

PROCEEDINGS  
OF THE  
AMERICAN PHYSICAL SOCIETY.

MINUTES OF THE PHILADELPHIA MEETING, OCTOBER 10 AND 11, 1919.

THE ninety-ninth meeting of the American Physical Society was held in Philadelphia on October 10 and 11, 1919. On Friday, October 10, there were three sessions, arranged by the Committee on Technical Physics. These were joint meetings with the American Institute of Electrical Engineers and were held at the Hotel Bellevue-Stratford.

In the session of Friday morning, at which President Ames of the American Physical Society presided, the following program was presented:

A Discussion on the Present Status of Theories of Atomic Structure:

I. Introductory Remarks on Present Theories. SAUL DUSHMAN.

II. Special Applications of the Octet Theory. IRVING LANGMUIR.

III. Spectroscopic Evidence Regarding Atomic Structure. F. A. SAUNDERS.

IV. Bearings of High Pressure Phenomena on the Problem of the Constitution of Matter. P. W. BRIDGEMAN.

On Friday afternoon, under the auspices of the American Institute of Electrical Engineers, the following program was presented:

The Arrangement of Atoms in Metals. A. W. HULL. An X-ray study of crystal structures, a demonstration with models of crystals.

The Oscillating Vacuum Tube as a Generator of Electrical Power. J. H. MORECROFT AND H. T. FRIIS.

Electromagnetic Induction. S. J. BARNETT.

Piezo Electric Effect. A. M. NICHOLSON. (Demonstration.)

On Friday evening there was an informal dinner in the Clover Room of the hotel, followed by a joint meeting of the Institute and the Physical Society, at which two papers were presented as follows:

The Indispensability to each other of Pure and Applied Science. H. A. BUMSTEAD.

Pure Science and Industrial Research. J. J. CARTY.

On Saturday, October 11, 1919, there were two general sessions of the Physical Society held, by invitation, in the auditorium of the Leeds and Northrup Company, Vice-President Lyman presiding. In the intermission the members availed themselves of the invitation to inspect the laboratories of the Leeds and Northrup Company. A complimentary luncheon was provided by our hosts.

The program began with two papers presented by invitation of the Committee, as follows:

Research Development and Technical Control in a Small Industry. M. E. LEEDS.

Some Research and Development Problems of the Leeds & Northrup Co. R. B. SMITH.

The regular program consisted of eleven papers contributed by members in general, two of these being read by title, as follows:

A Precision Potentiometer. ARTHUR W. GRAY.

On Establishing of the Absolute Temperature Scale. FREDERICK G. KEYES.

The Crystal Structure of Ferro-Magnetic Metals. ALBERT W. HULL.

Hydrogen Overvoltage. D. A. MACINNES, LEON ADLER AND A. W. CONTIERI.

Note on a Method of Measuring the Decrease of Electron in Thin Films by Means of Characteristic X-Rays. (Read by title.) BARGEN DAVIS.

The Application of Motion Picture Photography to Ballistics and Airplane Performances. F. C. BROWN.

Unipolar Induction. W. F. G. SWANN.

Magnetic Resistance Effects in Films of Bismuth. F. K. RICHTMYER AND L. F. CURTISS.

The Spectral Photoelectric Sensitivity of Molybdenite as a Function of the Applied Voltage. (Read by title.) W. W. COBLENTZ and H. KAHLER.

Ionization and Resonance Potentials for Electrons in Vapors of Lead and Cadmium. F. L. MOHLER, PAUL D. FOOTE AND H. F. STIMSON.

The Calculation of Audion Constants. R. W. KING.

At the meeting of the Council held on October 11, 1919, the following elections were made: *elected to regular membership*, L. H. Adams, E. Ferrari, M. LaRosa, F. R. Moulton, S. Nakamura, O. Veblen; *elected to associate membership*, A. K. Aster, F. I. Bernhard, E. C. Brady, I. C. Cornog, L. F. Curtiss, R. C. Duncan, A. L. Ellis, J. L. Fearing, Miss M. K. Frehafer, J. C. Karcher, R. H. Kent, V. F. Lenzen, F. H. McBerty, W. C. Pomeroy, Miss J. A. Rodman, T. G. Seidell, A. F. Wagner, W. R. Williams; *transferred from associate to regular membership*, J. H. Morecroft, T. Takamine, E. D. Tillyer.

DAYTON C. MILLER, *Secretary*.

#### THE APPLICATION OF MOTION-PICTURE PHOTOGRAPHY TO BALLISTICS AND AIRPLANE PERFORMANCES.<sup>1</sup>

BY F. C. BROWN.

THIS paper shows, with the aid of motion pictures and lantern slides, the results obtained by photographing the reflected image of the Handley-Page airplane simultaneously with the Mark IV bomb. These

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

photographs were taken from the airplane with the motion-picture camera placed directly above the bomb.

From an enlarged reproduction of the motion picture film, of magnification of six, was calculated the axis of the bomb relative to the trajectory tangent from the time it left the airplane until it struck the water 2,500 feet below. Also, the trail angle of the bomb back of the reflected image of the plane was calculated to an accuracy of about .03 degree. The results show very clearly the free period of the bomb throughout the trajectory, and also a close correlation between the lag and lead of the bomb and the position of the bomb on the trajectory. The so-called skidding effect is measured quite accurately.

The altitude of the airplane is calculated from the size of the reflected image on the film to a probable accuracy of about 15 feet, while the distance that the bomb has fallen is calculated from the diameter of the bomb image on the film to a probable accuracy of 100 feet.

The rolling and pitching of the airplane carrying the bomb at the time of release and when the explosive wave hits the plane is shown to an accuracy of a few hundredths of a degree. The free period of the plane during flight is less than .5 degree on either side of the mean flying position. When the explosive wave hits the airplane, there is a transverse displacement of the wings of nearly 1 degree, but the explosive wave, when the bomb explodes above water, does not affect the pitching of the airplane by as much as .1 degree.

ORDNANCE DEPARTMENT,  
BUREAU OF STANDARDS.

#### THE CALCULATION OF AUDION CONSTANTS.<sup>1</sup>

BY R. W. KING.

GIVEN the characteristic equation of an audion as

$$I_p = \kappa \left( \frac{E_p}{\mu} + E_c \right)^\eta,$$

it has been found possible to deduce expressions for the constants  $\mu$  and  $\kappa$  from theoretical considerations which agree closely with experimental results. The calculation has been carried out for four classes of audions.

1. The structure with plane-parallel elements in which the filament is symmetrically placed between grids and plates;
2. The structure with cylindrical anode and grid and a coaxial strand of filament;
3. The structure with cylindrical anode and grid and several parallel strands of filament arranged on an internal coaxial cylinder;
4. The structure similar to Class 3 except that the strands of filament lie on an external coaxial cylinder. These calculations result in the following formulas.

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

*Class 1.*—Given  $\alpha$  the distance from plate to grid,  $\beta$  the distance from grid to filament,  $n$  the number of grid wires per unit length,  $r$  the radius of the grid wires, and  $A$  the total plate area,

$$\mu = \frac{2\pi r n}{\log_e \frac{1}{2\pi \alpha n}},$$

$$\kappa = 2.33 \times 10^{-6} \frac{A}{\sqrt{\alpha + \beta}} \left( \frac{\mu}{\alpha + (\mu + 1)} \right)^{3/2}.$$

In this and the following values for  $\kappa$  it has been assumed that the exponent  $\eta$  has the value  $3/2$ . This assumption in general gives good numerical agreement.

*Class 2.*—Given  $R_p$ ,  $R_g$ ,  $R_f$  the radii of plate, grid and filament respectively, and  $l$  the length of the structure,

$$\mu = \frac{\left( 2\pi R_g^2 \frac{1}{R_g} - \frac{1}{R_p} \right) n}{\log_e \frac{1}{2\pi r n}},$$

$$\kappa = 14.65 \times 10^{-6} \frac{l R_p^{1/2} \mu^{3/2}}{[(R_p - R_g) + R_g(\mu + 1)]^{3/2}}.$$

*Classes 3 and 4.*—The expression for  $\mu$  is that given under Class 2. The expression for  $\kappa$  is

$$\kappa = 14.65 \times 10^{-6} \frac{R_p l \mu^{3/2}}{\sqrt{\pm(R_p - R_f) \pm (R_p - R_g) \pm (R_g - R_f)(\mu + 1)^{3/2}}}$$

where the signs are taken in such a way as to make all terms positive.

It is evident from the above expressions for  $\mu$  and  $\kappa$  that these two quantities remain unchanged so long as the *relative* dimensions of any structure remain the same.

The accompanying table shows the numerical agreement obtained with some tubes of Class 1. All dimensions are in centimeters and currents in milliamperes.

TABLE.

$\alpha$ .	$\beta$ .	$n$ .	$r$ .	$A$ .	$\mu'$ .		$E_p$ .	$E_g$ .	$I_p$ .	
					Calc'd.	Obs'd.			Calc'd.	Obs'd.
0.228	0.169	2.52	0.01	12.1	1.97	1.90	120	-10.7	70	64
.466	.169	3.45	.01	12.1	6.6	6.1	300	0	79	69
3.17	.317	6.29	.01	22.6	13.6	13.0	700	0	112	99

RESEARCH LABORATORIES OF THE AMERICAN  
TELEPHONE AND TELEGRAPH COMPANY  
AND THE WESTERN ELECTRIC  
COMPANY, INC.,  
NEW YORK CITY.

IONIZATION AND RESONANCE POTENTIALS FOR ELECTRONS IN VAPORS  
OF LEAD AND CALCIUM.<sup>1</sup>

BY F. L. MOHLER, PAUL D. FOOTE AND H. F. STIMSON.

MEASUREMENTS of electron currents in three electrode vacuum tubes of the type previously described have been made in vapors of lead and calcium.

The lead and calcium were boiled in porcelain tubes at temperatures of about 1000° and 900° respectively. Current voltage curves in lead showed a resonance potential of 1.26 volts and an ionization potential of 7.93 volts. Applying the quantum relation  $Ve = h\nu$  we find that 1.26 volts corresponds within experimental error to the frequency of a strong infra-red spectrum line at  $\lambda = 10,291 \text{ \AA}$ . giving a theoretical value of the resonance potential 1.198 volts.

In calcium two resonance potentials were found at 1.90 volts and at 2.85 volts of which the first is the most prominent. Ionization occurred at 6.01 volts. The ionization potential corresponds to the limit of the principal series  $1.5S\lambda = 2027 \text{ \AA}$ . giving as the theoretical value  $V = 6.081$  volts. The first resonance is determined by the line  $1.5S - 2p_2$ .  $\lambda = 6572.78 \text{ \AA}$ .  $V = 1.877$  volts. The second resonance corresponds to the line  $1.5S - 2P$ .  $\lambda = 4226.73 \text{ \AA}$ .  $V = 2.918$  volts.

The spectral relations of the first resonance potential and ionization potential are analogous to the relation found with other metals in this group. Work of other observers shows that both the lines  $1.5S - 2P$  and  $1.5S - 2p_2$  appear below the ionization potential in most metals of this group.

BUREAU OF STANDARDS

October 1, 1919.

THE SPECTRAL PHOTOELECTRIC SENSITIVITY ON MOLYBDENITE AS A  
FUNCTION OF THE APPLIED VOLTAGE.<sup>1</sup>

BY W. W. COBLENTZ AND H. KAHLER.

IN a previous investigation it was observed that the spectral photoelectric sensitivity of molybdenite is confined practically within three spectral bands, the maxima of which are separated by equal intervals, when plotted in terms of frequency instead of wave-lengths.

The present investigation was undertaken in order to test the validity of this frequency relation, using for the purpose a quartz prism which gave twice the dispersion formerly obtained with a fluosite prism. The sample of molybdenite was soldered to copper wire terminals, and operated in an evacuated chamber as in previous work. The photoelectric substance, the dry battery and the d'Arsonval gavanometer were joined in series. The deflection caused by the

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

small dark current was overcome by rotating the suspension head of the galvanometer.

The results obtained with this apparatus appear to verify the previous observations, indicating that the frequency maxima are separated by equal intervals, which decrease with temperature; the arbitrary wave-number being  $n = 40$  at  $25^\circ$  C. and  $n = 30$  at  $-175^\circ$  C.

**A New Voltage Phenomenon.**—A photo-negative action (resistance increase) has been observed in certain samples of selenium,<sup>1</sup> when exposed to the total radiation from an incandescent lamp. A similar spectral photo-negative response was observed in some samples of stibnite,<sup>2</sup> when exposed to radiations of wave-lengths less than  $\lambda = .657 \mu$ . But heretofore no one appears to have observed that, for wave-lengths less than about  $0.65 \mu$ , the nature of the photoelectric response depends upon the voltage applied to the substance under test.

We have found in some samples of molybdenite that, for the visible spectrum extending to about  $\lambda = 0.647 \mu$ , the electric response is photo-positive or photo-negative, depending upon the voltage applied to the terminals of the receiver. For wave-lengths greater than  $\lambda = 0.647 \mu$ , the photoelectric response was observed to be photo-positive whatever the applied voltage.

The region of transition in the spectrum, in which the action changes from photo-negative to photo-positive, is very narrow,—less than  $9 \text{ \AA. U.}$

The critical voltage is very small as may be inferred from the fact that an increase of 1.3 volts (additional dry battery) changed a positive-negative galvanometer deflection of  $\pm 1 \text{ cm.}$  into a purely negative deflection of  $-24$  to  $-26 \text{ cm.}$ , which is the photo-negative response under discussion.

There seem to be two contending forces acting. The one which causes the photo-positive response acts quickly and prevails on low voltage. The photo-negative action builds up more slowly and is predominant on high voltages. As a result of these two forces, for certain applied voltages, on exposing the the molybdenite receiver to light of wave-lengths less than  $0.647 \mu$ , the galvanometer deflection is first positive, then decreases in value (and may even become negative) when, on shutting off the light stimulus, there is a further deflection in the negative direction, after which the deflection returns to the original zero scale reading.

For example, using the wave-length  $\lambda = .5876 \mu$  as a light stimulus, and applying a potential of 10 volts, the galvanometer deflection was almost entirely positive. On 20 volts the deflection was partly positive and partly negative. On 29 volts the positive response was almost eliminated, and the negative response prevailed. On 33 volts the galvanometer deflection was entirely negative and eight times as large as the observed maximum purely positive deflection, for 10 volts. In another test, at a slightly lower temperature ( $-104^\circ$  C.) which raises the critical voltage, changing from 35.6 volts to 37 volts transformed the positive-negative deflection of  $\pm 5 \text{ mm.}$  into a negative deflection of  $-230 \text{ mm.}$

<sup>1</sup> Ries, *Phys. Zeit.*, 9, p. 569; 1908. Brown, *Phys. Rev.*, 33, p. 1; 1911.

<sup>2</sup> Elliot, *Phys. Rev.*, (2) 5, p. 62; 1915.

These tests were carried out at  $-100^{\circ}$  C. to  $-178^{\circ}$  C. It is of interest to note that the photo-positive action is the same as a resistance decrease caused by a rise in temperature of the material, while the photo-negative action is similar to the building up of a counter-electromotive force (the electrolytic action) previously observed in silver sulphide. An equal energy spectrum was used for the radiation stimulus and if this phenomenon were the result of heating and of electrolytic action, then the photo-positive response should occur in the short wave-lengths where the absorption is greatest, and the photo-negative response should occur in the long wave-lengths where the photoelectric activity is the greatest. This is just the reverse of what has been observed.

No explanation of this phenomenon is attempted at this time. Even if it is "only a gas effect," "electrolytic action" or "surface charge," it is unique in being selective as to the wave-length of the exciting radiation and in being photopositive or photo-negative, depending upon the applied voltage. It therefore requires further investigation.

WASHINGTON, D. C.,

October 2, 1919.

#### MAGNETO-RESISTANCE EFFECTS IN FILMS OF BISMUTH.<sup>1</sup>

BY F. K. RICHTMYER AND L. F. CURTISS.

THERE is a disagreement among previous investigators concerning the magneto-resistance effects in films of bismuth obtained by cathodic sputtering. The present work has been undertaken as a preliminary attempt to obtain further information on this subject, which has an important bearing on the electron theory of metallic conduction. Films of various thickness were sputtered from chemically pure bismuth. It has been found that if especial care is taken to avoid heating these films during the sputtering, by allowing the process to go on only intermittently at short intervals, there is little or no change produced in the resistance of such films when placed in a transverse magnetic field of 16,000 gauss. Heating the films will restore this property. If the films are heated to a temperature near the melting point of the bismuth and allowed to cool and this process repeated several times, after each heating the film exhibits a greater change of resistance after each heating than before it, until a certain upper limit is reached, beyond which further heating, if the previous maximum temperature is not exceeded, has little effect. Likewise, heating to successively higher temperatures, beginning at a fairly low maximum and gradually approaching the melting point of the metal in each successive heating, restores the property under investigation to a greater and greater degree. Heating to temperatures under  $150^{\circ}$  has very little effect towards restoring this property, while heating to temperatures above this value has a correspondingly larger effect. If the film is strongly heated while being sputtered the initial increase of resistance in the magnetic

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

field is comparatively large and further heating produces only slight increases in this initial value. The heating produces no observable change in the negative temperature coefficient of resistance of these films, which was carefully measured before and after each heating.

UNIPOLAR INDUCTION.<sup>1</sup>

BY W. F. G. SWANN.

THE paper forms an enquiry as to the extent to which the so called "Moving Line Theory" of electromagnetic induction is the equivalent of the Maxwell-Lorentz Theory. The latter theory gives the force  $E$  on a fixed unit of charge in the form:

$$E = -\frac{l\partial U}{c\partial t} - \frac{\partial\psi}{\partial x}, \quad (1)$$

where  $U$  is the Maxwellian vector-potential, and  $\psi$  is the electro-static potential.

Consider the case of an infinitesimal amperian whirl of negative electricity on which is superposed a distribution of positive electricity which just cancels the electrostatic effect of the negative when the whirl is without translatory motion. As shown in the paper, the theory of relativity requires that, when the whirl is set into translatory motion perpendicular to its axis, there shall arise an electrostatic potential which is the equivalent of that of an electric doublet placed at the center of the whirl. The total electric field is thus composed of the field due to this doublet together with a part depending upon the time rate of change of the vector-potential; and, the inclusion of this electrostatic potential, which comes into existence by a rearrangement of the electric density in the whirl, makes the Maxwell-Lorentz theory agree with the "moving line theory" for this case.

Now in the case of a rotating magnet, the various elementary whirls partake of a translatory motion, an acceleration towards the center of rotation of the magnet, and the axes of the whirls may also undergo a rotary motion. To the extent that we may assume the constitution of the whirls to be unaltered by the motion except to the extent indicated above, we may calculate the field which would be produced by a symmetrical insulating magnet of unit specific inductive capacity rotating about its axis of magnetization, by applying the "moving-line theory" to each of the elements which constitute the magnet. In doing this, however, only the translatory motion of the elements which constitute the magnet. In doing this, however, only the translatory motion of the elements must be considered. We must exclude any idea of movement of the magnetic lines of force as a result of rotary motion of the elements; for, neither on the basis of physical intuition, nor on the more exact basis of the Lorentzian equations are we justified in expecting any field as a result of mere rotation of the frame of the whirl about its own axis.

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.



The fundamental difference between the "moving-line theory" as it is ordinarily applied, and the theory in the form in which it would be applied lies in the fact that, in the former, the motion attributed to the magnetic field is the same as if the magnetic lines from the elementary whirls were pinned down at places where they pass through the axis of rotation of the magnet. In other words, the motion of the lines as is calculated as though they partook of the rotational velocity of the *frame* of the whirl about its own axis as well as of the translatory velocity of the whirl. As we have remarked, the former part should be omitted; and, when this is done, we have the "moving-line theory" in its proper form.

In a symmetrical rotating system, the vector-potential does not change with the time so that the second member of the right-hand side of (1) is the only term which contributes to  $E$ . The effect of this term is equivalent to a set of electric doublets with their axes radial. We must suppose one doublet for each molecular magnet, and the moments of the doublets are proportional to their distances from the axis of rotation in the case of a uniformly magnetized system.

By Poisson's mathematical theorem on polarized media, the field due to the doublets is equivalent to that of a certain fictitious distribution of electricity throughout the volume, and a distribution of electricity of opposite sign and of equal total amount over the surface.

In a conducting magnet we have two additional facts to consider. The force on a unit of electricity which is in motion with velocity  $V$  is given by:

$$F = E + \frac{[TH]}{C} \quad (2)$$

If for the moment we ignore the second member of this force, it will be necessary for the potential to be constant and the field zero throughout the magnet. This can only result by the appearance of real surface and volume distributions which, at each element, are equal and opposite in amount to the fictitious charge corresponding to the element. The result is then a complete cancellation of the fields due to these fictitious charges, not only within the magnet but at all points outside.

If we now introduce the second member of the force  $F$  into the consideration, we see that, owing to the motion of the substance of the magnet in its own magnetic field, an electromotive intensity will arise, and this will bring into existence an electrostatic distribution whose field, at all points within the magnet, just cancels the electromotive intensity which caused it. The electrostatic distribution arising in this way is then the only factor which ultimately contributes to the field outside the magnet. Its effect is of course always completely shielded off from any space from which the magnet is shielded by an earthed shield which does not participate in the rotation.

The paper concludes with an application of the above discussion to certain typical experiments, and an extension of the ideas to the case of an elementary whirl rotating as a whole about an axis in itself, other than the primary axis of the whirl.

NOTE ON A METHOD OF MEASURING THE DECREASE OF VELOCITIES IN  
THIN FILMS BY MEANS OF CHARACTERISTIC X-RAYS.<sup>1</sup>

By BERGEN DAVIS.

IT is desired to point out briefly that the phenomenon of characteristic X-rays furnishes a convenient and probably accurate means of measuring the decrease of electron velocities in penetrating metal surfaces.

A method of applying characteristic X-rays for this purpose was described in the *PHYSICAL REVIEW* for June, 1918. The method here described is much simpler than the one suggested.

The method under consideration depends on the fact that there is a definite velocity of electron impact necessary to excite characteristic X-rays of any element.

If a thin film of the metal to be investigated be deposited on the surface of another metal giving characteristic X-radiation within the range of observation, the characteristic radiation will not be excited in the under metal unless the electrons have penetrated the film of known thickness above and reach the metal with the required velocity. This limiting velocity is already known. The velocity with which the electrons enter the film can be calculated from the voltage applied.

The velocity is thus determined on each side of a metallic film of known thickness.

A difficulty that may be encountered is a possible alteration in the thickness of the metal film both by the mechanical action and also by the slow evaporation of the metal as the target becomes heated.

The decrease of electron velocities in penetrating gold and aluminium foils has been measured by the direct magnetic deflection method by Whiddington. The decrease seemed to follow the law:

$$U_x^4 = V_0^4 - ax.$$

The constant  $a$  did not appear to depend in any simple way on the properties of the metals. It is very desirable that this constant should be determined for many metals as it enters largely into all theories of X-ray emission.

DEPARTMENT OF PHYSICS,  
COLUMBIA UNIVERSITY.

HYDROGEN OVERVOLTAGE.<sup>1</sup>

By D. A. MACINNES, LEON ADLER AND A. W. CONTIERI.

HYDROGEN overvoltage is due, primarily, to a layer of supersaturated dissolved hydrogen in the electrolyte surrounding an electrode. If, however, the electrode can hold nuclei of gaseous hydrogen on its surface the supersaturation will not rise to high values, since a portion of the hydrogen

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

will then go into the gaseous phase. Metals with small adsorptive powers hold small nuclei and have high overvoltages. This explanation of overvoltage is supported by experimental evidence as to the presence of gaseous nuclei, and by observations of fluctuations of overvoltage during the evolution of a single minute bubble. Further, the relation between the radius of the evolved bubbles  $r$ , the surface tension  $\gamma$ , the pressure  $p$  and the overvoltage  $E$  has been shown experimentally to be, for platinum electrodes,

$$2FE = \frac{3RT}{pr\gamma}.$$

The work of Goodwin and Wilson unpublished<sup>1</sup> has shown that the change of overvoltage with pressure follows, nearly quantitatively, the relation given above, for electrodes of nickel, lead and mercury, *i.e.*, the overvoltage rises with a decrease of pressure.

A study has also been made of the effect of the change of gaseous pressure on several chemical and electrochemical processes involving the evolution of hydrogen. The changes in rates of reaction and in reaction efficiencies were found in each case to be in the directions which follow from the change of hydrogen overvoltage with pressure, *i.e.*, a decrease of pressure produces (*a*) a decrease of the rate of solution of metals in electrolytes, (*b*) an increase in the efficiency of reductions by metals, and (*c*) an increased efficiency of metal deposition.

#### THE CRYSTAL STRUCTURE OF FERRO-MAGNETIC METALS.<sup>1</sup>

BY ALBERT W. HULL.

IT is well known that ferro-magnetism is not a specific property of the atom, that is, the atoms of ferro-magnetic materials are, in general, ferro-magnetic only when in pure metallic condition and between definite limits of temperature. The relative spacing of the atoms is apparently assential. It might have been anticipated, therefore, that ferro-magnetic metals would have the same crystal structure. That this is not the case is evident from the following table, which shows the type of lattice and distance between atoms of these metals as determined from powder photographs. (For method see PHYSICAL

TABLE.

Substance.	Type of Lattice.	Lattice Constant (Side of Elementary Cube or Triangle.)	Distance Between Nearest Atoms.
Chromium . . .	Centered Cubic	2.91	2.52
Iron . . . . .	Centered Cubic	2.86	2.47
Cobalt . . . . .	{ Hexagonal "Close-packed"	2.52	2.52
	{ Face-Centered Cube	3.57	2.52
Nickel . . . . .	Face-Centered Cube	3.54	2.50

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

REVIEW, 10, 661-696, 1917. The full data will be published elsewhere in this journal.)

It will be observed that the ferro-magnetic metal, nickel, has the same crystal structure as copper, while cobalt appears in two forms—one like copper and one like magnesium. Neither is like iron. Chromium, on the other hand, which is not ferro-magnetic has a centered cubic arrangement like iron. Manganese has not yet been accessible in sufficiently pure form to allow of its determination.

It is evident, therefore, that ferro-magnetism does not depend upon any particular arrangement of atoms. It is much more likely that it depends upon the distances between the atoms, which would explain the fact that this property is lost when the temperature is increased beyond a definite value.

RESEARCH LABORATORY,  
GENERAL ELECTRIC CO.

#### A PRECISION POTENTIOMETER.<sup>1</sup>

BY ARTHUR W. GRAY.

THE potentiometer forming the subject of this communication has been designed especially for the accurate measurement of small electromotive forces, such as those produced by thermocouples; but its range can be extended by employing a volt-box in the usual way.

The instrument possesses the following advantages:

1. The galvanometer circuit is practically free from parasitic thermal electromotive forces.
2. An eliminating switch provides for easily correcting the galvanometer deflections for any parasitic electromotive forces that may happen to exist.
3. There are no sliding contacts in the galvanometer circuit.
4. The resistances of the sliding contacts in the battery circuits are negligible.
5. The operation of balancing the electromotive force to be measured does not change the resistances in series with either the galvanometer or the batteries: consequently, it does not change the galvanometer sensitivity.
6. A three-point switch provides a means of reducing the galvanometer sensitivity to 0.1 or 0.01 of the greatest sensitivity used.
7. The galvanometer is critically damped for each sensitivity when balancing either the standard cell or the electromotive force to be measured, and also when the eliminating switch is closed.
8. The range of the instrument can be multiplied by 10 by shifting switches operable by a single handle.
9. An electromotive force can be balanced as closely as with a slide-wire potentiometer without introducing any of the disadvantages of a slide wire.
10. The potentiometer can be used either as a null-method instrument or as a deflection instrument.

<sup>1</sup> Abstract of a paper presented at the Philadelphia meeting of the American Physical Society, October 11, 1919.

11. While the manipulation is as convenient as that of a potentiometer in which all the essential parts are contained in one box, the instrument is made up of parts which can readily be used separately for other purposes.

12. Its cost is low in comparison with that of other potentiometers yielding the same accuracy.

For some time past there has been in regular use a potentiometer of this type which measures any E.M.F. up to 10,000 microvolts with a precision of one microvolt. A galvanometer deflection of 5 millimeters indicates 1, 10, or 100 microvolts, depending upon the position of a switch. The operating current is furnished by dry cells.

PHYSICAL RESEARCH LABORATORY,  
THE L. D. CAULK COMPANY,  
MILFORD, DEL.,  
Sept. 19, 1919.

#### ON ESTABLISHING OF THE ABSOLUTE TEMPERATURE SCALE.<sup>1</sup>

BY FREDERICK G. KEYES.

BY employing the equation of state whose physical basis was set forth by the writer in the Proceedings of the National Academy for 1916, corrections have been made for the constant pressure nitrogen thermometer. The hydrogen and helium equations have in addition been employed to compute the position of the ice point on the absolute scale. The scale corrections are practically the same as those arrived at by Buckingham by the use of the available Joule-Thomson coefficients. The ice point is found, employing the recent Day and Clement Pt-Ir bulb constant volume nitrogen expansion coefficients, to be about 273.14.

The form of equation for one type molecule systems is a linear function of the temperature at constant volume and accordingly the constant volume thermometer readings would lie on the absolute scale. The recent work of Eumorfopoulos on the boiling point of sulphur employing a quartz bulb with the Callendar constant pressure thermometer is free from the disturbing effect inherent to the porcelain and glass bulb previously employed. The values obtained by Eumorfopoulos, corrected to the absolute scale, lead to a mean value for the S.B.P. of 444.54 whereas the mean obtained with the constant volume nitrogen thermometer is 444.52.

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