PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

Minutes of the New York Meeting, February 21 and 22, 1930

The 162nd regular meeting of the American Physical Society was held in New York City at the Physics Laboratories of Columbia University on Friday and Saturday, February 21 and 22, 1930. The presiding officers were Professor Henry G. Gale, President of the Society, Dr. W. F. G. Swann, Vice-President, Professor John Zeleny and Dr. Arthur E. Ruark.

The Saturday morning session was given over to a Symposium of Photoelectric and Thermionic Phenomena. The speakers were F. L. Mohler, F. K. Richtmyer, William V. Houston, C. E. Mendenhall and G. Wentzel. The titles of their papers appear in the following list of abstracts, numbered 46–50 inclusive. The symposium was attended by over 400 persons.

At the regular meeting of the Council held on Friday, February 21, 1930 twenty-two were elected to membership. *Elected to Membership*: Eugene C. Bingham, Kenneth C. Blanchard, Willard E. Bleick, Leo P. Delsasso, A. M. I. A. W. Durnford, Frank M. Exner, Charles F. Ffolliott, D. A. Fogelsanger, Omer R. Fouts, James D. Hardy, Mituyosi Igari, A. L. Johnson Jr., Wendell R. Koch, Richard H. Lee, William G. Moran, Yoshio Nishina, Luhr Overton, Elmer N. Turnquist, J. S. Webb, Herman G. Wehe, Donald B. Woodbridge and Oliver R. Wulf.

The regular scientific session consisted of 63 papers, Numbers 1, 2, 3, 8, 14, 15, 20, 32, 33, 42, 57 and 58 were read by title. The abstracts of these papers are given in the following pages. An **Author Index** will be found at the end.

W. L. Severinghaus
Secretary

ABSTRACTS

1. Transient earth currents accompanying the recent Newfoundland earthquake of 1929. Richard Hamer, *Acadia University.*—It does not seem to have been recorded hitherto that transient electric and magnetic disturbances were associated with earthquakes. It seems certain that such did accompany the recent earthquake off Newfoundland. Observations, similar or related, of others, besides personal, have been reported supporting the author's contention. The geophysical importance of such a fact is obvious. Several years ago the author proposed to account for variations of the earth's magnetic elements by assuming circulating earth currents. This granted, earth movements would obviously be accompanied by transient electron readjustments. However other possible causes exist; such as temporary readjustments of the electric activity of large mineral deposits and certain strata; also the possible frictional electricity generated due to the relative motion at the long break; and also polarization from fracture or piezoelectric effects on variations of stresses. By induction if not by conduction the temporary influence of such electrical disturbances was transmitted with a speed approaching that of light in an expanding area around the epicenter. Ordinary seismic waves followed arriving later and later relatively at more distant regions. Thus the author determined the epicenter. The importance of studying earthquakes from this new angle is emphasized.

2. A modification of Wiechert's experiment. T. R. WILKINS AND J. A. WOOD, *University of Rochester.*—Wiechert's single equation method for a direct determination of the speeds of corpuscles has been modified by using a vacuum tube oscillator and an electrostatic deflecting field. This revives an experiment, theoretically very attractive but which has been experimentally extremely difficult. (See J. J. Thomson—Conduction of Electricity through gases.) Since the period of the oscillator can be held very constant, the difficulties experienced by earlier experimenters who used Tesla Coils and large high frequency currents to energize the deflecting fields disappear. The method would seem equally applicable to positive ray analysis or as a general corpuscular filter.

3. Polar molecules—their contribution to energy loss. F. HAMBURGER JR., *Johns Hopkins University,* (*Introduced by J. B. Whitehead*).—Some discussion has taken place during the last year as to the possible effects of molecular orientation as a source of dielectric loss. The suggestion has been offered that even at frequencies as low as those of commercial power circuits the theory of molecular orientation may be offered as an explanation of at least a portion of the dielectric loss. This paper is an attempt to examine this suggestion on the basis of the Debye theory and the available experimental data. It shows that in the case of glycerine at temperatures of zero and ten degrees Centigrade the loss due to orientation, at frequencies below ten thousand cycles per second, is negligible. Furthermore, it indicates that for the usual insulating oils, the possibility of accounting for even a portion of the dielectric loss observed at commercial frequencies, on the basis of molecular orientation, is remote.

4. Magnetoresistance and elastoresistance in permalloy. L. W. MCKEEHAN. *Yale University.*—A continuation of preliminary work reported by Arnold and McKeehan (Phys. Rev. [2] **23,** 114 (1924)). The effect of intensity of tensile stress upon the change in resistance due to magnetization has been observed in straight wires of annealed permalloy over a wide range in composition. Additional studies have been made on specimens containing 45, 77 and 84 percent nickel. In these latter wires the magnetization and resistance have been measured simultaneously. The resistance for a given magnetization is not single-valued, although a symmetrical "hysteresis" loop on the magnetization-resistance plane may cross itself. The magnetic fields were produced by long solenoids and the magnetic field intensity did not exceed 50 gauss in the definitive experiments. Under suitable conditions, however, this field intensity is sufficient for approximate saturation of the magnetoresistance effect. The results lend support to the view that adjacent atoms in a pure ferro-magnetic metal, and—*a fortiori*—in a ferromagnetic alloy, differ widely in those constraints which determine their dirigibility by externally applied forces.

5. Stabilized oscilloscope with amplified stabilization. FREDERICK BEDELL AND JACKSON G. KUHN, *Cornell University.*—One stage of amplification included in the stabilizing circuit of the Bedell-Reich oscilloscope, which comprises a cathode-ray tube with linear time-axis for observation of periodically varying quantities, extends the range of frequencies through which the curves on the screen of the cathode-ray tube may be stabilized and maintained stationary so that they can be photographed either with camera or contact print. Linearity of time-scale is shown by equality of successive wave-lengths and is controlled by an equalizing adjustment. Although not primarily intended for use beyond the audio range, the instrument has in this way been stabilized above 100,000 cycles. Curves are given showing the use of the instrument for the study of electrical quantities, as in the study of modulation and rectification, the ripple voltages in B-eliminators and filters and the wave-form of different oscillators; also curves obtained with photo-electric cell, showing flicker in candle-power in light sources, and curves, obtained with condenser microphone, showing wave-form of notes from musical instruments, the violin and clarinet. To be published in Review Scien. Instruments, April, 1930.

6. The initial stages of electrical breakdown. J. W. Beams and J. C. Street, *University of Virginia*.—A Kerr cell method (Beams, Jour. Franklin Inst. **206**, 809, (1929)), a simple comparison arrangement and a method making use of a rapidly rotating mirror (Beams, Phys. Rev. **33**, 1086 (A) (1929) have been used to determine the average time lag of the spark. The last method has also been used to photograph the different stages of the discharge. The time lag is decreased by ultra-violet light on the cathode, ions in the gap or by increasing the field strength. When a field of 4×10^4 volts/cm is very suddenly impressed, in ordinary air at atmospheric pressure containing the usual number of ions the average time lag is less than 5×10^{-8} sec. In dry filtered air, at atmospheric pressure, from which as many ions as possible were removed by auxiliary fields, 6×10^5 volts/cm could be applied for over 10^{-6} sec. without breakdown. Similar results were obtained with dry filtered hydrogen and nitrogen. Brass ball electrodes were used. The velocity of expansion of the spark is increased with decrease of pressure. At atmospheric pressure, the luminosity near the cathode becomes the most intense in approximately 2×10^{-7} sec. and gives rise to the well-known streamers. However at pressures roughly rom 0.008 mm to 0.001 mm the anode luminosity was found to be the most intense.

7. Some new types of electrical discharge in high vacua. R. W. Wood, *Johns Hopkins University*.—Discharges excited in such high vacua as to be called non-conducting in the usual sense, excited through external electrodes with high frequency oscillators of wave-lengths varying from two to thirty meters. The effects of electric and magnetic fields upon the curious luminous balls and spindle shaped bodies (which have been named "plasmoids" provisionally) have been exhaustively studied, as well as the curious red phosphorescence of the glass which usually appears. Some progress has been made towards the explanation of these discharges by employing stroboscopic methods. The remarkable pressure changes which occur in the sealed off tubes as a result of "clean-up" or gas-evolution have been followed by vibrating quartz fiber mano-meters.

8. Complete dissociation of H_2. E. U. Condon, *University of Minnesota*.—It is well known that where nuclear motions are involved mere energy sufficiency does not always make possible processes of excitation by electron impact or light absorption. Usually the critical potential in molecular hydrogen near 30 volts is interpreted as $H_2 \rightarrow H^+ + H^+ +$two electrons for which the energy needed is 4.4+twice 13.5 =31.4 volts. But this cannot be since if both electrons be removed the nuclei possess a mutual potential energy of about 18 volts. Therefore this process should require about 50 volts and when it occurs the protons formed would have kinetic energy of about 9 volts each. Just as Condon and Smyth (Proc. Nat. Acad. **14**, 871 (1928)) have interpreted the 11 volt dissociation as due to transitions from the normal state to the repulsive Heitler-London potential energy curve so now it is suggested that the loss at 30 volts is due to transitions from the normal state of H_2 to the repulsive Morse-Stueckelberg curve of H_2^+ in which case the process produces protons having about 6 volts of kinetic energy.

9. The primary ions formed by electron impact in hydrogen. Walker Bleakney and John T. Tate, *University of Minnesota*.—The results of a study of the primary products of ionization in hydrogen obtained with a mass spectrograph previously described (Phys. Rev. **34**, 157 (1929)) indicate that there are at least three different processes by which an ion may be formed by a single impact with an electron. (1) The molecular ion H_2^+ appears at 15.4 ± 0.1 volts as the result of the removal of one electron. (2) Ionization and dissociation occur simultaneously, yielding the atomic ion H^+ at a minimum potential of 18.0 ± 0.2 volts. (3) At about 30 volts another ion is formed, presumably H^+, which is characterized by the fact that it has several volts kinetic energy. It appears in the analyzer as a very broad peak and it also has been found to reach a side plate against the influence of a retarding field. The reactions (2) and (3) are much less probable than (1). These effects find a theoretical interpretation in the potential energy curves of Morse and Stueckelberg for the hydrogen molecule, as Condon has pointed out in the preceding paper.

10. The reflection of hydrogen Atoms from crystals of lithium fluoride. Thomas H. Johnson, *The Bartol Research Foundation*.—The reflection of hydrogen atoms from crystals studied at first with NaCl and KCl crystals is now being extended to other alkali halides. The preliminary results with lithium fluoride are interesting in two respects. In the first place a sharply defined specular beam appeared as with the other alkali halides heretofore tried but LiF may, under favorable conditions, reflect up to about fifty percent of the incident beam in the specular direction as compared with 5 percent for NaCl and 0.5 percent for KCl. In the second place it has been found that the reflecting power of LiF is strongly affected by the action of the atomic hydrogen or other products of the discharge tube which is used as the source of the atomic beam. Thus it has been found that a crystal at room temperature, though exposed to atmospheric air and to the molecular hydrogen from the unexcited discharge tube for some time, reflected the atomic beam intensely at first but the reflection had fallen off to one half of its initial intensity in a time of the order of one minute. At higher temperatures the same fatigue occurred but the reflection persisted for longer times up to about an hour.

11. Molecular beams in electromagnetic fields. D. E. OLSHEVSKY, *Yale University.*—A systematic synthetic study of possible arrangements of the vector quantities characteristic of a molecular beam experiment such as field strength, field gradient, molecular moment, velocity of beam and force is made. Known experimental arrangements of Kallman-Reiche, Stern-Gerlach, Rabi and of Clark are thus classified and their features clearly brought out. Analysis yields several new experimental arrangements of interest. Briefly, they are: (a) Reversal of beam direction in Rabi's experiment, the last slit being in the magnetic field and beam coming *out* of the field, with expected improvement in resolution; (b) Arrangement of field gradient at right angles to field and beam direction with possibility of detecting molecules oriented perpendicular to field; (c) Arrangement with the second slit consisting of two closely spaced, field producing wedges, the beam perpendicularly to the plane of the slit. Arrangement (c) seems to be particularly efficient due to the fact that the beam can be left larger than slit spacing, the second slit serving as a highly efficient microscopical field-producing unit.

12. Recombination of hydrogen-like atoms. E. C. G. STUECKELBERG AND PHILIP M. MORSE, *Princeton University.*—The probability that an electron moving with a velocity of V volts recombines with a hydrogen ion or with an ion having a similar field and resultant nuclear charge Ze to form an atom in a state defined by the quantum numbers n, l is usually expressed by the effective cross section of recombination $q(n, l, Z, V)$ cm^2. The transition probabilities have been calculated from the matrix elements referring to the two states. A solution of the Schroedinger equation in a Coulomb field giving at large distances a plane wave has been found by Mott and by Temple. With the aid of this function an exact expression for the q's has been obtained, which decreases monotonicly with increasing V. For V small compared to $-E_{n,l}$ (the term value) an asymptotic formula can be used of the form $q(n, l, Z, V) = 1.237 \times 10^{-19} \cdot e^{-4n} \cdot C_{n,l}, Z^2/V$. The values for $C_{n,l}$ have been computed for $l=0$ and $n=1$, 2 and 3; for $l=1$ and $n=2$ and 3. $C_{n,l} \cdot e^{-4n}$ decreases for increasing n and approaches 0 for $n=\infty$. For some of the states the exact expressions for any V have been computed. They show in order of magnitude as well as in functional behavior a fair agreement with the older theories and the experiment. However, this theory can not explain the experiments by Barnes and Davis and it seems that their results must be due to a more complex reaction than simple recombination.

13. A search for critical potentials for electron recombination with Hg^+. A. M. CRAVATH, (*National Research Fellow*), *Princeton University.*—The discovery by Davis and Barnes (Phys. Rev. **34**, 152 (1929)) that electrons which have just enough energy to ionize He^+ recombine astonishingly rapidly with He^{++} suggested a search for recombination of 10.4 volt electrons with Hg^+. A cylindrical ring electrode 0.6 cm long, 2.5 cm diameter, was placed in a large Hg vapor arc, pressure 0.01 mm, ions per cm^3 up to 1.5×10^{11}. Electrons from a small oxide coated filament along the axis of the cylinder were accelerated in the thin sheath around the filament and then travelled out radially through the nearly equipotential ionized vapor to the cylinder whose potential was positive to the filament but negative to the space. The effect sought was a sharp reduction in the electron current reaching the cylinder when the electron energy passed through 10.4 volts. No effect was found. This may be due to the narrowness to the range of energies for which recombination has a high probability, only a fraction of the electrons in the stream from the filament ($T \sim 1000°K$) having energies in this range. If this range had been comparable in width to the peaks in Davis and Barnes' experimental curves practically the whole electron stream would have been stopped.

14. Sorting the variables in the crystal structures of certain chromium-nickel alloys. F. C. BLAKE AND JAMES O. LORD, *Ohio State University*.—Microphotographs of certain chromium nickel alloys containing from 63 to 85 percent chromium revealed three phases present. The melts were made in a partial vacuum in crucible of alumina and were practically free from carbon. It was noted in general that after the power for the furnace was shut off but the partial vacuum maintained that the vacuum increased showing that some of the residual gases were being absorbed by the melt. Examination revealed nitrogen present in the melt. One phase was readily found to be body-centered chromium. Further experimentation revealed another phase to be chromium nitride and by the use of proper etching reagents a third phase was found to be chromium nickelide, Cr_2Ni, with ninety-six atoms to the unit cell, the cell consisting of four interpenetrating lattices of nickel with four other interpenetrating lattices of chromium, the lattice being body-centered tetragonal with $a = 10.64$A and with an axial ratio of 1.040. The density of the tetragonal phase is identical with that of body-centered chromium, *viz.* 6.93. Both the nickelide and the nitride are very hard and practically insoluble in hot aqua regia, especially the nitride. The lattice of chromium nitride was proved to be close-packed hexagonal with $a = 2.751$A., the axial ratio being 1.605, the unit cell consisting of two atoms of chromium and two of nitrogen. This gives a calculated density for chromium nitride of 7.75. The space group for the nitride is D_3^2 with the two nitrogen atoms interpenetrating. The possibility of a fourth phase being present is discussed.

15. An interesting case of a unit lattice made up of interpenetrating lattices. F. C. BLAKE, *Ohio State University*.—Some of the most interesting and important cases of alloys and solid solutions can be studied only by the powder method, for with several phases present no method has yet been devised for obtaining large single crystals of the phases separately. Indeed the importance of many of the alloys industrially is due to the very fact that their crystallinity consists only of *micro*crystals. Thus the powder method is the only one available. After considerable effort spent more or less uselessly trying to guess at the structure of a tetragonal chromium nickelide a deliberate attempt was made to see if one could build up synthetically a series of interpenetrating lattices of chromium and nickel which would give the reflection intensities observed. This was found to be possible, the lattice consisting of thirty-two atoms of nickel and sixty-four of chromium and having the property of unusual hardness spoken of by Professor W. H. Bragg (Proc. Royal Inst. **XXVI,** 6 (1929)) for many-atomed lattices of alloys of copper with aluminum, zinc and tin. The most interesting property of such a lattice is that the first sixteen lines that one might expect to be strong on the powder photograph do not appear at all, in agreement with observation. The space-group of the lattice found is D^{10}_4, a hemihedral form.

16. The classes of symmetry possible in crystals of elements. R. H. CANFIELD, *Naval Research Laboratory, Anacostia, D. C.* The object of this study is to determine the types of space-lattices possible in crystals composed of atoms of one kind and subject only to mutual central forces, the force between two atoms being zero for only one value of the distance. It is found that the conditions of equilibrium of one atom require that the center of gravity of any group of atoms which lie on the surface of a sphere shall lie at the center of the sphere. This condition of what may be termed "barycentric symmetry" limits the possibilities to 21 out of the 32 recognized classes of symmetry. Equilibrium against a generalized infinitesimal strain of the whole crystal imposes the condition that the principal axes of inertia of all such spherical groups of atoms shall have the same directions, and the principal moments of inertia be in the same proportion. This limits the possible classes still further to the five classes of the cubic system. It is concluded that since there are many exceptions to the latter rule many crystals even of elements cannot be regarded as homopolar in the sense of the first paragraph.

17. Excitation potential of the *Lα* satellites of Ag (47). S. W. Barnes and F. K. Richtmyer, *Cornell University.* A precise knowledge of the excitation potentials of satellites should make it possible to distinguish between the Wentzel-Druyvesteyn theory of their origin and the so-called "two-electron jump" theory proposed by one of the present authors. The very meagre data in existence indicate that the excitation potentials of satellites are of the order of 20–40 percent higher than those of the corresponding parent lines. Using a Siegbahn vacuum spectrograph and a transformer-kenotron-inductance voltage supply which gave a ripple of much less than one percent, a series of exposures were made at 7, 6, 5, 4.5 and 4.4 kilovolts, respectively, on the *Lα* line of Ag(47), the excitation potential of which is 3.35 k.v. Satellites were clearly visible on the plates taken at 4.5 k.v. and higher, but were not visible on the plate taken at 4.4 k.v., although the intensity of the parent line on the 4.4 k.v. plate was greater than on that at 4.5 k.v. However, the *Lα* line at 3.8 k.v. shows an unsymmetrical "foot", which may indicate the presence of an unresolved satellite structure. If so, the excitation potential of the satellites may be much lower than 4.4 k.v. Acknowledgment is made of assistance from the Heckscher Research Council of Cornell University.

18. Satellites of *Kα* for the elements Ni(28) to As(33). F. K. Richtmyer and E. Ramberg, *Cornell University.*—The satellites $K\alpha_{3,4}$ of the line *Kα* have been recorded previously from Na(11) to Zn(30) at which point they seemed to disappear. At Zn(30) the *N* shell begins to grow, which fact, it was previously thought, might be in some way related to the disappearance of the satellites. However, exposures made to bring out the satellite structure of the *Kα* line of the elements Ni(28) to As(33) show that satellites (unresolved on the photographic plate) are clearly visible up to As(33), although they are relatively much less intense than for elements of lower atomic number. Observations by means of the two-crystal spectrometer show that the satellites $K\alpha_{3,4}$ of Cu(29) are clearly resolved into the two components, as is found by the photographic method for lower atomic numbers. These new data fit the Moseley type of graph for satellites proposed by one of the authors (F. K. R., Phil. Mag. **6**, 76 (1928)). Acknowledgment is made of assistance from the Heckscher Research Council of Cornell University.

19. Position and width of the modified line of the spectrum of scattered x-rays. F. L. Nutting, *The Drexel Institute, Philadelphia.*—The Compton Shift $\delta\lambda = h/mc(1-\cos\phi)$ was tested at definite, large scattering angles by two independent methods. (a) *Photographic method.* Using fluorescence radiation before and after for fiducial marks, Mo radiation was scattered at 169 degrees from paraffin for 300 hours (maximum spread of scattering angle 12.5 degrees). The mean value of the shift of the center of gravity of the $K_{\beta\gamma}$ line on microphotometric curves gave $h/mc = 0.0231\text{A} \pm 0.00023\text{A}$. The shift of the peak of the β line (corrected for the presence of the γ line of 1/7.7 its intensity) gave $h/mc = 0.02376\text{A} \pm 0.00023\text{A}$. (b) *Ionization method.* Using two narrow cylindrical Mo tubes side by side and a Soller slit to increase intensity and scattering at 170 degrees from graphite (maximum spread of scattering angle 8 degrees), the mean of a large number of runs gave $h/mc = 0.0240\text{A} \pm 0.00024\text{A}$ for the shift of the K_α doublet. *Components.* No definite evidence of components appeared in the mean microphotometric curve, although the fluorescence α doublet was clearly resolved and the angular spread of scattering small.

20. The quantitative application of the irregular doublet law to an isoelectronic sequence. R. A. Sawyer, *University of Michigan,* and J. E. Mack, *National Research Fellow, University of Minnesota.*—Heretofore the irregular doublet law of x-ray spectroscopy has been applied in isoelectronic sequences only qualitatively. (i.e. $\nu(n, l_1) - \nu(n, l_2)$ is a linear function of Z). Now Wentzel's result $\sigma_1(n, l+1) - \sigma_1(n, l) = 0.58 \cdot 2^l n$ for the first order screening number σ_1 in x-rays is applied, determining the rate of dependence of the energy of the transition $2s^2 2p^5 \leftarrow 2s2p^6$ upon the atomic number Z in the fluorine-like sequence, to be $49 \cdot 10^3\ \text{cm}^{-1}$. New experimental results in Na III and Mg IV show it to be $48.01 \cdot 10^3\ \text{cm}^{-1}$. Although such accurate predictions are not generally possible for an arbitrary number of electrons, certain regularities may be used for interpolation in many cases.

21. The quantum theory of x-ray exposures on photographic emulsions. A. P. H. Trivelli, *Eastman Kodak Co.* (*Introduced by L. A. Jones.*)—The quantum theory of photographic exposures as proposed in 1922 by L. Silberstein had to be given up on account of the fact that the differences in sensitivity of the grains are determined not only by the projective area of the grain; a chemical factor is also entering into it for visible radiation. Kinoshita and Th. Svedberg have showed that every α-particle hitting a silver halide grain makes it developable. The sensitivity of the grain is, therefore, determined by its projective area and the probability that a grain is made developable by exposure to α-particles is given accurately by the equation, $p=1-e^{-na}$ (a = projective area, n = number of α-particles). An investigation with L. Silberstein has shown that the same equation holds for x-ray exposures.

22. A theoretical and experimental study of the resonance radiometer. J. D. Hardy, *Johns Hopkins University.* (*Introduced by A. H. Pfund.*) The voltage sensitivity limit of steady deflection galvanometers, regardless of degree of magnification or precision of manipulation, has been shown to be of the order of 10^{-9} volts. This is the natural sensitivity limit set by the Brownian fluctuations in the suspended system causing a random zero unsteadiness The calculation has been made for the case of the resonance radiometer (See Abstract of A. H. Pfund, Science Feb. 1929) and the results show that this natural limit has been lowered by about one hundred times, that is, to the order of 10^{-11} volts, in the present apparatus with a possibility of still further lowering the limit by mechanical and electrical improvements. Some results are given to show that without much precaution a sensitivity surpassing that hereto-fore obtainable can be realized and one that is very close to the theoretical limiting value. The smallest energy difference that has been with certainty distinguished is of the order of 10^{-4} ergs per second per square millimeter. A method is described for measuring the speed of response of thermocouples. The average speed of the thermocouples used was found to be 0.2 sec. in air and 2 minutes in vacuum.

23. High dispersion in the infra-red. R. Bowling Barnes, *Johns Hopkins University.*—For the purpose of comparing the Raman effect with infra-red absorption spectra, the following organic liquids have been measured from 3.1μ to 3.6μ: benzene, toluene, ortho-, meta- and para xylene, ethyl-, butyl-, monochlor-, and monobrombenzene. The spectrometer employed an echelette grating, which had 3600 lines per inch, and which concentrated the energy of a Nernst filament into the region which was investigated. The dispersion of the instrument was such that with the slits each 0.25 mm in width, one "slit width" was approximately 25A″. The calibration was obtained in terms of the positions of the 5461 line from an auxiliary Hg arc, and the wave-lengths as given are considered accurate to $\pm 0.003\mu$. In every case the bands in this region, due to the C-H vibration, which have hitherto been reported only under low dispersion have been resolved into many component parts. The 3.25μ band of benzene was resolved into three equally strong components lying at 3.231, 3.253 and 3.291μ respectively. The shifts of these bands caused by the various substitutions were studied, and in no case was a shift of over 0.01μ found. Published data on the Raman effect failed to reveal the complexity shown by these absorption spectra.

24. Iodine fluorescence in the infra-red. F. W. Loomis, *University of Illinois.*—Oldenberg has photographed in the infra-red the fluorescence spectrum of iodine excited by the mercury arc. The spectrum is chiefly an extension of the well-known series of doublets excited by the green mercury line; but in the neighborhood of the infra-red doublets there appear other lines. Pringsheim attributes these to transitions to the extraordinary new molecular level which he reported. It is now found, however, that they disappear when the yellow lines are filtered from the light of the mercury arc. They should therefore be attributed to the higher members of the fluorescence series excited by the yellow lines. The relatively high intensities of these members is due to their being on the right arm of the Franck-Condon parabola.

25. The relation between Raman spectra and the molecular structure of organic compounds. Donald H. Andrews, *The Johns Hopkins University.*—The following procedure is proposed for identifying the type of vibration in the molecule to which an observed frequency in a Raman spectrum corresponds. It is assumed that the only forces acting between the atoms in the molecule are those produced by the chemical bonds, and that there is a restoring force if the bond is stretched or if the angle which the bond makes with the other bonds on an atom is altered from the normal equilibrium value. It is also assumed that all non-polar chemical bonds have the same force constants. The different frequencies observed in the Raman spectra may then be considered as due solely to the variation in mass of the atoms concerned and to their space relation to each other, that is, whether they are in a straight chain, a branching chain, a ring, etc. It is possible to calculate in this way the number of Raman lines which should be observed for any compound, and the frequencies they should have. There is fair agreement with the observed spectra, close enough so that the lines can be identified with different types of motion in the molecule, and calculations of specific heat can be made.

26. A theory of zodiacal light. E. O. HULBURT, *Naval Research Laboratory.*—Since solar outbursts which give rise to aurorae and magnetic storms also cause changes in the zodiacal light it is possible that the zodiacal light is mainly sunlight re-emitted by the absorbing particles and not scattered or reflected by them. This permits a reconsideration of an old view that the particles originate in the earth's atmosphere, although the 15 percent polarization of the zodiacal light is left unexplained. Neutral atoms and molecules of the upper fringe of the earth's daytime atmosphere upon collisions of the second kind are ejected upward with velocities around 11 km sec^{-1} to 30,000 or 80,000 km levels where they are ionized by the solar ultraviolet light. Under the action of gravitation, the earth's magnetic field and the pressure of solar radiation, an oblong ring of ions and electrons is formed around the earth in the plane of the ecliptic, the ion densities being fairly low, below 10^3 cm^{-3}; this gives rise to the zodiacal light. The ring is perhaps 50,000 km distant on the daylight side of the earth. On the night side the ring stretches out to great distances 10^5 or 10^6 km. At its far end ions continually stream away in the direction of the sun's rays, so that the ring merges into a sort of comet's tail which may be the Gegenschein. Quantitative estimates are made throughout which depend on apparently acceptable assumptions of light pressure, time of ionization, etc. The estimates suggest a rate of escape of the earth's atmosphere of perhaps 10^6 ions cm^{-2} sec^{-1}, or about 10^{-6} of the atmosphere in 10^6 years.

27. A recording interferometer. C. W. CHAMBERLAIN, *Michigan State College.*—Light from a broad slit, illuminated by an incandescent filament, is collimated and divided into two parts which travel separate paths, one variable in length. The beams are reunited, with their wave fronts parallel, passed through a Wadsworth or constant deviation prism, and viewed through a telescope focussed for infinity. With eyepiece removed circular Fizeau fringes are seen in monochromatic light, when the interfering paths are unequal. With the eyepiece in position, a new type of interference system in white light is brought into view. The continuous spectrum is crossed by sharp dark bands whose positions in the spectrum correspond with the wave-lengths for which the interference system is opaque, or the path difference is an odd number of half wave-lengths. The number of bands appearing in an octave is identical with the path difference of the interfering beams, measured in terms of the longest wave. Lines appearing in that portion of the spectrum between 5016 and 6678 of helium correspond to a linear movement of one ten thousandth of a centimeter. In a similar manner, a range of spectrum may be arranged such that a change of one line in the range corresponds to a movement of five hundred-thousandths of an inch or any desired decimal part of an inch or centimeter.

28. An interference method of measuring distance. STUART H. CHAMBERLAIN, *Michigan State College. (Introduced by C. W. Chamberlain.)*—A collimated beam of white light is divided into two parts, slightly separated and converging toward a mirror, at a distance to be determined. The returning beams, slightly diverging, are received by an interference system which renders them parallel and permits lateral and linear displacements of the parallel wave fronts. The beams are passed through a prism and viewed through a telescope focussed for infinity. A dual system of interference bands is formed; one serviceable for accurately adjusting the instrument to receive the returning beams, the other to measure the distance between the light source and the distant mirror. The distance is determined by the number of dark bands appearing in a continuous spectrum. The new method substitutes a portable base line measured in wave-lengths of light and an interference method of determining the angle subtended by this base line at the distant mirror for the present method of measuring by means of angles and a fixed base line.

29. On the question of aberration of the light from terrestrial sources and its application to the experiment of Esclangon. N. GALLI-SHOHAT, *Mount Holyoke College.*—The definition of the "relative" ray in the classical ether-theory is usually given by means of two small openings through which light passes. The question is how to direct the moving telescope (two openings) —one system—in order to observe the light traveling along a wave normal in the other system (ether). A more careful analysis of this definition from the standpoint of the cinematics of the question gives the result that the direction of the ray actually observed depends upon the orientation in space, the angle x representing ***the aberration of light from terrestrial sources*** being $\beta^2/2 \sin 2\theta_0$, $[\beta^2=(v^2/c^2),\ \theta_0=(l_0,\ v)]$. This method of construction of the relative ray when applied to the experiment of Esclangon gives a satisfactory explanation of the effect observed. The curve calculated for this case, using for the declination of the apex δ 68°, coincides with that given by Esclangon and the values of the right ascension, α and the velocity v of the apex came out as $\alpha=20^h$ and $v=200$ km/sec in agreement with modern astronomical data. This second order aberration should also give account for anomalies observed by astronomers and may change the theory of the Michelson-Morley-Miller experiment.

30. Resonance and quenching of the third principal series line of caesium. C. BOECKNER, *Bureau of Standards, Washington D. C.*—A helium discharge is used as a source for the study of the resonance radiation from the third principal series line of caesium. This is possible, due to the coincidence of a strong helium line with the caesium line. In addition to the resonance line, a number of caesium arc lines are observed. These have their origin in lower levels populated by radiation transfers from the initial 4 $P_{1/2}$ level. The effect of helium on the fluorescence radiation is studied. It is found that collisions between helium atoms and caesium atoms in the 4 $P_{1/2}$ state transfers the latter only to states differing by less than several hundredths of a volt from the initial state. This type of transfer occurs at approximately every kinetic theory collision. Transfers to states differing by as much as 0.18 volts are improbable.

31. The effect of gases on ionization of caesium by line absorption. F. L. MOHLER AND C. BOECKNER. *Bureau of Standards, Washington.*—Measurements consisted of obtaining sensitivity curves for a space charge tube containing caesium at a constant partial pressure when various foreign gases were put in the tube. Hydrogen and nitrogen at pressures of one or two cm reduce the ionization by line absorption to nearly zero. With helium and argon the effects at the fourth and higher lines approach at high pressure values ranging from 60 to 90 percent of the vacuum value but helium increases the effect of the third line. From data on the effects at different pressures we obtain values for the product of the lives of the excited states of caesium and the effective collision areas. This product remains of the same magnitude for different gases and for different excited states.

32. The spectrum of doubly-ionized antimony. R. J. LANG, *University of Alberta.*—The spectrum of the 49 electron atom of antimony consists of term of even multiplicity of which twenty-six have been found as follows: $(s^25p)^2P$, $(s^26p)^2P$, $(s^24f)^2F$, $(s^25f)^2F$, $(5p^3)^4S$, $(s5p^2)^4P^2D^2S^2P$, $(s^25d)^2D$, $(s^26d)^2D$, $(s^26s)^2S$, $(s^27s)^2S$, $(s^28s)^2S$, $(s^25g)^2G$, $(s^26g)^2G$. The ionization potential corresponding to the approximate value of the deepest term $(s^25p)^2P_1=200\ 272$ is 24.72 volts. In Sn II the $(s\ 5p^2)^4P^2S$ terms are located and also the $(s\ 5p^2)^2S$ in In I.

33. Nuclear spin and hyperfine structure. H. E. WHITE, *Physikalisch-Technische Reichsanstalt, Berlin, Germany.*—It appears that when hyperfine structure is to be attributed to nuclear angular momentum or spin i, that the relation $\Delta\nu_g:\Delta\nu_f=m_k:4im_e$, should approximately hold where $\Delta\nu_g$ is the gross or multiplet structure separation, $\Delta\nu_f$ the hyperfine structure separation, m_k the mass of nucleus and m_e the mass of electron. From a discussion with Dr. Schüler it appears that the hyperfine structure of λ5486 in Li II (Zeits. f. Physik **42,** 487 (1927) $^3S_1-{}^3P_{0,1,2}$, may be accounted for by assigning an angular momentum $i=\frac{1}{2}$ to the nucleus of Li^7. From the observed hyperfine structure the $^3S_1(1s2s)$ term and the $^3P_2(1s2p)$ term have normal doublet separations of about 0.60 cm^{-1}, and 0.45 cm^{-1} respectively. From the already known relations in hyperfine structure, the $^1P_1(1s2p)$ term should have an inverted doublet separation of about 0.40 cm^{-1}. The gross-structure difference, $^3P_2-{}^1P_1$, 5700 cm^{-1} as compared with the hyperfine structure difference $\sim$0.85 cm^{-1} gives a ratio of 6700 in good agreement with the theoretical value 6440. Equally as good agreement between theoretical and observed values is found in several other elements. A more detailed explanation will be given in the Physical Reviews.

34. Average lives of lines of mercury triplet 2^3P-2^3S. R. H. Randall and Harold W. Webb, *Columbia University.*—The average life of each of the three components of the mercury triplet $2^3P_{012}-2^3S_1$, when excited by electron impact under conditions involving negligible ionization has been measured. The method used was that previously described (H. W. Webb, Phys. Rev. **24,** 113 (1924)), in which high frequency voltages are applied in phase to the excitation and detecting systems. From the variation of the current with frequency the rate of decay of the radiation after the exciting impact is calculated. The lines were excited in a sealed-off tube with mercury pressures between 0.004 and 0.03 mm. The exciting voltage was less than ten volts. The excitation was such that there was no appreciable concentration in the excited 2^3P states. A specially designed potassium hydride photoelectric cell was used as the detecting system. Optical filters were used to isolate the line under measurement. The results agree with the assumption that the radiation decays exponentially after impact. For the lines λ4047 and λ4358 the lives were found to be the same within the experimental error (0.75%), viz. $\tau=5.75\times10^{-8}$ sec. The value for λ5461 was four times greater, $\tau=2.37\times10^{-7}$ sec. No satisfactory explanation of these results has been found. It is suggested that the fine structure of the lines may be involved.

35. The comet tail bands of carbon monoxide. Louis R. Maxwell, *Research Fellow, Bartol Research Foundation.*—The experimental arrangement described by the writer (Phys. Rev. **32,** 715 (1928)) for measuring the life in the excited states, can be used for determining whether the emitters of band spectra are positive or negative ions or neutral molecules. This method is now applied to the comet tail bands which were produced by impurities in the tube containing helium when excited by 140 volt electrons. The bands experienced a displacement along their length by such an amount as to show clearly that they are produced by positive ions. This confirms the conclusions which have been made in regard to their origin.—By decreasing the pressure to less than 1×10^{-4} mm these bands appeared strongly without the presence of other bands and with the helium spectrum extremely weak. By circulating helium through the tube at 1×10^{-3} mm both spectra were obtainable while further increase of the helium pressure lessened the intensity of the bands until at 2.8×10^{-3} mm they had practically disappeared leaving only the helium spectrum. This effect is opposite in character to the phenomena found by Merton and Barrett and others where small traces of CO in helium at 20 to 60 mm were capable of producing the comet tail bands quite brilliantly.—Since the positions of the bands are altered by the cross-electric field, it is possible to measure their mean life by the method previously used for the mercury spark spectrum.

36. The application of least squares. W. Edwards Deming, *Bureau of Chemistry and Soils, Washington, D. C.*—By writing general relations between the most probable values of observed quantities and of p parameters, it is possible to get a solution to the general problem. The different relations that may exist between the most probable values and the parameters constitute the distinctions between the various types of problems. The general solution takes the form of symmetrical equations. When $p=0$, it reduces to the so-called "method of correlates." For curve fitting, the general solution can be transformed into two sets of equations;

one gives the parameters, the other corrects the observations. Provision is made for cases where the empirical surface must pass through given points. Heretofore it has been customary to throw all the adjustment on to one group of observations and none on to the others—a practice that often contravenes the foundation of least squares and yields unreasonable results, resulting in unjustified criticism of the principle. The present method allows the proper weight of each observation to be used in the adjustment. The corrections give interesting geometrical generalizations of those discussed by the writer in the Proceedings of the London Physical Society for February 15, 1930.

37. Simultaneous irreversible processes. L. ONSAGER, *Brown University.*—A general theorem applying to simultaneous irreversible processes is derived from the assumption that the dynamical laws are symmetrical with regard to past and future. The derivation involves the consideration of fluctuations. The adaptation to processes obeying linear differential equations of the first (or second) order with regard to the time yields an extension of Lord Rayleigh's "principle of the least dissipation of energy." This result provides a satisfactory basis for certain theorems which were originally derived from the consideration of cycles differing from those accepted in thermodynamics in the essential respect that reversible operation is impossible. One of these theorems applies to thermoelectric phenomena (W. Thomson), another to liquid junction potentials in electrolytes (H. v. Helmholtz), a third one to the Soret effect (E. D. Eastman). A new theorem applying to diffusion is also obtained. An external magnetic field disturbs the straight symmetry in past and future (a rotating frame of reference has the same effect). In such cases another symmetry condition connected with a simultaneous reversal of the time and the magnetic field is applicable. On this basis a relation between the Nernst and the Ettingshausen effects, first proposed by P. W. Bridgman and H. A. Lorentz, is confirmed.

38. Thermodynamics of systems with several equilibria. N. RASHEVSKY, *Westinghouse E. and M. Co., East Pittsburgh.*—Further studies on thermodynamical systems having more than one equilibrium constitution for given external conditions, and discussed in a paper presented at the last February meeting, are made. A reversible reaction between two substances which are either dissolved or gaseous, but which in either case are following not the ideal gas laws, but van der Waals' equation, is considered. It is shown that for certain values of temperature, total volume and other external conditions; the free energy of the system, considered as a function of the ratio of the two reacting substances, has *two* minima. Hence, for given external conditions, the system may have two equilibrium concentrations. In other words, the state of the system is not defined by the external conditions alone, but, as has been shown in a previous paper, it depends also on the previous history of the system. We may say that the system possesses hysteresis. Different possible kinds of such a hysteresis and possible application, especially to some biological problems, are discussed.

39. An acoustical analogy of the Schrödinger wave equation. R. B. LINDSAY, *Yale University.*—Investigation is made of the one-dimensional compressional vibrations of an ideal fluid of variable density (in equilibrium under the action of an external force) confined in an infinite tube of bounded but variable cross section. The non-homogeneity is so chosen that the wave velocity is everywhere the same. It is assumed that the ordinary acoustic equations are applicable except as modified by the non-homogeneity and that the cross section is small enough so that transverse motions may be neglected. It is then found that the problem of determining the allowed vibrations in such a tube satisfying the boundary condition that the condensation $s=\delta\rho/\rho_0$ (where ρ_0 is the equilibrium density at any point and $\delta\rho$ the excess density) shall remain analytic, everywhere $<<1$ and vanish at infinity, is formally equivalent to the problem of solving a one-dimensional Schrödinger wave equation subject to the usual boundary condition. The appropriate density variation and the shape of the tube are shown to be related to the potential energy of the particle whose motion is described by the Schrödinger equation. As illustrations the free particle, the simple harmonic oscillator and the one dimensional hydrogen atom are investigated. It is believed that generalization to three dimensions will prove possible.

40. A general formulation of the uncertainty principle and its classical interpretation. H. P. Robertson, *Princeton University*.—Denoting the mean value of a quantum mechanical variable α in a state ψ by α_0 and its uncertainty or standard deviation by $\Delta\alpha$, the uncertainty principle $\Delta\alpha \cdot \Delta\beta \geqq (h/4\pi)|\gamma_0|$, where $(h/2\pi i)\gamma$ is the commutator $\alpha\beta-\beta\alpha$ of α and β, is obtained for general systems, which may include spin. It is found to be a consequence of the more restrictive inequality $\Delta\alpha \cdot \Delta\beta \geqq \{[(\alpha\beta)_0-\alpha_0\beta_0]\;[(\beta\alpha)_0-\beta_0\alpha_0]\}^{\frac{1}{2}}$. The former result is interpreted classically as meaning that we can only determine that two quantities $\alpha(p, q)$, $\beta(p, q)$ have values lying between $\alpha_0 \pm \Delta\alpha$, $\beta_0 \pm \Delta\beta$ provided the integral invariant $J=|\Sigma(i)\int p_i dq_i|$ taken over the area normal to these four hypersurfaces in phase space is at least of order h.

41. Thomson effect in zinc crystals. L. A. Ware, *University of Iowa*.—The Thomson coefficient, σ, is directly determined for a group of zinc crystal rods with orientations distributed fairly uniformly over the entire possible range of orientations. At 49.5°C, and at 125°C, the values of σ seem to obey the Voigt-Thomson symmetry relation, although not as good a check is obtained at the higher temperature due probably to increased experimental error. The principal values obtained are: at 49.5°C, $\sigma_\perp=0.98\times10^{-6}$, $\sigma_\| =0.38\times10^{-6}$; at 125°C, $\sigma_\perp=2.09\times10^{-6}$, $\sigma_\|=1.08\times10^{-6}$ Cal./coul./degree C. The increase of σ with increased temperature is greater than has been previously reported for polycrystalline zinc but is in approximate agreement with some earlier determinations by the writer. In addition, specific resistivity and temperature coefficient of resistivity are determined.

42. Thermal expansion of copper-nickel-tin alloy. Peter Hidnert and W. T. Sweeney, *Bureau of Standards*.—In 1926 determinations were made at the Bureau of Standards on the linear thermal expansion of a copper-nickel-tin alloy known as Admiralty nickel or Adnic. It is claimed that this white nickel alloy resists corrosion and shows good strength at elevated temperatures. The sample, 1–3/10 inches in diameter, was extruded from 1–3/8 inches and finished hard with a 1/16 inch draught after a suitable anneal. The chemical analysis was as follows: Copper 69.57, nickel 28.70, tin 0.91 percent. Scovill Mfg. Co., Waterbury, Conn. prepared the sample and furnished information about the treatment and the chemical composition. The following coefficients of linear expansion were obtained:

Temperature Range	Average Coefficient of Expansion per Degree Centigrade
20 to 100°C	15.2×10^{-6}
100 to 200	15.5
200 to 300	18.0
20 to 200	15.4
20 to 300	16.3

Data on physical properties of this alloy are given in Mining and Metallurgy **8**, 474 (1927).

43. A new method for measuring the variation of specific heats of gases with pressure. E. J. Workman, *University of Virginia*.—The method determines the ratio of c_p at a high pressure to c_p for the same gas at a pressure of one atmosphere taken as a standard. The continuous flow principle is used in such a way that the necessity for measuring rates of gas flow and heat input is avoided. A stream of gas at high pressure is brought to a temperature t_1 and passed through a heat interchanger acquiring there a temperature t_2, after which it is throttled to atmospheric pressure, brought to a temperature t_3 and returned to the heat interchanger, where its temperature again becomes t_2. If there is no heat leakage the ratio of c_p at high pressure to that at atmospheric pressure is equal to $(t_3-t_2)/(t_2-t_1)$. Measurements on commercial oxygen taken at a mean temperature of 26°C and pressures ranging from 15 to 100 atmospheres indicate, when corrected, a pressure coefficient in this ratio 0.0017 ± 0.0001 per atm.

44. The effect of hydrogen ion concentration on the measurement of the mean particle size of emulsions. ISABEL C. WEEKS, *The Pennsylvania State College. (Introduced by Wheeler P. Davey.)*—W. P. Davey proposed (Science **64**, 252 (1926)) measuring the mean particle size of emulsions by a water-spreading method. The present work investigates the effect on such measurements of the $pH(=1/\log$ concentration of $H^+)$ of the water used. Three emulsions were tested, stabilized with the sodium soaps of myristic, palmitic and stearic acids respectively. The pH was varied from 3.0 to 11.0 by means of buffer solutions. No effect was found traceable to the buffer materials used. At a pH less than 7.0 (i.e. the water is acid) the area of the water-spread emulsion for a given pressure increases with time without reaching an equilibrium value. At a pH greater than 7.0 (i.e. the water is alkaline) the area for a given pressure finally becomes constant with time, but the values are large and depend upon the pH. In every case the emulsion area was corrected for the area covered by pure buffer. At $pH=7.0$ (i.e. the water is neutral) the water-spread emulsion shows a constant area with time for a given pressure, and reaches equilibrium very quickly. Areas found at $pH=7.0$ are therefore taken as the true areas to be used in plotting pressure-area curves for particle-size calculations.

45. Molecular aggregation. A. M. TAYLOR. *Institute of Applied Optics, Rochester, N. Y. (Introduced by T. R. Wilkins.)*—A brief résumé of the lines of evidence by which molecular aggregation in pure liquids may be recognized; from the surface tension, from viscosity, from optical anisotropy, and from the Raman effect. The question of molecular size in the solid state can at present be answered only by x-ray analysis and by comparison of specific heat data with theory. A third method is suggested based on the Vant-Hoff equilibrium equation $d(\log k)/dt=Q/RT^2$. Q is here the differential heat of solution of the solid in a given solvent, while k is the equilibrium constant regulating the exchange between the molecules in the solid and the molecules in the solution; k may be expressed in terms of the change of solubility with temperature. For iodine the method gives I_2 as the molecular size in the solid state; this agrees with x-ray measurements which show that solid iodine has a molecular lattice of I_2. Lack of data prevents further application of the method at present.

51. Phenomena in oxide coated filaments. E. F. LOWRY, *Westinghouse E. & M. Co., East Pittsburgh.*—It has been suggested in a previous paper that the phenomena of oxide emission might be explained by assuming that the source of electron emission is a layer of metallic barium occluded on the surface of the core metal. The activity of such a filament is characteristic of this composite surface and the peculiar effects met with are due to the diffusion of the electrons through the pores of the oxide coating. In the present paper experiments are described which tend to support this view. Filaments made by vaporizing metallic barium on clean Konel ribbon give emissions of the same magnitude as those coated with oxide in the usual way but approach saturation rapidly while oxide filaments approach saturation very gradually if at all. The "three halves power" law is obeyed exactly by both types. "Bariated" Konel filaments show very little if any "fading" of emission with time, while considerable fading is experienced with oxide filaments, particularly in a certain range of temperatures and with heavy coatings. No activation of these filaments is necessary other than thermal decomposition of the alkaline earth carbonates in vacuum.

52. Density distribution of electron gas in equilibrium with a hot body. A. T. WATERMAN, *Yale University.*—The variation of potential and of electron concentration with distance from a plane emitting surface is investigated, using Poisson's equation and the equilibrium relation between electron concentration and potential in the form $A=A_0e^{-V\epsilon/kT}$, where A and A_0 are the Fermi A's outside and inside the hot surface, respectively, and V is the corresponding potential difference. Solutions are found for the equilibrium condition in the absence of applied field and for negative fields, and assuming the electron gas within the body to be degenerate or classical. Results indicate: (1) that on the average an electron is closer to its neighbors than to the surface, except when very close to the latter, and therefore that the image force explanation of the work function is here not applicable; (2) that space charge is quite competent to give the magnitude of the work function; (3) that if the electron concentration within the body is that of the atoms, the external gas remains degenerate to approximately 10^{-7} cm from the surface; (4) that an applied negative field of the magnitude required for cold field currents materially alters the electron concentration down into the degenerate region. The current obtainable under retarding fields is discussed with a view to estimating the feasibility of experimental proof of the relations established and of the electron concentration within conductors.

53. A space charge interpretation of thermionic work function. RUSSELL S. BARTLETT, *Yale University*.—We try to account for the thermionic work function by the space charge field of electrons streaming out from the surface and turning back in this same field. To account for the increase in thermionic currents in strong electric fields it is necessary that the work function field extend so far out that an escaping electron is much nearer to its neighbors than to the surface. If we extend Fry's space charge analysis, with classical velocity distribution, right down to the surface of the metal, assuming an electron concentration about midway in the range of prediction, we find something resembling saturation currents, a suitable value for the work function, and an increase of current with strong fields agreeing better with experiment (Proc. Roy. Soc. **A121**, 456 (1928)) than does Schottky's expression depending on image force alone. A first order correction for Fermi-Dirac distribution brings improvement, though the variation of work function with temperature is too great. But the strict application of the Fermi-Dirac statistics for a degenerate gas, with its large zero point energy, should remove that difficulty, and should provide for an explanation of field currents, since the large fields necessary should penetrate into the region of degeneracy.

54. Effective photoelectric work function reduced by weak accelerating fields. W. B. NOTTINGHAM, *Bartol Research Foundation*.—Photoelectric experiments on thin alkali metal films reported (Phys. Rev. **33**, 633 and 1081 (1929)) seemed to indicate a nonlinear relation between current and light intensity and a departure from Einstein's photoelectric equation. A study of amplifier-galvanometer systems for measuring small currents (Journal of Franklin Institute, March 1930), showed that the nonlinearity was in the current measuring system. A thin alkali metal film on nickle or platinum changes the work-function (ϕ) of the surface by a small amount, and greatly alters the space distribution of the electric field against which the electron must work in order to escape. This redistribution makes it possible to reduce the *effective* work-function (ϕ_e) of the surface by applying a small accelerating field. The photoelectric long wave-length limit is a direct measure of ϕ_e. With a retarding field, ϕ_e is greater than ϕ and the Einstein equation gives the relation between ϕ_e and the potential. At zero field, $\phi_e=\phi$ while with an accelerating field, ϕ_e is less than ϕ. For example, ϕ_e has been observed to be reduced by 1.95 volts by the application of an accelerating potential of 4 volts between the electrodes. A further increase in accelerating potential to 750 volts gave a further decrease in ϕ_e of only 0.32 volt.

55. Photoelectric properties of extremely thin films of alkali metals. HERBERT E. IVES AND H. B. BRIGGS, *Bell Telephone Laboratories*.—Films of alkali metal much thinner than those previously studied (Astrophys. J. **60**, 209 (1924)) have been investigated by using an electrometer of approximately 100 times the sensitiveness of the galvanometer used before. Attention has been directed to the variation of emission with the angle of incidence and plane of polarization of the exciting light. In agreement with the earlier work, the ratio of emissions for obliquely incident light polarized with the electric vector in and perpendicular to the plane of incidence decreases as the film is reduced in thickness. The new measurements show further that this ratio continues to decrease with film thickness to the value unity, where no variation of emission with angle occurs, and that with further decreases in film thickness, the relationship *reverses*, ("normal" greater than "selective") and the emission increases with the angle of incidence of the light. It is suggested that when the alkali metal particles become sparsely distributed their absorption of light corresponds to that of a matt surface (Lambert's law). When the particles are still more widely separated, deviation from Lambert's law occurs and the exciting light is in part that reflected from the underlying platinum surface, stronger for light polarized with the electric vector parallel to the surface.

56. Validity of Einstein's photoelectric equation for red sensitive sodium compounds. A. R. Olpin, *Bell Telephone Laboratories, Inc.*—Using a photoelectric cell specially designed so that the cathode could be sensitized in a side compartment and then slipped into position within a soot-coated nickel anode, stopping potentials were obtained for electrons liberated by highly resolved light of wave-lengths ranging from 3500A to 8000A. The cathode consisted of a nickel plate heavily coated with sodium and specially treated with sulphur and air [abstract 57 Bull. Am. Phys. Soc. 4, 2 (1929)]. The anode of such a cell is not sensitive to light, so the voltage at which the emission from the cathode just becomes zero is a measure of the true stopping potential. Plotting the voltages so obtained versus the exciting light frequencies a perfectly straight line is obtained. From the slope of this line, a value of Planek's constant *h equal to* 6.541×10^{-27}, significant to three figures, is obtained. It is possible with one cell to obtain stopping potentials for electrons released from sodium before and after treating it with sulphur and air. In such cases the voltage at which the photoelectric emission ceases is the same, but after treatment the current saturates at a higher voltage, exhibiting a change in the contact difference of potential of 0.8 volt.

57. Photoelectric cell thermoregulator. F. G. Brickwedde and R. B. Scott, *Bureau of Standards, Washington, D. C.*—Recently a photoelectric cell was used with a thermocouple as the thermosensitive element to make a new kind of thermo-regulator. There are many laboratory problems requiring automatic regulation to which the photoelectric cell can be applied. Photoelectric cell regulators possess great sensitivity, small lag and a wide range of temperatures over which they can be used and be quickly and conveniently adjusted for operation at any desired temperature. The parts of the thermo-regulator are analyzed and it is shown how they can be modified to adapt this regulator to special problems. Improvements are described and causes of trouble pointed out. A photoelectric regulator has been made which will automatically maintain any temperature from 0° to liquid air temperatures constant to 0.001°. It is operated on a 240 volt D.C. power, without batteries, using only one slide wire rheostat with four sliding contacts to furnish all the sources of potential for the photoelectric cell and its amplifier thus making the regulator less expensive and obviating all the inconveniences of run down batteries.

58. Apparatus for maintaining constant low temperatures. R. B. Scott and F. G. Brickwedde, *Bureau of Standards, Washington, D. C.*—A cryostat of improved design for use in the temperature range from 0°C to liquid air temperatures has been constructed. The cryostat bath is contained in a double-walled cylindrical glass vessel surrounded by liquid air, and the amount of refrigeration controlled by varying the air pressure between the walls. Constant temperature is automatically maintained by the use of a photoelectric cell thermoregulator operating a heating coil on the stirrer tube. Adequate circulation of the liquid, careful heat insulation, and symmetrical distribution of all the parts assure great uniformity of temperature. The temperature is easily adjusted to the desired value and can be maintained constant to 0.001°C. Nonflammable liquids are used for the bath between 0°C and −150°C.

59. Raman spectra excited by the helium hot-cathode arc and a new type of tube for small volumes of liquid. R. W. Wood, *Johns Hopkins University.*—A hot-cathode helium arc of great brilliancy, carrying three amperes, kindly supplied by the research laboratory of the General Electric Company of Schenectady, has been very successfully used in combination with a filter of nickel oxide glass for the excitation of Raman spectra. Exposures of less than three hours are required as against fifteen hours with the spiral tube which I described last year. A new type of tube for the investigation of volumes of only eight or ten cubic centimeters of liquid has been developed, adapted to the investigation of liquids of low boiling point or solids which liquify below 100°C.

60. The calculation of the specific heats of solid organic compounds from Raman spectra. Donald H. Andrews and John C. Southard, *The Johns Hopkins University.*—It seems to be possible to identify the lines in the Raman spectra of a number of organic molecules with definite modes of vibration in the molecule (see abstract Number 25). This permits the assigning of the correct number of degrees of freedom to each frequency and it is found that the sum of the degrees of freedom so assigned has a value consistent with the number of atoms in the molecule. If we then consider that the various modes of vibration in the molecule act as independent Einstein oscillators, it is possible to employ the frequencies from the Raman spectra and calculate the specific heat of the molecule for any temperature. This has been done for methyl alcohol, ethyl alcohol, benzene, toluene, chlor benzene and brom benzene over the temperature range of 15° to 260°K. The average deviation between the results so calculated and the experimental values is about five percent.

61. Mosaic crystals of elements. R. H. CANFIELD, *Naval Research Laboratory, Anacostia, D. C.*—Assuming that the atoms of a crystal of an element are all exactly alike and exert mutual central forces, and that the force between any two atoms vanishes for only one value of the distance, it is found that the conditions of stability of equilibrium of the crystal against an infinitesimal generalized strain require that certain series of terms in the second derivatives of the energy function shall be greater than zero. If this is granted, it is shown that any translation of a part of the perfect crystal relative to the remainder causes the potential energy of the lattice to increase. Hence all such imperfections are to be regarded as unstable.

62. Selective maxima in the spectral response curves of light-sensitive compounds as a function of valence. A. R. OLPIN, *Bell Telephone Laboratories, Inc.*—Lindemann proposed a formula for computing the frequency of light under excitation by which a substance should yield electrons most readily. This formula, $\nu=(1/2\pi)[(ne^2)/(mr^3)]^{1/2}$, gives the frequency of an electron revolving in an orbit of radius r about a stationary charge ne [m = mass of electron]. The n term is determined by the valence of the substance, a choice of unity for the monovalent alkali metals corresponding to an electron revolving around a singly charged ion. With the normal valence of the alkali metals, Lindemann computed selective frequencies which have been checked by many observers. Under certain conditions, the alkali metals manifest different valences, such, for instance, as those exhibited in the oxide series Na_2O_2, Na_2O, Na_3O, Na_4O. These compounds are light sensitive and can be prepared in photoelectric cells. Spectral response curves for such cells exhibit all the selective maxima called for by the Lindemann formula when the value of n is chosen to agree with the valence of the metal. Data are presented showing this condition to be general for the other alkali metals, a maximum response to red or infra-red light being dependent upon the formation of a subvalent compound, as a suboxide.

63. The scattering of atomic hydrogen by gases: mercury, argon, oxygen and iodine. E. G. LUNN AND F. R. BICHOWSKY, *Naval Research Laboratory.*—A beam of hydrogen atoms defined by two small holes passes through a gas-filled space and impinges on a plate coated with molybdenum trioxide. The loss in intensity of the beam due to collision of the hydrogen atoms with molecules of the various gases depends on the sum of the radii of the hydrogen atom and the gas molecules. The collision diameter of the hydrogen atom can then be calculated directly and simply by using the known collision diameters of the several gases. While the collision diameter of hydrogen determined by comparison with mercury is about eight Angströms, that calculated from preliminary results on the scattering in argon and oxygen is about two Angströms. Similar measurements in iodine, made uncertain by a fading of the reduced molybdenum oxide due to oxidation by the atomic iodine formed, indicate a collision diameter of over twenty Ångströms. The collision diameter is thus a property of the degree of interaction between the colliding particles. This is in accordance with the Heitler and London picture of chemical reaction.