PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY.

MINUTES OF THE STANFORD MEETING.

THE eighty-eighth meeting of the American Physical Society was held in Room 370, Physics Department, Stanford University, on Saturday, April 7, 1917, in connection with the meeting of the Pacific Division of the American Association for the Advancement of Science. Morning and after noon sessions were held. Professor Sanford presided.

After brief addresses by Professor J. C. Merriam, chairman of the Pacific Coast Sub-Committee on Research, and Director Campbell, urging cooperation between the various affiliated societies, the Committee on Research, the State Council of Defence, and similar national organizations, it was unanimously voted to pledge such coöperation on behalf of the physicists of the Pacific Coast. Professor Sanford and the Local Secretary were authorized to organize this coöperation.

The following papers were presented:

Physical Significance of Entropy. W. P. ROOP.

Experimental Data Illustrating Fundamental Theorems of Kinetic Theory. W. P. ROOP.

A Note on the Relationship Between Ionizing Potentials and Atomic Charges FERNANDO SANFORD.

An Optical Trough for High School and College Demonstration. R. S. MINOR.

The Relation Between E.M.F. of a two-Solution Cell with Calomel Electrodes and the Difference in Specific Inductive Capacity of the two Electrolytes. DAYTON L. ULREY.

The Effect of Occluded Gases on Photoelectric Emission. L. A. WELO.

The Relation Between Current Strength, Voltage, and Luminosity in the Mercury Arc. H. O. RUSSELL.

The Mercury Arc Pump; The Dependence of its Rate of Exhaustion on Current. L. T. JONES and H. O. RUSSELL.

Note on the Use of the Electrometer for Measuring the Conductivity of Gases. J. A. GILBREATH.

A Study of the Stark Effect. J. A. ANDERSON.

Leading Features of the Electric Furnace Spectra of Calcium, Strontium, Barium, and Magnesium. A. S. KING.

Elimination of Pole Effect from Secondary Standards of Wave-Length. H. D. Babcock and C. E. St. John.

Oscillating Systems Damped by Resistance Proportional to the Square of the Velocity. J. P. Van Zandt.

The Surface Tension of Molten Metals. R. H. Coon and E. E. Hall.

Description of a New Apparatus for Exciting X-Rays. Frank Rieber.

A Mechanical Analogy to Electrostatically Coupled Electric Circuits. W. J. Raymond. (By title.)

Optics of the Microscope. C. W. Woodworth.

Note on Electrical Conductivity. F. J. Rogers.

Rigidity of the Earth from Earthquake Waves. F. J. Rogers.

A Method of Determining *J* Based on the Adiabatic Expansion of a Gas. J. C. Shedd.

A Hydrodynamical Paradox. Grandison Gardner.

Members were guests of Stanford University for luncheon, and in the evening there was a subscription dinner at Stanford Inn. About thirty-five were in attendance at the sessions and twenty-five at the dinner. At the conclusion of the dinner there was an informal discussion of radiation and atomic theories. At this evening session the following resolution was adopted:

Resolved, that in view of the limited supply of platinum and the great importance of this metal in the manufacture of sulphuric acid, the conversion of ammonia into nitric acid, and many other industrial and scientific purposes closely connected with the national defense, we, the Pacific Coast members of the American Physical Society, urge the State Council of Defense to take immediate steps (1) To conserve our platinum supply; (2) to prevent its waste through the manufacture and sale of platinum jewelry and through other similar unproductive uses; (3) to secure an immediate inventory of our platinum resources; (4) to bring this matter, through suitable channels, to the attention of the National Council of Defence or other branch of the national government, to the end of securing nation-wide conservation of platinum.

The Society also passed a vote of thanks to the authorities of Stanford University for the courtesies and facilities afforded by them.

E. P. Lewis,
Local Secretary for the Pacific Coast.

On the Origin of the Earth's Electric Charge.[1]

By W. F. G. Swann.

Measurements of the variation of the penetrating radiation, with altitude, point to the upper atmosphere as the origin of a part of this radiation. The whole of the penetrating radiation is probably of the γ-ray type, but the part which reaches the earth's surface from the outer atmosphere

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

is naturally the most penetrating part. Indeed, it is so penetrating that it passes through a thickness of air which would be equivalent, in absorptive action, to a column of mercury 76 cm. high, if absorption coefficients were simply proportional to density and were independent of material. The γ-ray radiation from the outer layers of the atmosphere will consequently be very "hard," and, in accordance with the known results of laboratory experiments, we must conclude that the negative corpuscles which it emits from the air molecules are emitted almost entirely in the direction of the radiation, and further, that they can have a range in air at least equal to that of the swiftest β-rays from radium products, a range, for example, of 8 meters. The emission of corpuscles by these γ-rays will consequently result, at each point of the atmosphere, in a downward current of negative electricity, which we shall call the corpuscular current. This corpuscular current will charge the earth until the return conduction-current balances the corpuscular current at each point of the atmosphere.

Taking, for the purposes of this abstract, a simplified case where the penetrating radiation considered is all directed vertically downwards, if q is the number of corpuscles liberated per c.c. per second by the penetrating radiation, and h the average distance which a corpuscle travels from its point of origin, the corpuscular current density will be

$$i = qeh,$$

where e is the electronic charge.

If q be taken as 2, which is probably about equal to the number of pairs of ions produced per c.c. per second in a closed vessel as a result of the part of the penetrating radiation in question, and if h be taken as 3 meters, we have

$$i = 2 \times 4.8 \times 10^{-10} \times 800 = \text{about } 8 \times 10^{-7} \text{ E.S.U./cm}^2.,$$

which is just of the order of magnitude of the air-earthcurrent-density, so that on this view, the penetrating radiation from the outer layers of the atmosphere provides a sufficient basis for the explanation of the maintenance of the earth's charge.

The corpuscular current-density, and consequently the conduction current-density, will not necessarily be independent of the altitude, for the factors upon which i depends, viz., the intensity and quality of the penetrating radiation, the number of molecules per c.c. available for possible ionization by the radiation, and the range of the corpuscles set free all alter with the altitude.

A few minor difficulties present themselves if the above view be adopted. Thus, for example, near the surface of the earth, a considerable portion of the whole penetrating radiation comes from the soil, and is directed upwards, but this difficulty disappears when it is remembered that the average "hardness" of the radiation from the soil is very much less than that of the radiation which reaches the earth from the outer layers of the atmosphere. Again, it might appear that the corpuscles set free by the penetrating radiation should, on account of their great energy, produce in the atmosphere many more ions per second than are actually found to be produced. This difficulty, and others of allied nature become greatly reduced in magnitude, however, when considered in the light of our present knowledge of the action of very swift β-rays when passing through a gas.

The existence of any contribution to the penetrating radiation other than that arising from the radioactive materials in the air and soil has been questioned by some authorities, and it has been supposed that the walls of the ionization chamber are ultimately responsible for such residual ionization as remains when the radiations from the earth and the air are shielded off. To the extent that the "wall effect" arises from an α-particle radiation it could be detected and allowed for, and a probable estimate of the β- and γ-rays radiation accompanying it could be made, if the electroscope were so sensitive that the contributions to the apparent natural ionization were observable as distinct kicks in the recording fiber. The author has succeeded in obtaining the necessary degree of sensitivity for this purpose, and for illustration of the process has obtained photographs showing the rate of emission of the α-particles from a small amount of radioactive material contained in an ionization chambeı.

Department of Terrestrial Magnetism,
Washington, D. C.,
February 3, 1917.

The Effect of X-Rays on the Length of Life of Tribolium confusum.[1]

By Wheeler P. Davey.

THE proper use of a physical agent in biological work necessitates the physical measurement of the agent employed. A great deal of work is reported in the literature on the effect of X-rays on various forms of animal life. A study of this literature shows that with very few exceptions the measurements of the dosage have been so incomplete as to render the work of little scientific value. It therefore seemed that the effect of X-rays upon living organisms could be quantitatively studied to some good. The organism studied was the "flour weevil," *Tribolium confusum*. These little beetles are especially adapted to such work as is reported here because they are small, harmless, easy to handle and count in large numbers; they propagate readily, cannot crawl out of glass beakers or small porcelain crucibles, and show little tendency to fly.

It was shown that the effects noticed were really due to X-rays and not to some accidental circumstance, such as static field, ionized air, effect of X-rays on food, etc.

A method has been developed which eliminates the error due to idiosyncrasy, thus making it possible to obtain bio-physical laws of a considerable degree of precision. This method consists in plotting probability curves from the data.

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 17, 1917.

If the number of individuals used in the experiments is sufficiently large and if they have been gathered from the same brooder at the same time, then corresponding points on the probability curves may be quantitatively compared. The slope of the probability curves is a measure of the idiosyncrasy of the organism to the physical agent employed.

It was shown that X-rays are able to cause premature death if the dose is larger than a certain threshold dose, but that there is a latent interval between the time the X-rays are administered and the time death occurs. This latent interval depends accurately, for any given individual, upon the logarithm of the X-ray dose, according to the formula

$$Y = A - B \log X,$$

where Y is the length of the latent interval and X is the X-ray dose measured in terms of the electrical input of the X-ray tube, material used as anti-cathode, etc. Voltage, current and distance were kept constant, dosage being varied by varying the time. Too much emphasis can not be given to the necessity of keeping the voltage constant, as the X-ray output of the tube varies greatly with the voltage.

With a standard tungsten target Coolidge tube, operating on sine-wave voltage without X-ray filters, the threshold dose for *Tribolium confusum* is 500 milliampere-minutes at 25 cm. distance at 50 kilovolts, *i. e.*, 500 $\text{MAM}/25^2$ at 50 KV. RMS.

The formula for the length of the latent interval may be easily derived from an extension of the phycho-physic law if the *resistance* rather than the susceptibility of the organism to X-rays is considered.

It is hoped later to present results on the effect of wave-length of X-rays, and on the sterilizing effect of doses below the threshold lethal dose.

RESEARCH LABORATORY,
GENERAL ELECTRIC CO.,
SCHENECTADY, N. Y.

THE PASSAGE OF PHOTO-ELECTRONS THROUGH METALS.[1]

BY K. T. COMPTON AND L. W. ROSS.

EXPERIMENTS by Ladenburg and by Rubens and Ladenburg have shown that the electrons liberated from metals by ultra-violet light escape from a surface layer of the metal, of small but measurable depth, and that the electrons are therefore able to pass a certain distance through the metal and still retain sufficient kinetic energy to enable them to escape from its surface.

We have designed a sputtering chamber in which twelve quartz plates may be successively exposed to the cathode deposit and with which we have been able to secure metal films whose thickness is proportional to the time of sputtering.

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

These films were then mounted on a rotating disk in a vacuum chamber so that they could be interposed successively in the path of a beam of monochromatic ultra-violet light and the photo-electric current then measured from their emergent side.

After passing through the film, the light fell on a second electrode, producing a current from the latter which was proportional to the amount of light transmitted by the interposed film.

The photo-electric current from the film is given by

$$N = KI_0 e^{-\alpha d} \int_0^d e^{\alpha x} F(x) dx,$$

where I_0 is the intensity of the light entering the film, α is the coefficient of light absorption in the film, d is the thickness of the film and $F(x)$ is the probability that an electron liberated at a depth x in the film may escape from the surface. The form of $F(x)$ has been determined for several simple assumptions regarding the nature of electronic absorption. The simplest assumption is that

$$F(x) = e^{-\beta x},$$

where $1/\beta$ is the average distance which an electron can travel through the metal, normal to its surface, without losing its ability to escape.

Our measurements with platinum films indicate that β is very near the value $0.60(10)^7$ cm^{-1}, which corresponds to a mean free path of $1.67(10)^{-7}$ cm. This is of the order of magnitude of the distance between the atoms in the film. We have detected no difference in the values of β as determined for various wave-lengths, which probably indicates that the escaping electrons lose energy as the result of discrete catastrophies (collisions) rather than by a gradual process.

This value of β is larger than that suggested by the work of Rubens and Ladenburg, but it agrees with the order of magnitude predicted from measurements of the Hall effect in platinum.

If our value of β is correct, it probably disposes of the possibility of explaining the thermionic effect as an integrated photo-electric effect.

Palmer Physical Laboratory,
Princeton, N. J.

The Electromagnetic Mass of the Parson Magneton.[1]

By David L. Webster.

In the Parson magneton theory [2] of the atom, and other non-spherical models, the lack of symmetry of the electromagnetic field makes it evident that the electromagnetic mass of a single magneton or whole atom is not the same for

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] A. L. Parson, "A Magneton Theory of the Structure of the Atom," Smithsonian Miscellaneous Collections, November, 1915.

accelerations in all directions, even when the magneton or atom is at rest. If this were the whole mass of the system, then as Ehrenfest[3] and others have proved, the system when in motion would orient itself in the position of maximum kinetic energy, and thereby give an indication of its absolute motion to any observer moving with it. The principle of relativity therefore demands the existence of another kind of mass that will vary in such a way as to keep the total mass constant. The origin of this mass must be investigated before any definite statements can be made about the relation between the total observed mass and other properties of the magneton.

To take a simpler problem first, if two equally charged spheres are held at a fixed distance a by a string, the mutual electromagnetic mass of the pair is $2e^2/c^2a$ for accelerations along the line of centers, but only e^2/c^2a, or $1/c^2$ times the mutual electrostatic energy, for accelerations across this line. In very rapid motion the tendency of the electromagnetic forces to turn their line of centers toward the direction of motion will be balanced by the effects of the tension in the string, whose direction, according to relativity, is no longer that of the string itself. Therefore it is reasonable to expect this tension to supply the forces opposing acceleration from rest that give the variable "internal mass." It will do this provided that its changes are propagated with the velocity f light according to the following law: The force of the string on each sphere always acts as though the direction of the other were that of the point where it would be if it had not been accelerated since it was last heard from through signals with the velocity c, but as though its distance were still equal to a. Any electrostatic system with this type of internal forces will have a total mass equal to twice $1/c^2$ times its electrostatic energy.

The same idea may be extended to a steady current system, with strings having the peculiar property of adjusting their forces to balance all changes of direction of the line between the elements of current they connect, but with no change of force for a change of distance. The same postulate on propagation of internal forces will then give a variable mass, but in this case the internal mass will be negative and will always exactly balance the mass due to magnetic action. This is not, of course, the only possible system of internal forces, but is suggested tentatively in the absence of any more plausible one. If it is incorrect, it would be possible to make assumptions leading to either positive or negative values of the resultant mass. The zero value therefore does not represent any sort of lower limit, and is as plausible as any other.

In any system of static charges and steady currents, the fields due to the charges and to the currents may be proved to have no mutual electromagnetic momentum. For the case of the magneton, then, we may combine the above suggestions and conclude that its mass when at rest is most probably equal to $2/c^2$ times its electrostatic energy alone.

JEFFERSON PHYSICAL LABORATORY,
CAMBRIDGE, MASS.

[1] Ann. der Phys., 1907.

Gyroscopic Effects in the Parson Magneton.[1]

By David L. Webster.

From the experiments of Barnett[2] on magnetization of iron by rotation, and those of Einstein and de Haas[3] on the converse of this effect, it appears that the ultimate magnetic particle shows gyroscopic effects of the order of magnitude of those of an electron moving in an orbit of sufficient size and speed to have the required magnetic moment. In view of the difficulties of accounting for stability in the orbits required for observed magnetic phenomena except by the Parson magneton hypothesis, it is necessary to investigate the possible gyroscopic properties of the magneton.

That such properties exist in it appears from a brief consideration of the retarded potentials near a magneton in precessional motion, but the easiest way to obtain an estimate of their magnitude is from a calculation of the moment of electromagnetic momentum[4] around the axis of the ring. Since at all points very near the circumference of the ring the Poynting vector varies approximately as the inverse square of the distance, r, from it, practically all the energy will be concentrated in this region. At such points the electric vector is $2\rho A/r$ and the magnetic vector is $2\rho Av/rc$, or v/c times the electric. Hence the magnitude of the Poynting vector is $v/4\pi$ times the square of the electric vector, and the electro-magnetic momentum per unit volume is twice v times $1/c^2$ times the electrostatic energy per unit volume. That is, the total moment of this momentum is that of a particle of velocity v and mass equal to twice $\frac{1}{c^2}$ times the electrostatic energy of the system. This mass is exactly that of the magneton as found in the previous paper. In an earlier paper on heat radiation[5] the magneton has been treated as a ring structure on which the electric charge is free to flow. Continuing this line of argument we should not expect any gyroscopic effects from the internal forces of the ring, since without rotation on its principal axis no unsymmetrical accelerations are introduced by rotation on an axis lying in its plane. The resultant gyroscopic effect is therefore exactly the same as for an electron of the classical type in an orbit equal in size to the ring and in speed to that of the electricity on the ring, as required by the experiments of Barnett and Einstein and de Haas.

Jefferson Physical Laboratory,
Cambridge, Mass.

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Science *30*, p. 413, 1909, Amer. Phys. Soc., November, 1913, et seq.; Phys. Rev. [2], *6*, 239–70, October, 1915.

[3] Deutsch. Phys. Gesell, Verk., 17.8, pp. 152–170, April 30, 1915.

[4] The theorem that the electromagnetic momentum concept can be used for calculation of moments as well as resultant forces can be proved by a method similar to the ordinary resultant proof.

[5] Proc. Amer. Acad., Jan., 1915.

ON MOSELEY'S LAW FOR X-RAY SPECTRA.[1]

BY H. S. UHLER.

THE experimental data were taken from tables compiled by Siegbahn from his own investigations and those of his co-workers. The constants, a and b, in Moseley's law, $\sqrt{\nu_N} = a + bN$, were first calculated by the method of least squares and then the percentage deviations of the computed wave-lengths from the experimental ones were evaluated. This was done for the α and β_1 sub-series of the K series and for the α_1, β_1, and γ_1 lines of the L series. In all cases it was shown that Moseley's law does not hold throughout the entire ranges of wave-lengths now known. The deviations at the extreme wave-lengths were always appreciable and amounted to as much as 13.4 per cent. for the L–β_1 line of arsenic.

The equation $\sqrt{\nu_N} = A + B \cdot N + C/(D - N)$ was shown to reproduce the given data well within the limits of experimental error. The parameters A, B, C, and D are constants for any one sub-series but change from one sub-series to another. By extrapolating with power series in N it was shown that the characteristic radiations from hydrogen probably have wave-lengths less than 300 angstroms. Attention was called to the fact that, so far as X-ray wave-lengths alone are concerned, it is not necessary to assign the series of natural numbers to the chemical elements from hydrogen to uranium, but that there exist a high order of infinity of other sequences of numbers which may be taken to represent the atomic numbers.

YALE UNIVERSITY,
January, 1917.

THE ELECTRICAL DISCHARGE FROM POINTS.[1]

BY JOHN ZELENY.

THE results of some experiments indicate that the electric intensity at the surface of a point discharging a current is independent of the material of the point. Measurements were made in air at different pressures with brass, water, glycerine and methyl alcohol.

The dependence of the electric intensity at the surface of a point when a current can just be maintained, upon the radius of curvature of the point and upon the pressure of the surrounding gas has been investigated for water points in air.

When ions of both signs are supplied by some outside source to the gas near a point, they have a much larger effect upon the current when the point is charged positively than when it is charged negatively.

When points show a retardation in the commencement of a current, this current begins to flow at any voltage above a certain minimum value, only a

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

certain interval of time after this voltage has been applied, which interval of time decreases rapidly as the value of this applied voltage increases above the minimum value. On lowering the voltage the current stops suddenly at nearly this last value of the voltage. The minimum current that can be maintained with such sensitive points diminishes regularly with the pressure of the gas.

When single alpha rays enter the region near a charged sensitive point, the range of voltage over which they can produce the large temporary increase in ionization, which is used in counting these particles, includes the minimum potential for which a current can be maintained from the point.

Yale University.

On the Production of Soft X-rays by Slow Moving Electrons.[1]

By H. M. Dadourian.

Electrons from a hot line-cathode were made to impinge against an aluminium target after falling through accelerating electric fields varying from 20 volts to 1,000 volts. The properties of the resulting X-rays were studied by the "photo-electric" effect of the X-rays.

Evidence was obtained of the generation of soft X-rays by electrons impinging against an aluminium target with velocities corresponding to 20 volts.

If a stream of electrons impinge against a solid with velocities corresponding to a voltage V only a very small proportion of the resulting X-rays have the maximum frequency given by the relation

$$Ve = h\nu$$

When soft X-rays fall upon metal plates from 5 to 20 per cent. of the rays are scattered or reflected.

Thin films of celoidine have been obtained which transmitted from 20 to 40 per cent. of the X-rays.

The "photo-electric" current was found to be proportional to the cathode ray current.

Sloane Laboratory,
Yale University.

Experiments Concerning "Magnet-Photography."[1]

By L. A. Bauer and W. F. G. Swann.

In the number of the Scientific American for November 4, 1916, experiments by F. F. Mace are recorded showing that certain articles possess the power of affecting a photographic plate when they are allowed to remain in contact therewith under the influence of a magnetic field. A confirmation of some of Mace's results was recorded by the authors at the meeting of the American

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

Physical Society in December, 1916, and the present paper deals with the continuation of the investigation.

A large number of experiments have been performed at the laboratory of the Department of Terrestrial Magnetism, some with permanent and some with electro-magnets. The details of these experiments are too numerous to be recorded in abstract, but it is concluded that while a magnetic field is not essential to the production of photographs of the kind cited, it probably has an influence in intensifying the effect.

As W. J. Russel and others have shown, wood possesses the power of affecting a plate when allowed to remain in contact with it for some time. The action of the wood is primarily due to the resin in it, and is considerably enhanced if the latter, before use, is stimulated by light.

The action of the resin extends beyond the place of its immediate contact, and in the present experiments, when some stimulated resin was placed on a plate in company with a metallic article, it was found that the image of the article appeared without the employment of a magnetic field, and simply because of the shielding action of the metal on the plate. On evacuating the vessel which contained the article, the effect of the resin extended more uniformly over the plate and was less concentrated in the immediate vicinity of the resin than before; as a result, the image of the metallic article was much more uniform in the case of a vacuum than in that of air.

It has been shown by Russel that metals, especially zinc, when freshly sandpapered, possess the power of influencing a photographic plate when in contact therewith; but in the experiments here described, this action is overpowered by the shielding action of the metal as regards the influence of the resin.

When, in the experiment with resin and the metallic article described above, the resin was replaced by pieces of wood, no apparent image of a set of *metallic articles* appeared after a 7-day exposure in a vacuum, but the absence of effect in this case is probably only one of degree, since the wood contains resin. It is interesting to observe, however, that when the same experiment was carried out under the influence of a magnetic field, distinct impressions were obtained in a vacuum after an exposure of 6 days.

The experiments are being continued.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
WASHINGTON, D. C.,
February 3, 1917.

THE CRYSTAL STRUCTURE OF ALUMINIUM AND SILICON.[1]

BY ALBERT W. HULL.

THE author's method of applying X-ray crystal analysis to microscopic crystals has been briefly described in this journal in connection with the crystal structure of iron.[2] It consists in sending a narrow beam of mono-

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] PHYS. REV., 9, 84, January, 1917.

chromatic X-rays through finely powdered crystals, and photographing the diffraction images of the slit, produced by reflection in all the possible planes belonging to the crystal structure. To make sure that all orientations are equally represented in the aggregate of tiny crystals, the powder is made as fine as possible and kept in continuous motion during the exposure. The positions and intensities of the lines on the photograph are compared with the theoretical values for different possible arrangements of atoms, until an arrangement is found which represents completely the observed lines.

In the preliminary calculations it is assumed that the scattering electrons are concentrated at the centers of the atoms. This gives wrong intensities for the lines, but causes no error in their positions. The relative intensities of the line should be completely accounted for by the position and condition of the electrons in the atoms, and since the number of lines that can be photographed is very large, this offers a powerful means of testing theories of atomic structure. It is hoped to report the results of such an investigation in the near future.

Aluminium.

Fine filings from chemically pure sheet aluminium, in a thin-walled glass tube of 2 mm. diameter, were exposed for 3 hours to a narrow beam of rays from a Coolidge tube with molybdenum target, running at 40,000 volts, 9 milliamperes. The diffracted rays were photographed on Eastman X-ray film with calcium tungstate intensifying screen, bent in a circle of 11.1 cm. radius. The rays were filtered, before striking the crystals, by a paste of powdered zircon crystals 0.3 mm. thick, which completely absorbs the β lines of the K radiation and leaves, as a practically monochromatic radiation, the α doublet, $\lambda = .710$ Å. and $\lambda = .714$ Å. The reflection of this doublet in the different crystal planes gives the lines which appeared on the photograph.

They are tabulated in the accompanying table, together with the corresponding spacing (calculated from the angle of the line and the wave-length) and the theoretical spacing for the assumed lattice. The last column gives the indices of the plane which produced each line.

Aluminium has usually been considered to belong to the isometric system. The X-ray data shows that it must be tetragonal. The unit of structure is a *centered rectangular prism*, with square base 2.85 Å. $\times$ 2.85 Å. and height 4.05 Å., *with an atom at each corner and one in the center of the prism.* The structure is thus similar to that of iron, except that the unit is a rectangular parallelopiped instead of a cube. The number of atoms per unit parallelopiped is

$$n = \frac{[\text{density}] \times [2d_{100}]^2 \times [2d_{001}]}{\text{mass of atom}} = \frac{2.70 \times \overline{2.85}^2 \times 4.05}{2.69 \times 1.663} = 1.99.$$

This is equal, within the limit of error of the measurements, to 2, which is correct for the assumed structure.

Silicon.

Fine crystalline silicon, pulverized in a steel mortar, was mounted in the same manner as aluminium, and exposed for 4 hours to filtered Mo rays at 32,000 volts, 8 milliamperes. The results are given in the table. The lattice is identical with that of diamond, *i. e.*, two-face centered lattices intermeshed, the one being displaced with reference to the other along a cube diagonal a distance of $\frac{1}{4}$ the length of the diagonal. The side of the cube is 5.43 Å., as compared with 3.56 Å. for diamond, and the distance between nearest adjacent atoms is 2.35 Å. as compared with 1.54 Å. for diamond.

The number of atoms per unit cube of the lattice is

$$n = \frac{\rho [4d_{100}]^3}{M} = \frac{2.34 \times \overline{5.43}^3}{28.1 \times 1.663} = 8.00,$$

which is correct for the assumed lattice.

Aluminium.						Silicon.					
Distance of Line from Center, Cm.	Spacing of Plane, Ångströms. Experimental.	Spacing of Plane, Ångströms. Theoretical.	Intensity of Line. Experimental (Estimated).	Intensity of Line. Theoretical.	Indices of Plane.	Distance of Line from Center, Cm.	Spacing of Plane, Ångströms. Experimental.	Spacing of Plane, Ångströms. Theoretical.	Intensity of Line. Experimental (Estimated).	Intensity of Line. Theoretical.	Indices of Plane.
3.45	2.33	2.33	100	100	011	2.58	3.13	3.14	100	100	111
3.99	2.02	2.02	60	64	001	4.21	1.93	1.93	80	344	110
					110	4.97	1.64	1.64	75	148	311
5.67	1.426	1.426	50	86	100			1.57	0	0	111 (2)
					112	6.00	1.36	1.356	25	118	100
6.68	1.21	1.21	60	142	211	6.54	1.25	1.25	45	108	331
					013	7.39	1.11	1.11	50	370	211
6.95	1.17	1.17	20	45	011 (2)	7.84	1.05	1.04	40	116	511
8.09	1.01	1.01	5	28	001 (2)						111 (3)
					110 (2)	8.59	.96	.96	20	152	110 (2)
8.86	.93	.93	25	101	301	8.98	.92	.92	30	144	531
					213	9.66	.86	.86	25	262	310
9.11	.90	.90	25	96	111	10.01	.83	.83	10	63	533
					114			.82	0	0	311 (2)
					130	10.62	.79	.79	5	77	111 (4)
10.05	.82	.82	10	85	132	11.00	.76	.76	10	110	711
					102						551
10.66	.78	.78	15	104	011	11.58	.73	.73	20	414	321
					105	11.90	.71	.71	15	148	731
					321						553
11.75	.71	.71	2	34	100 (2)			.66	0	47	100 (2)
					112 (2)			.64	0	45	733
12.30	.68	.68	4	128	411	13.33	.64	.64	5	172	411
					233	13.60	.63	.63	5	98	751
					215						111 (5)

RESEARCH LABORATORY,
GENERAL ELECTRIC COMPANY,
SCHENECTADY, N. Y.

"It will be noted that the structure here given for Aluminium is identical with a face-entered cubic lattice of side 4.05 A°, a fact which had escaped notice, owing to a numerical rror in preliminary calculations."

Ionization Potentials in Hydrogen, Nitrogen and Nitrous Oxide.[1]

By Fred M. Bishop.

THE ionization potential of certain gases has been studied under conditions which tend to minimize the photo-electric effect on the receiving electrode due to radiations in the tube.

Two different forms of apparatus were used, one a modification of the one used by Franck and Hertz in which plate electrodes were substituted for cylindrical ones. The other piece of apparatus contained an aluminium plate and quartz window and photo-electrons were used.

Ionization in hydrogen began at 11 volts and a second and more intense type set in at about 15.8 volts. No ionization could be detected in nitrogen until an accelerating potential of 7.5 volts was applied. The method was extended to nitrous oxide to see if the combination of one atom with another in a compound had any effect on its ionizing potential. Curves for nitrous oxide did not differ appreciably from those in nitrogen.

Yale University.

New Methods for Counting the Alpha and the Beta Particles.[1]

By Alois F. Kovarik.

THE principle of the method is the discharge to a point properly sensitized and is due to Geiger. The method of observation used by Geiger and by myself with L. W. McKeehan in former researches has been the optical method: observing the sudden movement of the fiber in a string electrometer when an alpha or a beta particle caused a flow of electricity to the point. The C. T. R. Wilson's inclined leaf electroscope has also been adapted for the purpose.

I have found recently a very convenient instrument for the same purpose to be Zeleny's electroscope.[2] In the latest form, the leaf is hinged and the instrument is very sensitive. Its sensitiveness is increased by using a potential difference between the plate and the leaf and case. The leaf is connected directly to the discharging point. The apparatus so arranged is very convenient also for lecture demonstrations.

Another method of observation is based on the utilization of the current to the point in connection with a sensitive telephone. If the discharging point is connected to earth through a sensitive telephone, the discharges are made just audible. The effect was greatly magnified by adapting an audion amplifier. The discharging point is connected to earth through the primary coil of a small induction coil (telephone amplifier). One end of the secondary coil is connected to the grid of the audion bulb while the other end is connected to one plate of a

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Phys. Rev., 32, p. 255, 1910.

condenser, the other plate being earthed. The plate of the audion is connected in series with a sensitive telephone and a battery of about 50 volts, the negative end being earthed. The filament is lighted from a 6-volt battery whose positive pole is earthed. When the number of particles counted is fairly large, this method seems even more accurate than the observation of the fiber of the string electrometer.

Experiments are under way to modify this method so that the particles may automatically register themselves on a chronograph.

It is not difficult to make a point which will respond to alpha particles and give their number accurately but for the beta particles, greater care must be taken to have the point carefully made and to have it quite sensitive. The experiments under way show that their number is also correctly given when proper precautions (see former publications) are taken. Gamma rays also may be studied by these methods and just what these observations signify is being investigated.

YALE UNIVERSITY.

ON THE MEASUREMENT OF "h" BY MEANS OF X-RAYS.[1]

BY F. C. BLAKE AND WILLIAM DUANE.

IN April, 1915, Duane and Hunt presented a paper to this Society describing experiments with X-rays in which it was shown that the equation

$$Ve = h\nu$$

(where V represents a constant voltage applied to the tube, e, the elementary charge and h, Planck's action constant) holds true when, and only when ν represents the *maximum* frequency of the X-rays produced.[2]

In fact we may define "h" to be the kinetic energy of an electron divided by the maximum frequency of the radiation it can produce, when it hits an atom.

The law furnishes us with one of the most accurate methods we have of determining h, e being supposed known.

The authors of this paper have begun a series of experiments designed to determine the value of h under widely different conditions, and also the variation in the amount of X-radiation when different substances are used as targets.

Many improvements have been made in the methods of measurement. A new spectrometer has been designed, with Mr. Franklin L. Hunt's assistance, which enables us to read the positions of both the crystal and the ionization chamber to within 10″ of arc, corrected as usual for eccentricity by means of two verniers at the ends of a diameter. As we make measurements with the

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Dr. D. L. Webster and Dr. A. W. Hull have since verified the law under different conditions.

ionization chamber first on one side and then on the other of the zero line, thus avoiding the necessity of determining the zero point at all, and as the smallest angle measured amounts to about 6°, the error from reading angles does not exceed 1/10 per cent. for each individual determination.

The electrical current through the X-ray tube comes from a high tension storage battery of 20,000 cells. An electrostatic voltmeter (kindly loaned to us by Dr. Webster and Dr. Clark) measured the voltage applied to the tube. This we calibrated by means of a measured current flowing through a manganin resistance of 898,000 ohms. To avoid errors due to changes in the constants of the voltmeter we calibrated it over the range used each time we made a determination, thus referring each measurement of a voltage to that of a current and a resistance. We estimate that each voltage measurement is correct to within 1/10 per cent.

The errors in measuring the voltage and the "glancing angle" are small as compared with the error that depends upon the interpretation one gives to the shape of the curve near the point at which the radiation vanishes. (Slides were shown illustrating these curves.) The shape of the curve is largely due to the widths of the slits and source of the rays (focal spot on X-ray target).

Using Millikan's value of $e = 4.774 \times 10^{-10}$ our values of h vary from 6.507×10^{-27} to 6.559×10^{-27} according to the estimates we make of the effects of the widths of the slits and source.

Harvard University,
February, 1917.

Determinations of Luminous Efficiency and the Mechanical Equivalent of Light.[1]

By W. W. Coblentz and W. B. Emerson.

In connection with the value of the mechanical equivalent of light as determined by using the visibility curve of the average eye, the radiation constants of a black body, and the brightness of a black body at various temperatures,[2] it was of interest to obtain further data upon this important constant. The present measurements were made upon a standardized vacuum tungsten lamp obtained from the Photometric Section of this Bureau. The lamp was operated (stationary) at 1.23 watts per candle, giving 26.5 c.p. or 26.5×10^{-4} lumens per $\overline{\text{cm}}^2$. The total radiation was 293.5×10^{-6} watt per $\overline{\text{cm}}^2$. at a distance of 1 m. from this lamp.

The radiant luminous efficiency was determined by means of a linear thermopile (of bismuth and silver) and a luminosity screen having a transmission curve which coincides very closely with visibility curve of the average eye.[3]

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Phys. Rev. (2), 9, p. 87, 1917.

[3] The constituents of the solution are:

Cupric chloride ($CuCl_2.2H_2O$)	5.7 grams
Cobalt ammonium sulphate [$Co(NH_4)_2(SO_4)_2.6H_2O$]	1.2 "
Potassium chromate (K_3CrO_3)	0.16 gram
Nitric acid (HNO,). 1.3 c.c. sp. gr. 1.05	0.123 gram
Water (H_2O)	100 mols (c.c.)

This solution is used in a glass cell 1 cm. in thickness backed by a cell of water 3 to 4 cm. in thickness.

The various corrections were of course applied. The weighted mean value of the luminous efficiency is $L_r = .0142$ per cent. for a "40-watt" vacuum tungsten lamp operated at 1.23 watts per candle.

The mechanical equivalent of light is obtained from a knowledge of the total radiation, the luminous efficiency, and the candlepower of the lamp used. The luminous equivalent is ($293.5 \times 10^{-6} \times .0142 =$) 4.16×10^{-6} watt per cm². Equating this to the candlepower data (26.5×10^{-4} lumens $= 4.16 \times 10^{-6}$ watt) gives a value of 1 *lumen* = .00157 *watt* of radiant energy of maximum visibility, which is in close agreement (3 per cent.) with the value given in the main part of the paper,[1] which gives further checks upon this value.

Our conclusions are therefore in agreement with Ives and Kingsbury[2] that the value of the mechanical equivalent of light is close to 1 lumen = .0016 watt of radiant energy of maximum visibility.

BUREAU OF STANDARDS,
WASHINGTON, D. C.,
January 24, 1917.

THE ELECTRO-MAGNETIC MASS OF THE PARSON MAGNETON.[2]

BY C. DAVISSON.

EXPRESSIONS are obtained for the electro-magnetic mass of the Parson magneton for small velocities parallel and at right angles to its axis. These, in general, are not the same and vary with the velocity of the charge in the ring. It is shown, however, that when the velocity of the charge in the ring is equal to that of light the directional variation of the mass disappears. The masses parallel and at right angles to the axis are the same and given by

$$m = \frac{1}{c^2}\frac{e^2}{8\pi\rho}\overline{K},$$

where c = velocity of light,

e = charge of the magneton (Heaviside units),

ρ = radius of ring,

[1] PHYS. REV. (2), 9, p. 87, 1917.

[2] PHYS. REV. (2), 8, p. 254, 1916.

[3] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

$$\bar{K} = \frac{2}{\pi}\int_0^{\pi/2} \frac{d\theta}{(1 - \bar{u}\sin^2\theta)^{\frac{1}{2}}},$$

$$\bar{u} = 1 - \frac{r^2}{4\rho^2},$$

and

r = radius of cross-section of ring.

Carnegie Inst. of Technology,
Pittsburgh.

Intensities of X-Rays of the L Series as a Function of Voltage.[1]

By David L. Webster and Harry Clark.

It was shown by one of us[2] that all of the lines of the K-series of the X-ray spectrum of rhodium appear only at voltages greater than a definite critical value. This is the quantum voltage corresponding to a wave-length equal to or slightly shorter than the shortest line of the series. Above this critical voltage all of the lines of the series were found to increase in the same ratio with increase of voltage. In this paper are presented the results of preliminary experiments of a similar nature on the L-series of platinum. The apparatus and methods of work were similar to those referred to above.

Friman's[3] graphs of the square root of frequency against atomic number may be divided into two classes according to slope and curvature; thus suggesting that the L-series consists of two groups, L_1, containing lines α_1 α_2 β_2 and β_5, and L_2, containing η β_1 β_3 β_4 γ_1 γ_2 γ_3 and γ_4.

We have studied the intensities of α_1 β_2 β_1 β_4 and γ_1 as functions of voltage and have found that α_1 and β_2 have the same critical voltage. 11.45 k.v. $\pm$ .05. This is the quantum voltage for the line β_5, the shortest line of the (supposed) series. β_2 β_4 and γ_1 have the same critical voltage, 13.20 k.v. $\pm$ .05, the quantum value for a wave-length between γ_1 and γ_2. Accordingly γ_2 γ_3 and γ_4 (not yet examined) belong to neither L_1 nor L_2.

We have found also that the intensities of the lines of both series are given by

$$I = k(V - V_c)^{\frac{3}{2}},$$

where V_c is the critical voltage of the series to which the line belongs and k is constant for any one line. The relation between the values of k for various lines has not been determined. This formula holds also for the K-series lines of rhodium according to the experiments referred to above.

The value of h derived from our experiments is 6.53×10^{-27} erg. seconds.

Harvard University.

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Phys. Rev., June, 1916.

[3] Phil. Mag., Nov., 1916.

APPLICATION OF THE PHOTO-ELECTRIC CELL AS A PYRHELIOMETER.[1]

BY W. W. COBLENTZ.

ABOUT 10 years ago Ångström[2] described a new method for studying solar radiation, based upon diffusion of the violet and ultra-violet rays by the atmosphere. He covered his pyrheliometer with a blue glass. In this manner he was able to study atmospheric diffusion of solar radiation independently of the water vapor present, and obtained some very interesting data on the variation of the solar constant.

In view of the fact that his instrument was lacking in sensitivity, a potassium photoelectric cell (made by Dr. Kunz) was tested in view of its high sensitivity in the blue-violet. It was found that the galvanometer deflection was not proportional to the stimulus; but for high intensities there were indications that the correction might be found quite uniform. A cell of improved construction gave direct proportionality.

The cell was found too sensitive (battery only 2 volts) to be used with a d'Arsonval galvanometer. Using a higher voltage and milliammeter, the current which passed through the cell, when exposed (through blue glass to reduce the intensity) to the sun was sufficient to damage the cell.

The experiments thus far indicate that by using a less sensitive photo-electric substance the application of this instrument as a pyrheliometer deserves further study.

BUREAU OF STANDARDS,
WASHINGTON, D. C.,
February 3, 1916.

ON THE INSTABILITY OF ELECTRIFIED LIQUID SURFACES.[1]

BY JOHN ZELENY.

THE behavior of a liquid whose surface has become unstable owing to electrification has been studied by means of photographs taken with instantaneous illumination, and also from so-called moving pictures taken at the rate of 800 per second.

When the unstable condition is reached on an alcohol drop a fine thread of liquid about 0.004 mm. in diameter is pulled out of the surface at the rate of about 8 meters per second. The thread of liquid breaks up into minute droplets at the rate of about a million or more per second. These droplets spread out in their flight so as to fill a conical volume and the mist thus formed appears colored by transmitted and by reflected light.

The length of the threads obtained from an alcohol surface is usually under a millimeter but threads 15 mm. long have been obtained from a glycerine surface. With a surface of the order of one square millimeter only one thread

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Ångström, Nova Acta Reg. Soc. Sci. Upsala, IV, Vol. 1, 1907.

is usually formed at any instant, but with a sufficiently high voltage several threads may be produced at once.

When highly electrified drops are made to issue from the end of a capillary tube the electrical field in the neighborhood undergoes rapid changes in direction and magnitude because of the flying material and the liquid masses assume some curious shapes which undergo modifications with extreme rapidity.

Yale University.

Bio-Physics.[1]

By Wheeler P. Davey.

THE application of chemistry to the study of biological problems has been of far-reaching importance. There is every reason to believe that a similar application of physics will be of like value. An outline of the present knowledge of the physics of the living cell will be given, together with some of the theory of the physical structure of cells. The effects of surface tension, adsorption, diffusion and osmosis upon the life of cells will be given. The relation of other branches of physics to biological problems—especially the study of medicine—will be given.

Research Laboratory,
General Electric Co.

Tungsten Electrode Loss in the Hydrogen Arc.[1]

By G. M. J. MacKay and C. V. Ferguson.

DUFFIELD[2] has made a great many determinations of the loss in weight of the electrodes of the carbon arc under varying conditions, and has concluded that the loss of an atom of carbon from the cathode is accompanied by the simultaneous emission of four electrons. From our experience with arcs between tungsten electrodes in various gases we are led to believe that there is no such amount of tungsten lost relative to the transfer of current, and that the phenomena involved do not necessarily require the emission of anything but electrons from the negative electrode.

A quantitative experiment to illustrate the magnitude of the different factors was performed by weighing the tungsten buttons used as electrodes of an arc in hydrogen at approximately 300 mm. pressure before and after operation.

The apparatus consisted of a spherical glass bulb about 12 cm. in diameter. Tungsten leads were sealed in, tipped with removable tungsten buttons of approximately equal size and about 2 mm. apart. The arc was operated from a 500-volt D.C. machine, and was started by heating the electrodes by an auxiliary high potential transformer. The arc was run continuously for 1,265 minutes, the volt ampere characteristics being

[1] Abstract of a paper presented at the New York meeting of the Physical Society, February 16–17, 1917.

[2] Proc. Roy. Soc., *92*, pp. 122–143, 1915.

Initial..................................201 volts, 1.40 amperes,
Final....................................245 volts, 1.40 amperes.

The dimensions of the electrodes were

	Positive.	Negative.
Length	3.17 mm.	3.81 mm.
Diameter	3.17 "	2.03 "
Initial weight	0.4435 g.	0.3785 g.
Final weight	0.4085 g.	0.4026 g.
Difference	−0.0350 g.	+0.0241 g.

The cathode had thus gained 75 per cent. of the material lost by the anode. This interchange could not be accounted for by convection currents since the arc being horizontal, the tendency would be for the metal vapor to go upwards to the top of the bulb. Apparently, then, the tungsten particles given off by the anode become positively charged and migrate towards the cathode.

The temperature of the electrodes was measured by an optical pyrometer of the Holborn-Kurlbaum type as follows:

	Positive.	Negative.
Back shoulder	2681° K.	2469° K.
Middle of side	2734	2681
Front shoulder	3056	3200
Face	3151	3112

Assuming the whole of the weight lost to have come from the face of the anode, the loss in grams per square centimeter per second would be $7.9 \cdot 10^{-6}$ which corresponds to the rate of evaporation in vacuum at 3040° K., less than the temperature found. At 3151° K. the rate would be $28 \cdot 10^{-6}$.

It might be expected that the normal rate of evaporation would be reduced by the gas present as in the nitrogen-filled lamp. There is evidence, however, that hydrogen lowers the rate of evaporation to a lesser extent than nitrogen which at atmospheric pressure reduces the rate to about 1 per cent. of the rate in vacuum. It is particularly difficult, also, to entirely eliminate water vapor from hydrogen, so that some loss of tungsten may be attributed to attack from this source.

It would therefore appear that the following conclusions may be drawn:

1. The cathode though at a very high temperature gains more weight than it loses.

2. The anode loses weight at a rate not appreciably greater than would occur from normal evaporation of the metal due to its temperature alone.

3. The metal leaving the anode becomes positively charged and migrates to the cathode. The number of atoms carried for each unit charge is about 10^{-4}.

RESEARCH LABORATORY,
GENERAL ELECTRIC COMPANY,
SCHENECTADY, N. Y.

A Note on the Relation between Ionizing Potentials and Atomic Charges.[1]

By Fernando Sanford.

THE ionizing potentials necessary to produce the single-line spectra of a number of elements have been determined. It was shown by the present writer at the last meeting of the Pacific Physical Society that on the assumption that the electrons which radiate light and X-rays are moving in approximately circular orbits about a positive central charge, the magnitude of this central charge may be computed from the formula $Q = 2.95 \times 10^{-12}/\sqrt{\lambda}$, where λ is the wave-length of the radiation emitted. It is accordingly possible to calculate the central positive charges for the electrons which give the single-line spectra and to compare these charges with the potential necessary to set up this radiation.

In the following table are given the wave-lengths of the single-line spectra

I.	II.	III.	IV.	V.
Element.	λ.	Q.	V Obs.	V Calc.
Mercury	2537	5.86	4.89	4.81
Zinc	3076	5.32	4.04	4.06
Cadmium	3260	5.17	3.81	3.85
Magnesium	2852	5.53	4.35	4.35
Calcium	4227	4.54	2.94	2.97
Strontium	4608	4.35	2.69	2.70
Barium	5536	3.96	2.24	2.16

as collected by Langmuir in a paper in Trans. Am. Electro-Chem. Soc., XXXIX., 152, with their central positive charges calculated from the above formula, while in the fourth and fifth columns are given the ionizing potentials in volts as determined experimentally and as calculated from the equation $V = (Q - 2.42)\,1.4$ where V is the ionizing potential in volts and Q is the positive charge in electrostatic units multiplied by 10^{10}.

It will be seen from the above table that when the ionizing potentials are plotted against the positive charges of the respective atoms a straight line relation will be found.

This is even more strictly true if the theoretical ionizing potentials of the single line spectra of the alkali metals as given by Langmuir in the same paper are plotted against their respective central charges.

A Study of the Stark Effect.[1]

By J. A. Anderson.

FROM the standpoint of astrophysics it is highly important to be able to examine for Stark effect the lines of such elements as Fe, Ni, Cr, Ti, V, etc., elements which are specially prominent and important in the solar spec-

[1] Abstract of a paper presented at the Stanford University meeting of the Physical Society, April 7, 1917.

trum. Such work requires fairly high dispersion, for the spectra are all rich in lines, and consequently the source must be reasonably bright. An apparatus which works quite well has been constructed recently, and with it some results of interest have already been obtained. The essential feature of the apparatus is the cathode, which is a metal cylinder 12 mm. in diameter and about 15 mm. long, surrounded by a silica tube which extends about 2 cm. beyond the cathode. The luminous discharge is thus confined within the silica tube and is observed through a slot extending from the end of this tube to the surface of the cathode. This cathode and a suitable anode are inclosed in a bell-jar which is exhausted until the dark-space has a length of 5 to 8 mm. Direct current of from 10 to 100 milliamperes at 6,600 volts supplied by a set of high-potential generators is used, the maximum field strength being about 16,000 volts per cm. When the current passes, the cathode heats up rapidly and can easily be melted; in general, however, the current is so regulated that the temperature of the cathode is between 600° and 1000° C. In the region λ 3800 to λ 4600, most of the lines of the metals enumerated above can be recorded in an exposure of 15 minutes, using a dispersion of about 4 Ångström units per mm.

The majority of the lines of these metals show no appreciable Stark effect. Exceptions are:

1. The lines λλ 4098, 4111, 4129, 5275, 5298, and 5329 of chromium, which break up into components in a complicated way, the maximum separation being about one fourth that given by Hδ.

2. A group of about a dozen lines of nickel in the region λ 3940–λ 4027; these do not break up into components, but the wave-length is changed; *i. e.*, each line shifts bodily either to the red or to the violet.

3. Five faint iron lines in the λ 4100 region, which behave like the nickel lines.

An effect similar to that for nickel has been found for 32 lines of the secondary spectrum of hydrogen in the region λ4370–λ 4565.

Leading Features of the Electric Furnace Spectra of Calcium, Strontium, Barium, and Magnesium.[1]

By Arthur S. King.

The furnace spectra of calcium, strontium, barium, and magnesium have been studied by the method already employed for several other elements, the spectra produced at temperatures ranging from 1650° to 2500° being photographed for the interval λ 2600 to λ 7200. Material is thus obtained for a classification of lines according to the temperature at which they appear and the rate of increase in intensity with rise of temperature. Certain lines can be selected which are useful as temperature indicators in the spectra of other sources, lines strong at the lowest furnace temperature being of special interest. The fact that a considerable proportion of the lines in these spectra are known

[1] Abstract of a paper presented at the Stanford University meeting of the Physical Society, April 7, 1917.

to be connected by series relations furnishes an opportunity to note the behavior of series lines at various temperatures. While the members of the same series are affected similarly, large differences in behavior are found between separate series. A triplet series of calcium was found which is favorably situated to test the change, among the members of the same series, of relative intensity with wave-length at different temperatures. As the temperature rose, the violet members of the series were clearly strengthened to a greater degree than those of longer wave-length. This agrees with a previous observation for the principal series of cæsium in the furnace, and indicates a shift of the maximum with change of temperature similar to that shown in the spectrum of an incandescent solid. The close resemblance in structure between the spectra of calcium, strontium, and barium permits a comparison of the homologous lines of the three elements. Such lines are found to be affected in the same way in the furnace spectra.

From the point of view of wave-length measurement, the elimination of dissymmetry in line structure and the resolution in the furnace of groups of lines which form diffuse blends in the arc in air are of especial interest in these spectra.

Elimination of Pole Effect from Secondary Standards of Wave-Length.[1]

By Harold D. Babcock and Charles E. St. John.

The arc recommended by the International Committee on Wave-Lengths has been tested for pole effect. This disturbing influence is found to persist even at the center of the arc to the amount of 0.006 Å. The 6 mm., 6 ampere Pfund arc is also affected to about the same extent at its center, but by making it 12 mm. long and using 5 amperes or less, a central zone is found free from pole effect. That the values thus obtained are the fundamental wave lengths of the lines, is confirmed by observations upon arcs having negative poles of various constitution, operated so as to be free from pole effect. The importance of using fundamental wave-lengths as standards is pointed out.

An Optical Trough for High-School and College Demonstrations.[1]

By Ralph S. Minor.

The optical trough is rectangular in form, about 3 inches wide and $3\frac{1}{2}$ inches high and 26 inches long in size. The bottom is of metal and the sides and one end are plate glass. The other end carries a planomeniscus lens of less than 2 mm. thickness. The trough is suspended on a special tripod stand and the height may be regulated by means of an adjustable collar so that the trough may be rotated about a vertical axis after the height has been fixed.

[1] Abstract of a paper presented at the Stanford University meeting of the Physical Society, April 7, 1917.

This optical trough with its various accessories is designed to serve three purposes: First, as a piece of demonstration apparatus for a first course in physics, second, for the demonstration of a variety of phenomena which are beyond the scope of the first course; third, as a piece of laboratory apparatus for a course in college physics. The optical trough supplements the Hartl optical disk and has the advantage of using the entire wave front and not merely a section of it. The visibility of a beam of light passing through the trough is slightly greater than that produced by the Hartl disk with the same illumination.

The accessories include: plane and spherical mirrors, a plano-convex glass lens, double convex water lens, double concave air lens, trial case lenses and cylinders for studying the refraction of the eye, image and object screens for studying refraction at a single spherical surface, and models of both Huyghens and Ramsden eye pieces which may be used either in air or in water.

UNIVERSITY OF CALIFORNIA.

NOTE ON THE USE OF THE ELECTROMETER FOR MEASURING THE CONDUCTIVITY OF GASES.[1]

BY J. A. GILBREATH.

IN carrying out experiments on the conductivity of gases, a tube containing two parallel plate electrodes separated by a few millimeters is sometimes used. One of the plates is connected to an electrometer and the other to one terminal of a storage battery. H. S. Anderson used such a tube in working with the photoelectric effect and reports finding a current through the tube in a direction opposed to the E.M.F. of the battery.[2] This effect can be explained on the basis of induction. The two parallel plates constitute a condenser. If the E.M.F. of the battery decreases, the potential of the connected plate falls and this releases a part of the bound charge on the second plate. Thus, if one plate is connected to the positive pole of the battery it would have a positive charge and the second plate would have an equal negative charge. If the potential of the positive plate diminish it is unable to hold so large a bound charge on the second plate. Part of the negative charge from the second plate then flows into the electrometer giving the appearance of a current opposed to the E.M.F. of the battery.

If a battery is furnishing current, its E.M.F. is very apt to decrease. In the article referred to the cells were furnishing current through a water resistance which constituted a potentiometer system by which any desired E.M.F. could be applied to the tube. Under these conditions it is not strange to find a sensitive electrometer showing a negative " current " when a positive potential is applied.

[1] Abstract of a paper presented at the Stanford University meeting of the Physical Society, April 7, 1917.

[2] PHYS. REV., Vol. XXXV., October, 1912.

In using a tube of this kind with an electrometer whose sensibility was 4,000 divisions per volt the writer found that a potentiometer arrangement for varying the voltage was not satisfactory. The cells continually ran down, showing the negative effect. It was found more satisfactory to vary the voltage by varying the number of cells used. Before connecting the battery to the tube a small current was drawn through a high resistance for two or three minutes then the battery was allowed to recover for two or three minutes, and then connected to the tube. The negative effect then entirely disappeared and the electrometer showed no deflection.

Physics Laboratory,
University of Washington.