PROCEEDINGS

OF

THE ROYAL SOCIETY.

February 25, 1897.

The LORD LISTER, F.R.C.S., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "Note on the Dielectric Constant of Ice and Alcohol at very Low Temperatures." By JAMES DEWAR, M.A., LL.D., F.R.S., Fullerian Professor of Chemistry in the Royal Institution, London, and J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London.

II. "On the Relation between Magnetic Stress and Magnetic Deformation in Nickel." By E. TAYLOR JONES, D.Sc. Communicated by Professor ANDREW GRAY, F.R.S.

III. "On the Relations between the Cerebellar and other Centres (namely Cerebral and Spinal) with especial reference to the Action of Antagonistic Muscles. (Preliminary Account.)" By MAX LÖWENTHAL, M.D. (Würz.), M.R.C.P., and VICTOR HORSLEY, F.R.S., F.R.C.S.

IV. "On the Action of Light on Diastase and its Biological Significance." By J. REYNOLDS GREEN, Sc.D., F.R.S., Professor of Botany to the Pharmaceutical Society of Great Britain.

V. "Fragmentation in *Lineus gesserensis*." By ALEX. BROWN, M.B., B.Sc., M.A., Lecturer in Zoology, and Senior Assistant in the Natural History Department, University of Aberdeen. Communicated by Professor McINTOSH, F.R.S.

"Note on the Dielectric Constant of Ice and Alcohol at very Low Temperatures." By JAMES DEWAR, M.A., LL.D., F.R.S., Fullerian Professor of Chemistry in the Royal Institution, London, and J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London. Received January 27,—Read February 25, 1897.

Of late years many careful determinations have been made of the dielectric constants of water and ice by different observers. These evaluations may be divided into two classes. Firstly, those which are, strictly speaking, determinations of the specific inductive capacity of the material, and have been made by measuring the change in the capacity of a condenser when water or ice is substituted for air as the dielectric. Secondly, those which are really measurements of the electrical refractive index of water or ice for electric waves of various lengths, and which have been generally made by obtaining the reduction in wave-length experienced by an electric wave on passing from air into water or ice. The square of this refractive index or the ratio of wave-length reduction is then taken as the dielectric constant.

In order that results thus recently obtained may be compared, we have collected into two tables (I and II) some of the values for the specific inductive capacity, and the electric refractive index of water for waves of various lengths.

The determinations of the specific inductive capacity quoted all appear to have been made by methods which, whilst excluding, or believed to exclude, error arising from the conductivity of the water, may yet be regarded as giving the value corresponding to comparatively slow reversals of electromotive force or to waves of infinite wave-length. The electric refractive index observations have been made by using electric waves of lengths in air varying from 8 mm. to 600 cm.

Two very careful determinations of the specific inductive capacity of water seem to be those of W. Nernst (80·0 at 17° C.) and F. Heerwagen (= 80·88 at 17° C.), and that of J. F. Smale is in close agreement with that of Nernst.

As regards the electrical refractive index, it will be seen that the determinations of P. Drude for waves of 70 cm., which give $\mu =$ 8·95, and hence $\mu^2 = 80{\cdot}2$ at 17° C., and those of Cohn and Zeeman, which give $\mu = 8{\cdot}91$ and $\mu^2 = 79{\cdot}39$, as a mean value for waves from 155 to 560 cm. in length, are in fairly close agreement with one another, and with the best determinations of specific inductive capacity.

Table I.—Determinations of the Dielectric Constant (Specific Inductive Capacity) (K) of Water by Various Methods.

Observer.	Reference.	Value found.	Method.
W. Nernst ...	'Zeits. phys. Chem.,' 1894, vol. 14, pp. 622—633	80·00 at 17° C.	By condensers balanced on a Wheatstone's bridge arrangement using a telephone as detector.
C. B. Thwing	'Zeits. phys. Chem.,' 1894, vol. 14, pp. 286—300	75·5	By resonance of two electrical circuits. Capacity in each adjusted to identity.
L. Graetz and L. Fomm	'Wied. Ann.,' 1895, vol. 54, pp. 626—640	73·54	By deflection of a dielectric ellipsoid suspended in water in an electric field.
T. F. Smale ..	'Wied. Ann.,' 1896, vol. 57, pp. 215—222	80·05	By using an electrometer filled with water.
F. Heerwagen	'Wied. Ann.,' 1893, vol. 49, p. 279	80·88 at 17° C.	By using a double electrometer, one filled with water. Reversals of polarity 42—85 per second.
A. Franke....	'Wied. Ann.,' 1893, vol 50, p. 163	81·65 at 17° C.	By using a double electrometer and reversals of polarity made by an induction coil.
W. K. Röntgen	'Wied. Ann.,' 1894, vol. 52, pp. 593—606	86·0	By alternate currents and condenser.
E. B. Rosa ...	'Phil. Mag.,' 5th ser., vol. 31, 1891, p. 188	75·7 at 25° C.	By attraction of plates of a condenser, alternating potentials used. 2000 to 4000 reversals per minute.

The general results show that the square root of the specific inductive capacity of water as determined by relatively slow-speed electrostatic methods is expressed by a number which is not very different from that which denotes the refractive index of water for electrical waves varying in length from 8 mm. to 600 cm. Maxwell's law is, therefore, fulfilled in the case of water under these conditions.

The general evidence at disposal does not indicate any very marked dispersive power on the part of water for electric waves varying in length between the above-named limits; though the careful results of P. Drude in 1896, for waves from 40 to 200 cm. in length, taken by themselves, indicate a slight normal dispersion, the refractive index increasing with decreasing wave-length. Change of temperature has a marked effect upon the electrical refractive index, and conclusions cannot be drawn, therefore, from the comparison of observations not made at the same temperature.

There is, however, no such good agreement between the results of these two classes of physical measurement in the case of ice.

Table II.—Determinations of the Electrical Refractive Index (μ) of Water for Electric Waves of Various Wave-lengths.

Observer.	Reference.	Value found.			Wave-length of waves used in air.	Method.
		μ.		μ^2.		
P. Drude........	'Wied. Ann.,' 1895, vol. 54, pp. 352—370	8·9		79·21	300—600 cm.	Measured reduction of wave-length on passing from air to water.
P. Drude........	'Wied. Ann.,' 1895, vol. 55, pp. 633—655	8·7		75·69	72 cm.	Measured reduction of wave-length on passing from air to water.
P. Drude........	'Wied. Ann.,' 1896, vol. 58, pp. 1—20	9·07 8·95	(11·7° C.) (17° C.)	82·21 80·2	70 ,,	Measured reduction of wave-length on passing from air to water. Last result best.
H. Rubens and A. D. Cole	'Ver. phys. Ges., Berlin,' 1895, vol. 14, pp. 76—78	8·8 8·9		77·04 79·21	5 ,,	Measured intensity of rays reflected from surface of water at incidence of 45° and calculated μ by applying Fresnel's formulæ.
A. D. Cole	'Wied. Ann.,' 1896, vol. 57, pp. 290—310	8·85		78·32	5 ,,	Same as above.
V. von Lang.....	'Wien. Sitzungsber.,' vol. 105, Part IIA, p. 253	9·4		88 36	8·5 ,,	By interference of electric waves.
P. Drude........	'Wied. Ann.,' 1896, vol. 59, pp. 17—62	9·14 9·03 8·98		83·6 81·67 80·60	40 ,, 75 ,, 200 ,,	Measured reduction of wave-length in passing from air to water. Found μ varied with temperature. $\mu^2 = 88{\cdot}23 - 0{\cdot}4044t + 0{\cdot}001035t^2$.
E. Cohn and P. Zeeman	'Akad. d. Wissensch. zu Amsterdam,' Sept., 1895	8·91		79·39	155 ,, 350 ,, 560 ,,	Measured reduction in wave-length in passing from air to water.
A. Lampa.......	'Wien. Sitzungsber.,' 1896	8·972		80·49	8 mm.	
D. Mazzotto	'Rend. Acc. Linc.,' 5, 2, p. 301, 1896.	9·0	(19° C.)	81·0	234—1836 cm.	By use of Lecher apparatus. Measured reduction of wave-length in passing from air to water.

M. E. Bouty ('Journal de Physique,' 3 S., vol. 1, 1892, p. 454) found by a slow-speed method a value of 78·8 for the specific inductive capacity of ice at −23° C. and upwards, whilst R. Blondlot ('Compt. Rend.,' vol. 119, 1894, pp. 595—597), using electric waves and measuring the wave-lengths in air and in ice, found 1·41 for the electric refractive index of ice, and hence the number 2·0 as the value of the dielectric constant of ice at a temperature not stated, but presumably not far below 0° C.

Also A. Perrott ('Compt. Rend.,' vol. 119, 1894, p. 601, also 'Compt. Rend.,' vol. 114, June, 1892, p. 1528) found the value 1·43 for the refractive index, and hence 2·04 for the square of the electric and refractive index of ice. C. B. Thwing, working with electric resonance, and therefore very rapid reversals, gives ('Zeits. Phys. Chem.,' vol. 14, 1894, pp. 286—300) 3·36 at −2° and 2·85 at −5° C. as values for the dielectric constant of ice.

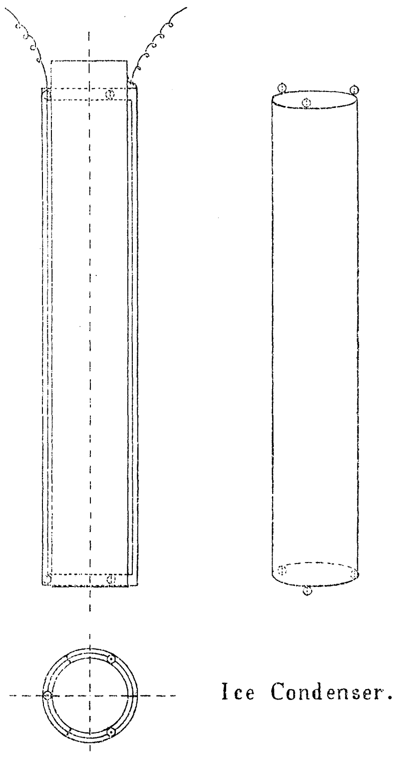
It seemed desirable to endeavour to throw light on the reasons for these differences by an examination of the dielectric constant of ice at very low temperatures.* We have accordingly applied the method and apparatus used by us in the latest determinations of the dielectric constant of liquid oxygen† for the purpose of making an examination of the dielectric constant of ice and frozen ethyl alcohol.

A condenser was constructed consisting of three very thin concentric brass tubes about 20 cm. in length. The extreme outer and inner tubes, having diameters of 3·74 and 3 cm. respectively, were connected together metallically at the bottom, and formed one plate of the condenser. An intermediate brass cylinder 3·37 cm. in diameter was suspended between the inner and outer tubes, thus forming the other plate of the condenser. This last plate was insulated and suspended from the others by providing it with small wire attachments, which were passed through the holes in six glass beads wedged in between the inner and outer connected cylinders at the top and bottom as shown in fig. 1. This condenser was contained in another brass cylinder closed at the bottom, and then had its dielectric formed of ice by filling the annular space between the cylinders with distilled water and freezing it. The terminal wires from this condenser were connected to a rapid contact maker driven by an

* *Note added February* 15, 1897. Since this Paper was presented a communication has been made to the Royal Society by Dr. J. Hopkinson and Mr. E. Wilson, in which they describe experiments on the dielectric constant of ice. These authors find that the specific inductive capacity of ice, when measured with electromotive force reversals having a period of from 1/100 to 1/10 of a second, is a number of the order of 80, but if measured with periods such as $1/10^6$ of a second it is a number less than 3. The difference they ascribe to residual charge. Hence it is clear that these observations are in accord with those of Bouty and Blondlot.

† Fleming and Dewar, "On the Dielectric Constant of Liquid Oxygen," 'Roy. Soc. Proc.,' 1896, vol. 60, p. 358. See note added December 18, 1896, p. 368.

FIG. 1.



electrically controlled tuning fork. The tuning fork used made 124 complete vibrations a second, and was made, by means of a mercury cap and steel stylus dipping into it, to close an electrical circuit 124 times every second, and thus drive synchronously an electro-magnetic contact maker, which placed one terminal of the condenser alternately in connection with a battery of fifty lithanode secondary cells, and with a sensitive galvanometer. The other terminals of the battery, galvanometer and condenser, were connected together. In this way the galvanometer was traversed by a rapid series of electric charges, which have all the effect of a continuous current. The galvanometer deflection remains perfectly steady as long as the battery voltage is unaltered. Other things remaining the same, the galvanometer deflection measures the capacity of the condenser. In employing this method, the galvanometer may be arranged so as to be affected by the series of *discharges* of the condenser, or it may be placed so as to be traversed by the series of *charges* of the condenser. If the condenser has any sensible leakage or dielectric conductivity

this will show itself by making the galvanometer readings in the two cases unequal. Mr. Petavel, who assisted us in these observations, and to whom our thanks are due, arranged a convenient switching device which enabled the galvanometer to have its position in the circuits instantly changed to take either the charge currents or the discharge currents of the condenser, and the equality of these readings is taken as an indication that no sensible leakage takes place across the dielectric during the passage of the contact maker from one stop to the other. This method of exchanging the position of the galvanometer also eliminates errors due to the setting of the scale, as the deflections are on opposite sides of the zero. The above-described arrangements having been made, the ice condenser was cooled down to the temperature of liquid air by immersing it in the liquefied gas contained in a large vacuum vessel.

In order to take the temperature of the condenser a platinum wire resistance thermometer was placed in the inside of the inner cylinder and in close contact with it. The ice having been reduced in temperature to $-185°$ C., or $-198°$ platinum temperature, the capacity of the condenser was measured. The condenser was then raised out of the liquid air and allowed to warm up very slowly, and its capacity taken at various stages as the temperature rose. Before and after the experiment with the ice the capacity of the condenser was taken when the metal cylinders were at the temperature of $-185°$, but the dielectric was gaseous air at that temperature instead of ice, and the results so obtained enabled the dielectric constant of the ice to be calculated.

These experiments being to a considerable extent preliminary experiments, and intended merely to explore the ground, we do not make any particular claim for the accuracy of the numbers as determinations of a physical constant. We are arranging improved methods for repeating the whole of these measurements. All we desired in the first instance to do was to examine the mode in which the dielectric constant varied with temperature and its approximate magnitude at each temperature. The following Table III shows the observed value of the dielectric constant of ice between $-185°$ C. ($-198°$ pt.) and about $-120°$ ($-130°$ pt.). The voltage used on the condenser was 24·1 volts, and kept perfectly constant during the whole time. In order to ascertain if the galvanometer deflection was really due to the sequence of capacity charges or discharges only, and not to any measurable admixture of conduction current through the ice, a resistance of 1,000 to 90,000 ohms was occasionally inserted in the galvanometer circuit, and the absence of any observed change in the galvanometer deflection was taken as a proof that sensible conduction did not interfere with the true capacity effect. The galvanometer used had a resistance of 500 ohms.

In the following table the temperatures are given in terms of platinum temperature (pt.) as defined by our standard platinum thermometer P_1.*

Table III.—Dielectric Constant of Ice at Various Temperatures. Frequency of Fork, 124.

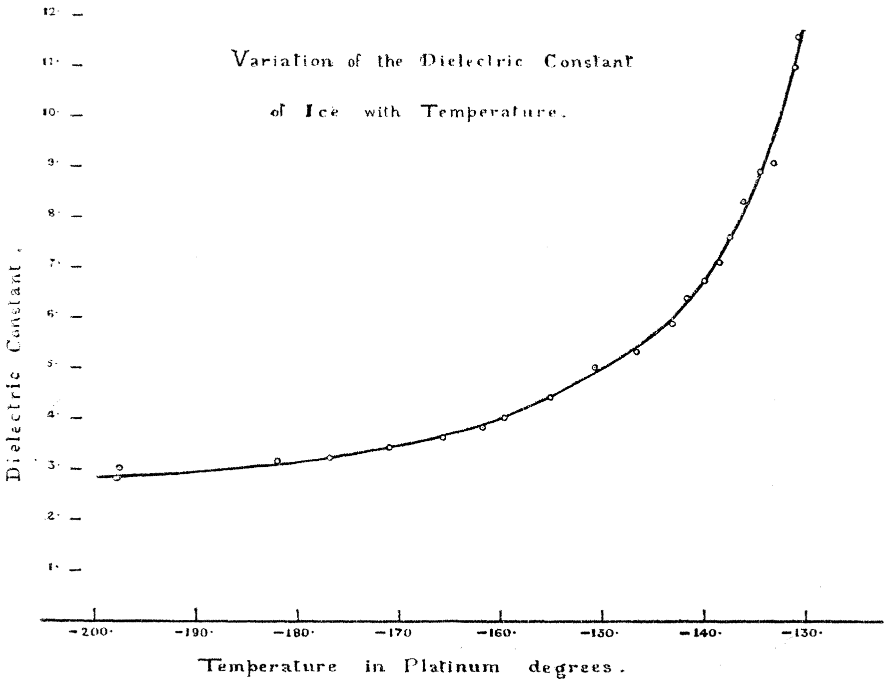
Temperature in platinum degrees by standard thermometer P_1.	Scale reading or galvanometer deflection in centimetres.	Dielectric constant of ice.
pt.		
−198·0	5·6	2·83
−197·8	5·6	2·83
−197·6	6·0	3·03
−182·0	6·25	3·16
−176·8	6·4	3·23
−171·0	6·8	3·44
−165·7	7·2	3·64
−161·8	7·6	3·84
−159·7	8·0	4·04
−155·2	8·8	4·45
−150·8	10·0	5·05
−146·7	10·6	5·36
−143·2	11·7	5·92
−141·7	12·7	6·42
−140·0	13·4	6·77
−138·5	14·1	7·13
−137·5	15·1	7·63
−136·2	16·5	8·34
−134·5	17·7	8·94
−133·2	18·0	9·1
−131·0	21·8	11·0
−130·7	23·0	11·6

With the above frequency (124) the conductivity of the ice began to make itself felt at about −130° pt.

The above numerical results are plotted out in a curve in fig. 2. They show clearly that the dielectric constant of the ice increases progressively from a value of about 2·8 to 11·6 between the limits of −198° and −131° pt. Moreover, the trend of the curve shows that at the absolute zero the dielectric constant of the ice would probably not be far from 2·0. With the above arrangements we were not able, partly for want of time and partly because of the very moderate frequency of the tuning-fork, to take the dielectric constant at higher temperature, but this we hope to do before long, and also to examine the effect of varying the frequency of the contact maker.

* See Dewar and Fleming, "On the Thermo-electric Power of Metals and Alloys," 'Phil. Mag.,' July, 1895, p. 100.

Fig. 2.



The broad general result which emerges from these experiments is that at a temperature of $-185°$ C. we find a value for the dielectric constant for ice, when using relatively very slow reversals of electromotive force, which is not very different from that found by observers using reversals of many millions per second by the use of electrical oscillations or waves, when working at temperatures of 0° C. or a little below.

C. B. Thwing ('Zeits. Phys. Chem.,' vol. 14, 1894), using an electrical resonance method, has examined the variation of the dielectric constant of water with temperatures from 0° C. to 88° C., and found a maximum value of 85·2 at or near the temperature of maximum density of water.

It seems therefore to be a matter of some importance to measure the dielectric constant of ice at all temperatures from the lowest which can be reached up to 0° C., using various frequencies of alternating electromotive force, and to explore the mode of variation of the dielectric constant with temperature and with frequency throughout this range. The point which especially needs to be cleared up is whether the dielectric constant of ice is, or is not, more changed by

change of frequency of the electromotive force than is the case with water. It appears certain that as far as water at 0° C. is concerned, the dielectric constant and the square of the electric refractive index is a number not far from 80, for waves having wave-lengths between 8 mm. and infinity, or for electromotive force reversals having frequencies varying from $37 \cdot 5 \times 10^9$ to zero. On the other hand, the values found for ice at or a little below 0° C. seem to indicate a dielectric constant of 78, when using very slow oscillations; and a value of about 2·0 when using oscillations having a frequency of some millions per second.

It is clear that in this matter there is still room for further investigation. It is evident, since the optical refractive index of water is a number lying between 1·3 and 1·4 for waves having a wave-length of 0·00005 cm. or reversals having a frequency of -400×10^{12} to 700×10^{12}, that water may be regarded as presenting the phenomenon of anomalous dispersion beyond the range of the visible spectrum, because the refractive index for waves of a length of 0·8 cm. and upwards is a number not far removed from 8·9, and this number is very much greater than that for wave-lengths of the order of visible light.

Within the octave of wave-lengths comprising visible light the refractive index of water lies between 1·3 and 1·4. We know very little about the refractive index of water for the fourteen octaves of radiation lying beyond the extreme red end of the spectrum, but we know that water has very considerable absorptive power for a large range of this radiation. The next ten octaves beyond the last, include the range of the Hertz radiation or of wave-lengths from $\frac{1}{2}$ to 500 cm. in length, and for all this the refractive index of water is approximately 8·9. It remains to be seen how the high value is connected with the low one, and whether this variation may be properly regarded as a case of anomalous dispersion analogous to that found in the case of an alcoholic solution of fuchsine within the range of the visible spectrum. It is evident that since the dielectric constant of any one substance, such as ice-water, is a function both of temperature and time, it can best be represented geometrically by a *surface*, which may be called the dielectric surface, and which is defined by the co-ordinates representing dielectric constant, temperature, and frequency of electromotive force reversals.

The details of two determinations of the dielectric constant of ice at −185° C. are given in Table IV.

The same readings were obtained both with 90,000 ohms and 1,000 ohms in the galvanometer circuit.

The above figures of observation require two corrections to be applied. In the first place, the pins which support the inner condenser plate, and which pass through glass beads, have a total area

Table IV.—Brass Condenser filled with Distilled Water and frozen into Ice. Ice reduced to −185° C. by use of Liquid Air.

Deflections of galvanometer when in charge circuit.	Deflections of galvanometer when in discharge circuit.	Volts on terminals of condenser.	Mean galvanometer deflection.
22·4 cm.	23·45 cm.	101·1 volts	22·93 cm.
22·3 „	23·50 „	101·1 „	22·90 „
22·35 „	23·50 „	101·1 „	22·92 „

Mean galvanometer deflection = 22·917. Frequency of contact maker 124.
Mean voltage on condenser = 101·1.

of 0·4 sq. cm., or 0·17 per cent. of the area of the condenser plate, and taking the specific inductive capacity of the glass as equal to 5·0 when cooled to −185° C., it can be seen that the glass supports form 0·85 per cent. of the effective capacity of the condenser when the dielectric is gaseous air at −185° C.

In order to determine this last capacity the brass condenser had its capacity taken at 20° C., air being the dielectric, and then it was cooled in liquid air and then lifted out into the cold gaseous air at a temperature of −185° C., lying above the liquid air, and in this condition the same readings taken. The following were the observed readings of the galvanometer :—

Table V.—Brass Condenser at 20° C., filled with Gaseous Air at that temperature. Frequency of Contact Maker, 124.

Deflection of galvanometer when in charge circuit.	Deflection of galvanometer when in discharge circuit.	Volts on terminals of condenser.	Mean galvanometer deflection.
8·32 cm.	8·31 cm.	101·0 volts.	8·315 cm.
8·35 „	8·30 „	101·1 „	8·325 „

Table VI.—Brass Condenser at −185° C., filled with Gaseous Air at that temperature. Frequency of Contact Maker, 124.

Deflection of galvanometer when in charge circuit.	Deflection of galvanometer when in discharge circuit.	Volts on terminals of condenser.	Mean galvanometer deflection.
8·30 cm.	8·48 cm.	101·1 volts	8·39 cm.

The difference between the mean galvanometer readings, viz., 8·31 and 8·39, in the two last cases, is due to the fact that the condenser capacity is changed by the cooling, owing to the fact that the plates contract. The actual difference due to the temperature of the air changing from 20° C. to −185° C. is very much smaller, and does not sensibly affect the capacity as far as the accuracy of the present measurements is concerned.

There is, however, another correction which needs to be applied, and that is for the capacity of the leads and of the contact maker. Experiment showed that this was equivalent to 4·15 mm. deflection of the galvanometer, and hence the amount has to be deducted from all mean galvanometer readings.

The final result then is as follows :—

The specific inductive capacity, K, of the ice at −185° C. is very nearly equal to the ratio of (22·917−0·07−0·415) to (8·39−0·07−0·415), or K = 2·83.

The correction 0·07 is the correction for the capacity of the glass separators, which is equal to $5 \times 0{\cdot}17 = 0{\cdot}85$ per cent. of the total capacity, and hence the remanent capacity of the condenser is $8{\cdot}39 - 8{\cdot}39 \times 0{\cdot}0085 = 8{\cdot}39 - 0{\cdot}07$. The correction 0·415 is the correction for the capacity of the contact maker and leads.

A second determination was made at a lower voltage, the details of which are as follows in Table VII.

Table VII.—Brass Condenser filled with Distilled Water and frozen into Ice. Ice reduced to −185° C. by use of Liquid Air.

Deflection of galvanometer when in charge circuit.	Deflection of galvanometer when in discharge circuit.	Volts on terminals of condenser.	Mean galvanometer deflection.
8·35 cm.	8·60 cm.	36·1 volts	8·48 cm.
8·35 „	8·60 „	36·1 „	8·48 „

Mean galvanometer deflection = 8·48 cm.
Mean voltage = 36·1 volts.
Mean deflection for voltage of 101·1 = 23·75 cm.
Corrected value of the deflection = 23·75 − 0·07 = 23·68.

$$\text{Specific inductive capacity of ice at } -185^\circ \text{ C.} = \frac{23{\cdot}68 - 0{\cdot}415}{8{\cdot}32 - 0{\cdot}415} = 2{\cdot}94.$$

Hence the mean value of the dielectric constant of ice at −185° C. for slow reversals of electromotive force is a number not far from 2·9.

We have in the same manner examined ethylic alcohol frozen and reduced to −185° C.

The observations with same condenser having frozen alcohol as the dielectric are as follows :—

Table VIII.—Brass Condenser filled with Absolute Ethylic Alcohol frozen and reduced to −185° C.

Deflection of galvanometer when in charge circuit.	Deflection of galvanometer when in discharge circuit.	Voltage on terminals of condenser.	Mean galvanometer deflection.
12·20 cm.	12·80 cm.	50·5 volts	12·5 cm.
12·10 „	12·50 „	„ „	12·3 „
12·10 „	12·50 „	„ „	12·3 „

Mean galvanometer deflection = 12·60.
Mean voltage = 50·5.

Galvanometer deflection corrected for capacity of glass separators and also of contact breaker, and reduced to correspond to a voltage of 101·1 = 24·665.

Since the corrected capacity of the condenser when at −185° C. and filled with gaseous air at −185° C. is represented by the number 7·905 = 8·39−0·07−0·415, we have for the dielectric constant of solid alcohol at −185° C. the value 24·665/7·905 = 3·12.

In addition to measuring the dielectric constants, the same experimental arrangements enabled us to measure approximately the dielectric resistance of the ice and frozen alcohol at and from the temperature of −185° C., and the following tables give the approximate total resistance of the condenser when the dielectric consisted of these substances and was slowly allowed to heat up from −185° C.

Table IX.—Variation in the Resistance of an Ice Condenser heated up from −185° C. = −200° pt. to about 70° C. Temperatures given in platinum degrees by standard platinum thermometer P_1.

Temperature of the ice in platinum degrees.	Resistance of the ice condenser in megohms.
−200·0°	26200·0
−172·2	5670·0
−135·0	1570·0
−126·0	1130·0
−108·4	706·0
−98·8	470·0
−95·2	353·0
−93·2	282·0

Temperature of the ice in platinum degrees.	Resistance of the ice condenser in megohms.
−91·8	209·0
−88·8	118·0
−88·2	91·4
−86·3	66·5
−84·4	53·4
−82·3	46·3
−75·0	42·8
−70·7	43·4

In the same way the resistance of the frozen ethylic alcohol condenser was taken at temperatures lying between −185° C., and about −160 C., as given in the table below.

Table X.—Variation in Resistance of the Frozen Alcohol Condenser Temperatures given in Platinum Degrees.

Temperature of the alcohol in platinum degrees.	Resistance of condenser in megohms.
−200·0°	14500·0
−190·0	45·0
−186·5	9·7
−168·0	1·0

The above numbers cannot be considered as more than moderate approximations, but they are sufficient to show the mode of variation of resistance in the two cases.

The values for the resistance of the ice and alcohol have been set out in the two curves in figs. 3 and 4.

These figures show that in the case of the alcohol, as soon as a temperature of −190° pt. is reached the resistance begins to fall with great rapidity or the conductivity to go up.

In the case of the ice the same rapid increase in conductivity begins to take place at about −90°.

We have designed a form of condenser which will enable us to repeat these measurements and free them from some sources of error due to the difference between the contraction of the metal plates of the condenser and that of the dielectric; but pending such more accurate measurements the above figures may be taken as showing approximately the course of events when the ice and frozen alcohol are heated up from the temperature of boiling liquid air.

We add two tables, XI and XII, giving some recent determinations of the dielectric constant of the ethyl alcohol, the results in Table XII showing that evidence apparently exists of abnormal dis-

Fig. 3.

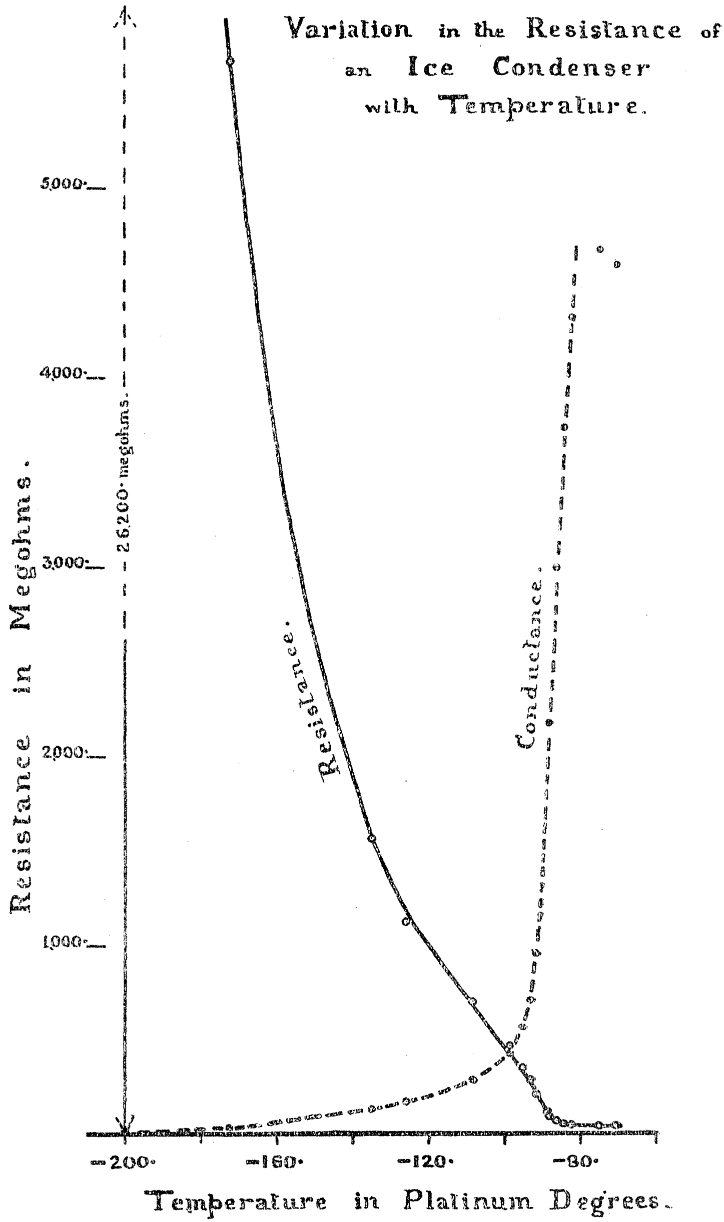
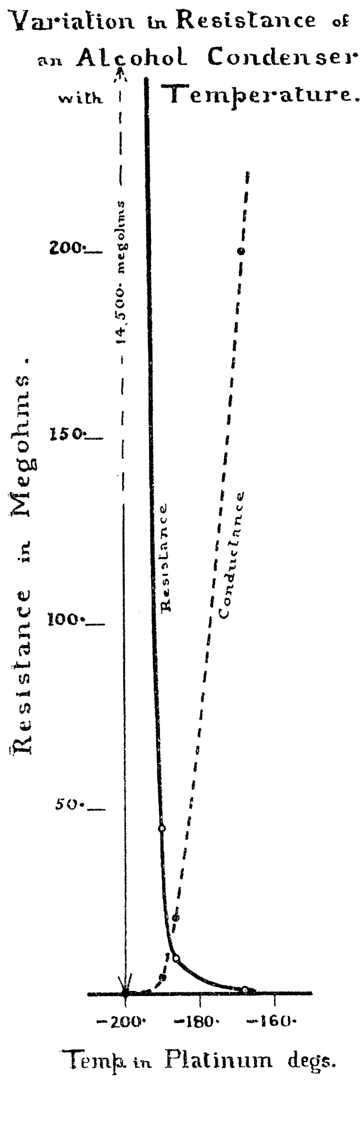

Variation in the Resistance of an Ice Condenser with Temperature.
Resistance in Megohms.
5000
4000
3000
2000
1000
26200 megohms.
Resistance.
Conductance.
−200
−160
−120
−80
Temperature in Platinum Degrees.

Fig. 4.


Variation in Resistance of
an Alcohol Condenser
with Temperature.
14,500 megohms
200
150
100
50
Resistance in Megohms.
Resistance
Conductance
−200
−180
−160
Temp. in Platinum degs.

persion in the case of alcohol for electric radiation lying within the limits of the ten octaves of waves comprised between wave-lengths of 8 mm. and 900 cm. measured in air.*

Table XI.—Determinations of the Dielectric Constant (Specific Inductive Capacity = K) of Ethyl Alcohol by Various Observers.

Observer.	Reference.	Value found per K.	Method.
W. Nernst ...	'Zeits. phys. Chem.,' vol. 14, 1894, p. 622	25·8	By comparing capacities of condensers with telephone.
J. F. Smale ..	'Wied. Ann.,' vol. 57, p. 215	25·8	By deflections of an electrometer filled with alcohol.
E. B. Rosa....	'Phil. Mag.,' vol. 31, 1891, p. 188	25·7	By attraction between plates of condenser filled with alcohol. Reversals of E.M.F. 2000—4000 per minute.
W. C. Röntgen	'Wied. Ann.,' vol. 52, p. 593	30·5	By alternate currents and condenser (not of such weight perhaps as the others here given).

* The different results found by A. D. Cole for long and short waves have been criticised by J. F. Mohler (see 'Physical Review,' vol. 4, p. 153), who ascribes the differences to conductivity. It has, however, been shown both by E. Cohn and L. Arons ('Ann. der Physik u. Chemie,' vol. 33, p. 13) and by G. U. Yule that the addition of salts to alcohol, which largely affect its conductivity, does not apparently alter perceptibly the dielectric constant, whether determined by slow or rapid reversals of electromotive force.

Table XII.—Determinations of the Electrical Refractive Index (μ) of Ethyl Alcohol for Electric Waves of Various Wave-lengths.

Observer.	Reference.	Value found.		Wave-length of waves used in air.	Method.
		μ	μ^2		
A. Lampa	'Wien. Sitzungsberichte'.	2·568	6·59	8 mm.	Reduction in length of waves passing into alcohol from air.
A. D. Cole	'Ver. Phys. Ges.', Berlin, vol. 14, 1895, p. 76	3·1 3·2	9·6	5 cm.	Ratio of intensities of original and reflected ray.
P. Drude	'Wied. Ann.', vol. 54, 1895, p. 352	4·74	22·46	60 ,,	Reduction of wave-length of waves passing into alcohol.
A. D. Cole	'Wied. Ann.', vol. 57, 1896, p. 290	5·24	26·32	259 ,,	Ratio of intensities of original and reflected rays.
G. U. Yule........	'Phil. Mag.', vol. 36, p. 531	5·16	26·7	900 ,,	Reduction in wave-length of waves passing into alcohol.
C. B. Thwing......	'Zeits. phys. Chem., vol. 14, p. 286, 1894	5·00	25·0	—	Resonance of electric circuits. Frequency not stated, but high.