite out of the question.

There is, therefore, at the present time no experimental evidence for the existence of a lag of the Kerr effect behind rapidly changing electric fields. This conclusion is quite in accord with prevailing theories of the Kerr effect which predict such lags to be considerably less than were detectable by any of the mentioned experiments.

SLOANE LABORATORY,
YALE UNIVERSITY,
June 12, 1928.

Journal
of
The Franklin Institute

DEVOTED TO

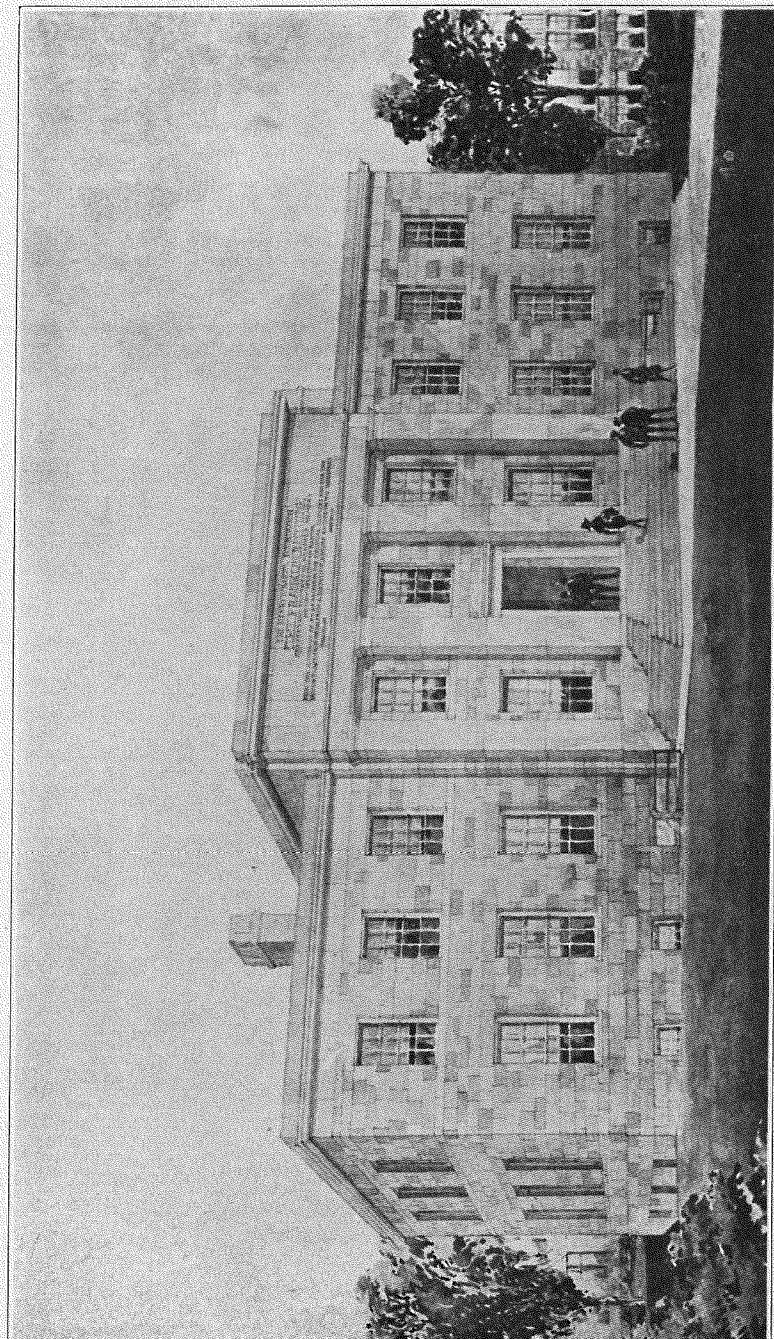
SCIENCE AND THE MECHANIC ARTS

VOL. 206.—Nos. 1231–1236
(103d YEAR)

JULY–DECEMBER, 1928

PHILADELPHIA
THE FRANKLIN INSTITUTE
15 South Seventh Street
1928

u. v. 82 –



BARTOL RESEARCH LABORATORY OF THE FRANKLIN INSTITUTE.

Journal of The Franklin Institute

Devoted to Science and the Mechanic Arts

Vol. 206 AUGUST, 1928 No. 2

PHYSICO-CHEMICAL CONSIDERATIONS IN ASTROPHYSICS.*

BY

PROFESSOR DOCTOR WALTHER NERNST,

Professor of Physical Chemistry, University of Berlin.

AMONG the greatest advances which astrophysics has made in recent years, undoubtedly belong the apparently extremely reliable determination of the age of the earth, which has been arrived at on the basis of measurements by numerous investigators using the methods and theories of radio-activity. It is now regarded practically everywhere as certain that the production of the solid crust of the earth took place about sixteen hundred million years ago.

We make the following assumptions:

1. The earth was split off from the sun as a ball of fire of high temperature.

2. The Universe is in a stationary condition, that is, the present fixed stars cool continually and new ones are being formed.

So far as the first assumption is concerned, I cannot conceive that it can really be brought into question; all other assumptions, of whatever character, appear so extremely artificial that they, at least for the present, can scarcely be dis-

* Read by Dr. Irving Langmuir.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)