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PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

Minutes of the Washington Meeting, April 20–21, 1928

The 151st regular meeting of the American Physical Society was held at the National Academy of Sciences in Washington, D. C., on Friday and Saturday, April 20 and 21, 1928. The presiding officers were Professor Karl T. Compton, President of the Society, and Professor Henry G. Gale, Vice-President of the Society.

On Friday evening there was a dinner for the members of the Society and their friends at the Hotel Raleigh. The speakers at this dinner were Professor J. Franck, Professor L. Brillouin, Dr. Herbert E. Ives, and Sir Richard Paget.

At the regular meeting of the Council held on Friday, April 20, 1928, one was elected to fellowship, eight were transferred from membership to fellowship and thirty were elected to membership. *Elected to Felloswhip:* R. J. Lang. *Transferred from Membership to Fellowship:* R. M. Bozorth, J. B. Johnson, A. L. Kimball, H. C. Urey, M. S. Vallarta, E. C. Watson, R. L. Wegel, and E. C. Wente. *Elected to Membership:* R. E. Badgley, S. W. Barnes, C. M. Blackburn, W. Bleakney, C. Boukner, J. G. Brainerd, H. C. Burbridge, A. F. Daniel, O. R. Ford, S. F. Gaddes, M. C. Holmes, P. A. Johnson, Jr., D. Kirkpatrick, C. A. Kotterman, E. S. Lamar, W. N. Lowry, E. R. Mann, K. J. Miller, N. M. Mohler, D. W. Mueller, I. O. Myers, R. D. Potter, R. H. Ranger, V. Rojansky, E. E. Smith, P. L. Spencer, J. E. Thompson, R. R. Tileston, M. W. Trawick, R. K. Waring.

The regular program of the American Physical Society consisted of 109 papers, numbers 8, 12, 31, 34, 40, 46, 70, 73, 77, 86, 90, 93, 94, 96, 100, 103, 104, 105, 106, 107, 108, and 109 being read by title. The abstracts of these papers are given in the following pages. An AUTHOR INDEX will be found at the end.

Harold W. Webb, *Secretary*

ABSTRACTS

1. Some photographs of optical images after Abbe. R. A. Wetzel and George Needham. College of the City of New York.—The new Pulfrich-Abbe demonstration microscope is rich in interference and diffraction phenomena. A camera attached to the visual system gave permanent records of many interesting images; for example: two different objects may be made to look alike by choosing the conditions of coherence. For "objects" we have used gratings with the following rulings per millimeter: one plane, 15; two reciprocal, 5; two displaced $\frac{1}{2}\delta$, 3; two crossed at 90 degrees, 7; three crossed at 60 degrees, 6. An interesting diffraction effect simulates spectroscopic self-reversal; another, absorption spectra.

2. The continuous spectrum of mercury. L. H. Dawson and W. H. Crew, Naval Research Laboratory, Washington, D. C.—Intensity maxima of the bands of continuous radiation from a mercury arc coincide with the spectral series limits; this is in agreement with the theory (Bohr, Wright, and others) that the continuous spectrum is due to electrons with various kinetic energies plunging into the outer orbits associated with spectral series. Band maxima observed in an arc at atmospheric pressure, excited by high voltage, low current discharge are: (associated series limits are given in brackets): λ4500[λ4580]; λ3300[λ3300]; λ2350[λλ2490; 2230; 2140]. Under these conditions no continuous radiation is emitted in the region λ2535–λ2350 corresponding to the limit λ2490. However, upon increasing the current through the arc, the bands broaden in both directions and fill up this gap; furthermore, the broadening of λ2536 and lines of the diffuse series give a fairly even distribution of continuous radiation throughout the entire spectrum. In passing from a high current to a low current arc certain lines rapidly decrease in relative intensity, which shows that the latter condition of excitation is unfavorable for electron transitions into the 2^3 P-levels, a fact consistent with the non-appearance of a band at λ2490.

3. Intensities of the lines of the mercury spectrum. E. O. Hulburt, Naval Research Laboratory, Washington, D. C.—The total radiation, measured with a thermocouple, in all directions in the spectral region λ600 to 230$\mu\mu$ from a small quartz mercury lamp of known size filled with mercury vapor at atmospheric pressure was 1.54×10^8 erg sec^{-1}. Assuming all the light to be in quanta of λ500$\mu\mu$, this gave about 50 quanta emitted per atom per second. The intensities of the lines of the spectrum were measured with a quartz spectrograph, a thermocouple and a photo-electric cell, all calibrated, and in some cases with a photographic densitometer. Plotting the logarithm of the intensity against the frequency for the lines of a series gave roughly straight lines of about the same slope for the sharp series ($2^3P_n-m^3S_1$) and for the diffuse series ($2^3P_n-m^3D_{123}$). The temperatures of the excited atoms derived from the slopes, on simple theory, were of order 10^3 degrees, which seemed reasonable.

4. The absorption spectra of mixtures of mercury and thallium vapors. R. K. Waring' Johns Hopkins University (Introduced by R. W. Wood).—In the absorption spectra of mixtures of mercury and thallium vapors certain bands have been photographed which have not been observed in the spectra of either metal alone. It is thought that the origin of these bands is a mercury-thallium molecule. Most of the bands are sharp on the side of shorter wave-lengths, and shaded toward the longer wave-lengths, broadening more toward the long wave-lengths than the short when the temperature is increased. The region investigated extends from about 2200A to about 7000A. The vapors were studied at temperatures ranging from 300°C to 1100°C. In no case has the resolving power been sufficient to show the fine structure. The results confirm an early experiment on the subject (Wood and Guthrie, Astrophys. Jour. 29, 211(1909). Contributary evidence in favor of a mercury-thallium molecule resulted from an experiment which indicated that the amount of thallium which was vaporized in a closed tube at 600°C was greatly increased by the presence of mercury vapor.

5. Optical excitation of mercury and the sensitized fluorescence of mercury-hydride, OH, ammonia and other compounds. R. W. Wood and E. Gaviola, Johns Hopkins University.—The reactions occurring in a quartz tube containing mercury vapor, in the presence of other gases when illuminated by the light of the water cooled quartz mercury arc have been studied. Band spectra appear together with the optically excited arc lines of mercury. Some of these bands have been identified with the bands of mercury hydride, OH and ammonia which have been studied by other observers. By employing a wire gauze as absorbing screen placed first between the lamp and the resonance tube, and then between the resonance tube and the spectrograph it is possible to determine whether a given line or band results from a single or two two stage absorption processes. An exhaustive study of the effects of other gases on the intensity ratios of the optically excited mercury lines has also been made.

6. Intensity variation at critical points in the helium spectrum. I. Cornog, J. T. Lay and C. B. Bazzoni, University of Pennsylvania.—Photographs of the helium spectrum produced in an equipotential space from an equipotential cathode have been studied photometrically in order to determine the variation in line intensities on passing the various critical potentials. The results here reported on cover the 54 volt point at which double ionization is first possible. Spectra were taken at intervals of 0.2 volt at suitable values between 50 and 60 volts. The plates show a marked minimum of intensity near 54 volts generally for all lines but interesting variations in rate of change of intensity in the different series are recorded. A photometer using a vacuum thermopile was developed for use in this work.

7. Ionizing potentials of light atoms. LOUIS A. TURNER, Princeton University.—Millikan and Bowen's Moseley curves for ionizing potentials of light atoms are extended by adding points for Ne^+ and Na^+, and improved in regularity by amending their tentative values for F and F^+ from 16.9 and 32.3 volts to 17.4 and 34.4 volts, on the basis of consideration of the energies of removal of $(3s)$ electrons from these excited atoms and ions. The energy for removal of a $2s$ electron can be computed from Bowen's data by adding to the ordinary ionizing potential the energy corresponding to the appropriate *a-b* line of the next spark spectrum. Absorption of this line after ionization raises an electron from the $2s$ to the $2p$ group filling the vacancy in the latter, leaving the atom as if a $2s$ electron had been removed directly. Moseley lines for these energies, the L_{11} energies, have somewhat smaller slopes than those of the corresponding $2p$ lines but nearly the same as is, of course, implied by the fact that the *a-b* lines follow the irregular doublet law. Extrapolations suggest that the 320.9 and 323.2 lines of Mg correspond to $(2s)(2p)^6(3s)^2 \rightarrow (2s)^2(2p)^5(3s)^2$ transitions and the 231.4 line to $(2s)^2(2p)^5(3s)^2 \rightarrow (2s)^2(2p)^6(3s)$ or $(2s)^2(2p)^5(3s) \rightarrow (2s)^2(2p)^6$ transitions.

8. Ionization potential of hydrogen atoms from the viewpoint of the electromagnetic quantum theory and polarization of light from canal rays. CORNELIO L. SAGUI, Castelnuovo dei Sabbioni, Arezzo, Italy.—The structure of a hydrogen atom, from the viewpoint of this theory, seems to result from the assembly of about 1800 electrons distributed in 60 energy levels in which the density of the electrons is proportional to the energy of each level. Such a density would consequently decrease from the center of the atom to its surface. The electrons of the energy-level $R((1/3)^2-(1/4)^2)$ would be those more easily ejected by impact of bombarding electrons, and 13.78 volts was in this case the ionization potential found. Polarization of light from canal rays was supposed due to a component of the oscillating electrons parallel to the motion of the hydrogen atoms. It is also shown that the polarization would not be uniform but would result in a sort of wave.

9. The nature of the production of one of the spark lines of mercury and the determination of the mean life. L. R. MAXWELL, National Research Fellow, Bartol Research Foundation.—In a paper presented to this Society recently the author described a method for obtaining spark lines due to Hg^{++}. These lines showed a displacement in the direction of the crossed-electric field. The variation of intensity of one of the lines (4797A) has now been measured for different positive ion currents and found to be the same for all points along the line and approximately proportional to the ion current. This shows, on calculating how the intensity should vary, that the line is the result of a single electron collision with the neutral atom. Line intensity measurements obtained as a function of the position across the beam show that when the ion is put into the excited state it will then radiate according to the probability law, and that the mean life is of the order of 10^{-7} sec.

10. An optical study of adsorbed films. K. HERZFELD AND J. H. FRAZER, Johns Hopkins University.—Rayleigh's and Drude's method which makes use of the ellipticity of light reflected from a surface covered with a thin layer, has been recently applied to the study of adsorption. This method was improved by using a Point-o-lite lamp as a source, and by measuring the light intensity photometrically instead of compensating the ellipticity with a Babinet compensator. Only one Nicol is necessary with this method. It is possible to detect a layer of about 1A on a surface of 5 sq. mm. With less accuracy a surface of 1/20 sq. mm is sufficient. The adsorption of water vapor and of other vapors on glass has been studied. In agreement with previous measurements by Langmuir and Frazer and Patrick, there is no adsorption of water vapor up to 1 mm. Then a layer of less than 1 molecule thickness goes up to the saturation point at 21 mm. The method has furthermore been applied to transition layers between glass and liquids. It can be used to study the corrosion of the glass and the adsorption of dissolved substances on the glass surface.

11. Spreading of illumination beyond the edge of an image. LUDWIK SILBERSTEIN, Kodak Research Laboratories, Rochester, N. Y.—This paper contains a theoretical investigation of the spreading of scattered light in a plane layer of turbid medium. A semi-plane bounded by a straight edge being assumed to be directly exposed to collimated light, a formula is derived for the scattered light flux as a function of the depth and the distance from the edge of the illuminated area.

12. The distribution on a surface of evaporating parallel wires for producing uniform metallic films. OTTO STUHLMAN AND E. R. MANN, University of North Carolina.—A theoretical discussion of the distribution on a concave surface of a small number of evaporating parallel wires, whose condensed metallic vapour can produce, upon a plane located at some distance below, a plane metallic film of any desired thickness. For a single wire placed at a height h above and parallel to the condensing plane, the thickness $t=mh/2\pi(h^2+x^2)$, where m is the mass evaporated per second per unit length of wire and x the distance in the plane of condensation, measured on either side of the wire. Theoretically the necessary conditions for uniform thickness are an infinite number of parallel wires placed infinitely close together in a plane parallel to the condensing plane. The best experimental approximation obtained by five wires is a distribution forming a cylindrical surface. A specific case experimentally under consideration is: positions of wires with respect to the condensing plane are $(-5, 5)$, $(-1.34, 8.66)$, $(0, 10)$, $(1.34, 8.66)$, $(5, 5)$ producing a film of uniform thickness having a width of 8 cm and any desired length. The thickness is expected not to exceed 2% in error at the edge.

13. A relation between thermal conductivity, specific heat and absolute temperature. C. C. BIDWELL, Lehigh University.—A study of recently obtained data on thermal conductivity and specific heat of lithium, sodium and zinc over the temperature range −250°C to +200°C reveals a simple relation between these quantities not hitherto reported, namely the law, $k/s=K/T+K'$. k is the thermal conductivity; s, the specific heat; T, the absolute temperature; K and K', constants. The values of k/s, when plotted against $1/T$ fit a straight line with remarkable precision. In the case of lithium the line goes through the origin. For sodium $K'=0.6$, for zinc $K'=2.0$. The law holds down to −200°C for lithium, below which the abnormal increase in k causes a deviation; to −225°C for zinc below which a deviation is noticeable. For sodium there is no deviation from the law even as low as −240°C the lowest temperature at which we have data. Considering the thermal conductivity of a metal as made up of two parts, transfer of energy by atomic collisions and by elastic waves along an ionic lattice we have $k=(\rho v'\lambda' s/4)+(\rho v\lambda s/3)$. The first term on the right refers to the ionic lattice (Debye). v' is the velocity of sound in the lattice. λ' is a dissipation factor and refers to the distance in which the energy of the wave is reduced to $(1/e)$th part. Assuming λ' inversely proportional to the temperature we get the law above.

14. Thermal and electrical conductivity of single and poly crystal zinc. E. J. LEWIS AND C. C. BIDWELL, Cornell University.—Thermal conductivity measurements over the range −250°C to +100°C were made on rods of single and poly crystal zinc using a modification of the Forbes bar method previously used by Bidwell on rods of sodium and lithium and described by him. The single crystal rod was prepared in vacuum by Bridgman's method. One of the poly-crystal rods, rod No. 1 was cast in the open air; the other, rod No. 2, in vacuum to avoid oxide contamination. The thermal conduction was found to decrease smoothly but not linearly with rise of temperature. The single crystal zinc shows 11% better thermal conductivity at 0°C than the poly crystal zinc No. 2 and about 18% better than No. 1. In the case of the single crystal rod the conductivity was measured in the direction of the basal or cleavage planes which are parallel to the axis of the cylinder. The density of the atoms is said to be greatest in these planes. The single crystal rod showed about 20% less electrical resistivity at 0°C than the poly crystal rod No. 2, and about 30% less than No. 1. The Wiedemann-Franz-Lorenz ratio

k/CT rises to a maximum at about −100°C, decreasing slightly at higher temperatures ultimately reaching for the single crystal rod the value 24.7×10^7, the value the simple theory requires as a constant.

15. A generalized Gibbs Boltzmann equation. F. RUSSELL BICHOWSKY, Naval Research Laboratory, Washington, D. C.—A generalized form of the Gibbs Boltzmann canonical equation $1 = \int \phi(\epsilon/\kappa T) e^{-(\alpha+\epsilon)/\kappa T} d\omega$ is derived by reversing the line of proof used by Gibbs in showing the correspondence of statistical formula with thermodynamics. The proof involves only the assumption of the first two laws of thermodynamics, the idea that thermodynamic quantities are the physical average of complicated molecular processes, and the assumption that energy entropy and temperature give a sufficient description of the system considered. The equation allows a treatment of statistics of the most generalized type of systems.

16. A method for the precise determination of thermal capacities. T. E. STERN, Princeton University. (Introduced by K. T. Compton.)—It was found that a modified Bunsen ice calorimeter was capable of yielding very consistent values for the total heats of substances at temperatures between 0° and 440°C. The substance under investigation was contained in a metal capsule, by the use of which errors due to cooling and radiation during the fall of the specimen into the calorimeter were largely eliminated. Thermal contact was established in the calorimeter by the use of a metal cup surrounded by water and containing mercury. Results were obtained directly in terms of the mean calory, since the heats liberated were compared with the heat given out by a capsule containing water. From the total heat equations the specific heats were readily obtained. The probable error of a single observation was, on the average, 1 part in 1000; for quantities of heat of the order of 240 calories. The probable errors of the total heat values were also 1 in 1000.

17. An improved arrangement for obtaining high speeds of rotation. ERNEST O. LAWRENCE, J. W. BEAMS, AND W. D. GARMAN, Yale University.—Henriot and Huguenard (Jour. d. Phys. et Ra., **8**, 443 (1927)) have described a method whereby high rotational speeds are obtained. Instead of usual mechanical bearings with oil lubrication, the rotating body rides on a whirling jet of air. In making use of this method we have found that an essential condition for satisfactory performance is the elimination of vibrations in the nozzle from which the compressed air jet issues. The "rotor" is separated from the nozzle by an air film of small thickness so that if vibrations of sufficient amplitude develop the rotor and nozzle come into direct contact. A rubber mounting for the nozzle is described which damps out such vibrations and permits steady speeds of rotation for a rotor 16 mm in diameter of between 5000 and 6000 revolutions per second.

18. Differential intensity sensitivity of the ear. R. R. RIESZ, Bell Telephone Laboratories, Inc.—The minimum perceptible increment in the sound intensity of a pure tone was measured as a function of frequency and intensity over practically the entire range of auditory sensation. The data are presented as the ratio of minimum perceptible increment in intensity to total intensity; i.e., $\Delta E/E$, which ratio has been called differential sensitivity by N. E. Dorsey. Measurements were made by impressing known alternating e.m.f.'s from two vacuum tube oscillators into the circuit of a special telephone receiver, the values of the e.m.f.'s being capable of independent adjustment. The most consistent results were obtained by keeping the frequencies of the two oscillators different by 3 c.p.s. An observer was unable to detect the two tones as such but heard a single tone whose intensity was beating or fluctuating three times per second. One e.m.f. was held at a known multiple of the threshold value and the other e.m.f. varied until the observer was unable to detect the fluctuation and the value of $\Delta E/E$ calculated from the e.m.f.'s. Measurements were made at frequencies of 35, 70, 200, 1000, 4000, 7000 and 10000 c.p.s. and at intensities from the threshold of hearing to the threshold of feeling. At any frequency $\Delta E/E$ is constant for intensities greater than 10^6 times the threshold intensity but increases as the intensity is decreased below this value. Above this intensity Weber's law ($\Delta E/E = \text{constant}$) holds. As a function of frequency $\Delta E/E$ is a minimum at about 2500 c.p.s. Curves are given and empirical relationships between differential sensitivity, frequency and intensity derived.

19. An experimental determination of the relation between viscosity and frequency in vibrating solids. S. L. Quimby, Columbia University.—A bar of the material under examination with a small iron armature attached to each end is suspended by light silk fishline. Opposite one armature is placed the magnet of a telephone receiver and opposite the other an electromagnet which is connected to a source of variable frequency alternating current. The bar is excited to resonance at one of its harmonics and while in this condition the excitation is suddenly removed. The amplitude of vibration diminishes exponentially at a rate which depends upon the frequency and the viscosity of the material. The e.m.f. induced in the telephone receiver, which is proportional to the amplitude, is rectified, amplified, and photographed on an oscillograph giving a record from which the decrement of the vibrations and the viscosity may be obtained. Experiments were made over a frequency range of 500 to 3000 cycles. The results are in agreement with those obtained by Kimball below 200 cycles and permit the generalization of his conclusion that in solid media the fractional loss of energy per cycle due to internal friction is a constant of the material independent of the speed of performance of the cycle.

20. Some experiments with a vibrating quartz sphere. K. S. Van Dyke, Wesleyan University.—The rotation which a vibrating piezo-electric quartz plate may perform is well known and has been attributed by Meissner to an air blast from the vibrating plate. The present author finds that a vibrating quartz sphere may perform either translational or rotational motions. Strong winds are sometimes found near the sphere which, undoubtedly, play a part in determining its motion. However, as the mechanical driving forces persist at pressures so low that the wind is thought ineffective, the ponderomotive effects, and presumably the air blasts as well, seem to be due to a sort of grip that the quartz has upon its support. This grip if greater at some parts of the vibration cycle than at others could account for the forces operating. The sphere can be made to slide along a track without rolling, to travel continuously around a circular track in either direction or to rotate continuously about an axis which it selects. Some notion of the character of the motion of the various parts of the surface of the sphere is obtained from the rotation which ping-pong balls take up when allowed to touch the apparently still, but vibrating, sphere.

21. Discussion of the kinetic theory of gravitation IV: Correlation of continual generation of heat in some substances, and impairment of their gravitational acceleration. Charles F. Brush, Cleveland, Ohio.—Long and careful search with sensitive calorimeters has discovered some substances, notably complex silicates, which remain permanently warmer than their surroundings. This continual generation of heat is thought due to ether-waves causing gravitation. (There is no appreciable radioactivity.) Conversion into heat of some of the energy of the ether-waves, however little, might be expected to impair to some extent the falling velocity of a heat-generating substance; *and all such substances thus far tested have clearly shown impairment.* Two aluminum containers are used, alike in size, shape, weight and smoothness of surface. These are dropped simultaneously, side by side, by sudden removal downward and side ward of the supporting horizontal metal plate. After falling about 110 cm, the small lower ends of the containers are photographed against a white background having many horizontal black lines, and illuminated by a bright electric spark. One container is filled with the silicates under test, while the other is loaded with an equal weight of lead sawdust. Eight photographs are made on successive strips of the same plate, the containers being reversed in right and left position after each exposure. The photographs easily show that the container holding the silicates is consistently slow. Exchange of loads in the containers makes no observable difference—the silicate container is always slow.

22. An active form of oxygen. L. C. Copeland, Johns Hopkins University. (Introduced by F. R. Bichowsky.)—An active form of oxygen presumably monatomic has been produced by passing oxygen gas saturated with water vapor through a discharge tube. Density measurements indicate a dissociated gas and association to a heavier molecule, such as O_3. Platinum and nickel wires are heated to glowing in this gas and copper and tungsten are apparently unaffected. Luminescence is produced by mixing iodine vapor or sulphur vapor with the active gas.

23. Atomic absorption coefficients. R. M. LANGER, National Research Fellow, Bureau of Standards.—It is difficult to check calculations of intensity of emission for atoms because the conditions of excitation can not easily be analyzed. Absorption measurements are more easily interpreted and it is interesting to calculate these by the new mechanics and try to compare with experiment. The theoretical values are surprisingly high. For example, the atomic absorption coefficient of normal hydrogen atoms for the first lines of the Lyman series are respectively 37, 7.0, 2.4, 1.2, 0.7, all multiplied by 10^{-4}. Correspondingly for the Balmer series (i.e., atoms in the first excited state), one finds 40, 13.5, 8.0, 6.0, 4.5, 4.0, all multiplied by 10^{-3}. These are presumably for radiation which differs from the absorption frequency of the particular atom by less than the natural line width. The apparent absorption coefficient will of course depend on the Doppler width and on the resolving power of the observing apparatus and will be much smaller than the values here given.

24. Investigation of materials useful in the construction of filters for the ultra-violet. CHARLES D. HODGMAN, Case School of Applied Science.—Gelatin film, ordinarily used in filters for the visible spectrum, may be employed where transmission is not required for wavelengths shorter than 0.30μ. Films of celluloid or collodion transmit very little below 0.32μ and it is less convenient to incorporate the absorbing agent. Cellophane film readily absorbs dyes from aqueous solutions and has a considerably higher transmission than gelatin in the shorter wave lengths. Measures of the transmission of equal thicknesses (0.005 cm) of gelatin and of cellophane made by the sector photometer show the values to be approximately as follows:

Wave-length, microns	0.20	.25	.30	.35	.40
Percent transmission of Gelatin	0	7	35	58	70
Percent transmission of Cellophane	16	30	47	65	78

Alteration of the transmission due to continued exposure to the ultra-violet is being investigated. Preliminary measures for gelatin and cellophane in which the materials were exposed to the radiation from a quartz mercury-vapor arc at a distance of 25 cm for a period of 12 hours indicate no measurable change. The transmission has also been determined for a large number of other materials which may be of use in filter construction.

25. On the distribution of ionic mobilities in air. JOHN ZELENY, Yale University.—The author's blast method of measuring ionic mobilities in gases has been modified to permit a determination of the distribution of the mobilities, which are found to cover a wide range of values. Gas is passed between the two electrodes of a cylindrical condenser, a narrow section of the inner of which is connected to an electrometer. Ions are introduced into the gas stream from the outside through small holes in the outer cylinder and the distance measured that they are carried downstream while they move from the outer to the inner cylinder under an electric field. The method has a high resolving power. Preliminary measurements made on ions over 3 seconds old, in filtered air containing about 4 mg of water per liter show a broad band of mobilities both for negative and positive ions, the positive band being somewhat broader than the negative. The highest mobilities in these bands are about 2.5 times as fast as the lowest. The most numerous ions were found to have mobilities of approximately 2.2 and 1.3 cm/sec. for the negative and positive ions respectively. The results are in agreement with the recent work of Laporte.

26. Gas ion mobilities in H_2–SO_2 mixtures. L. DU SAULT AND LEONARD B. LOEB, University of California.—Apparently two states of purity of SO_2 exist after careful fractionation whose appearance cannot be controlled. In the one the mobility at N. T. P. on the accepted scale is 0.28 cm/sec per volt/cm for positive ions and 0.26 for negative ions. In the purer sample the values are 0.40 cm/sec and 0.37 cm/sec. At lower pressures the reduced mobility apparently increases to 0.30 cm/sec and 0.28 cm/sec respectively. This is probably due to the purer sample predominating at these pressures. In mixtures with H_2 both samples give a mobility mixture curve for negative ions departing from Blanc's law as does NH_3. The lower mobility gas shows an identical effect with the positive ions. The purer gas *increases* the mobility of the *positive ion* in H_2 to *as high as twice the normal observed negative* mobility. Similar increases were observed on traces of NH_3 in H_2 but the increase was not so large. The curve in this case cannot be followed to higher percentages as the pure modification was obtained but once at higher pressures. As neither + nor − ions in H_2 are formed about an H_2 molecule this indicates that the SO_2 replaces some more bulky constituent and makes a more mobile ion. Contrary to Yen, the + mobility was universally higher than the −.

27. The nature of gaseous ions from a study of mobilities in mixtures. LEONARD B. LOEB, University of California.—After a general survey of the previous status of the question of the nature of the gaseous ion, it is concluded that for pure gases the dielectric attraction of the molecules by the charged ion can account for the order of magnitude of the mobility nearly equally well on either cluster or small ion theory. Such measurements are therefore indecisive. The measurements of mobilities in mixtures use Blanc's law as a criterion for the absence of the change of the cluster ion. The results show that Blanc's law holds in some cases and not in others. The observed nature of the mobility curves in mixtures shows three types of effects. These may be interpreted as indicating absence of clustering, labile clustering, stable clustering. The nature of the deviations in different gases indicates that where marked stable clustering occurs it is a specific effect depending on the chemical nature of the gas and sign of charge on the ion. Such effects are superimposed on the dielectric attractions mentioned above. Erikson's results on aging are discussed in their bearing on this work.

28. A proposed experiment on the statistical interpretation of quantum mechanics. ARTHUR EDWARD RUARK, Mellon Institute, University of Pittsburgh and Gulf Production Companies.—Consider the wave function $\Psi = \Sigma c_n \Psi_n$, where Ψ_n is the characteristic function of the nth quantum state. According to one view $c_n c_n^*$ measures the fraction of the systems of a statistical ensemble in the nth quantum state. Another view is that $c_n c_n^*$ measures the strength of excitation of the nth mode of vibration in each atom. If several modes of vibration can exist simultaneously in a single atom, then probably several quanta can be emitted at the same time. This could be tested for nuclear-spectra with a Rutherford-Andrade gamma-ray spectrograph. Instead of a photographic plate, small point counters would be so placed that each one receives diffracted gamma-rays of a definite wave length. The existence of double emissions from one and the same nucleus can thus be tested. The counting experiments of Kovarik (Phys. Rev. **23,** 599 (1924)) indicate that only one gamma-ray is emitted by each decomposing atom of RaB or RaC. The experiment of Compton and Simon (Phys. Rev. **26,** 290 (1925)) also speaks against the existence of double emissions, which would require that the law of conservation of energy should have only statistical validity.

29. Rotational Distortion and Zeeman Effect of Diatomic Molecules in Wave Mechanics. CLARENCE ZENER, Harvard University.—The condition that Pauli's equations $(H_0+H_1-E)\psi_\alpha=0$, $(H_0+H_1+E)\psi_\beta=0$ be soluble is that the determinant $|H_0+H_1-E|$ vanish. In rotational distortion and Zeeman effect, $H_1=A(\sigma_\kappa \cdot s)$, $H_1=A(\sigma_\kappa \cdot s)+(\sigma_\kappa \cdot H)+2(s\cdot H)$ resp. The solution of this determinant gives to the first approximation in the power series of A:

$$\Delta E = \pm\sigma_\kappa{}^2 As/(j+\tfrac{1}{2}\pm s)+\sigma_\kappa{}^2 As/2(j\pm s)(j+1\pm s)$$

$$\begin{aligned}\Delta E = &\{-(m+\tfrac{1}{2})\sigma_\kappa{}^2 H+\tfrac{1}{2}\sigma_\kappa{}^2 As\}/(j\pm s)(j+1\pm s)\\ &\pm[4s^2H^2+\{2\sigma_\kappa{}^2 sH^2-4(m+\tfrac{1}{2})\sigma_\kappa{}^2 s^2 AH+\sigma_\kappa{}^4 s^2 A\}/(j\pm s)(j+1\pm s)\\ &+\{\tfrac{1}{4}\sigma_\kappa{}^4 H^2-(m+\tfrac{1}{2})\sigma_\kappa{}^2 SAH\}/(j\pm s)^2(j+1\pm s)^2]^{1/2}\end{aligned}$$

The rotational distortion separation is in agreement with Kemble's and Van Vleck's formulae only for large values of j. The second term gives the anomaly when $j=\sigma_\kappa \mp s$. The second formula gives the coupling between the Zeeman effect and multiplet structure.

30. An attempt to detect a magnetic field resulting from the rapid rotation of a copper sphere. W. F. G. SWANN AND A. LONGACRE, Bartol Research Foundation of Franklin Inst.—In an explanation of the earth's magnetism as a result of rotation, the apparent current density i must be considered as a function of the density D, angular velocity ω, and distance r from the axis of rotation. Confining ourselves to forms of i involving only products of simple powers of r and ω, there are two expressions which would be consistent with the ratio of the earth's magnetic field to that of the sun, and with a reasonably small value for the field of a small sphere rotating at high speed. These expressions are: $i=ADr\omega$, and $i=BDr^3\omega^4$. As corresponding to the field of 0.5 gauss at the earth's pole, the former predicts 3.2×10^{-9} gauss and the latter 4.4×10^{-3} gauss for the magnetic field at a pole of a copper sphere 10 cm in radius rotating 200 times per second; observations made on such a sphere using a compensated earth inductor compass, and with the earth's field balanced by Helmholtz coils, gave measurements corresponding to a field at the pole of less than 7.0×10^{-4}. The experiment, while favoring the first of the above expressions for i does not form conclusive evidence against the second for bodies and sizes and angular velocities comparable with those of the earth and sun. Thus for example a law which made i proportional to $\omega^{3.8}$ would give practically the same ratio for the fields of the earth and the sun as would the fourth power law. For the high speed sphere, however, this expression would give a negligibly small field.

31. The rotation of permalloy and soft iron by magnetization in weak fields and the gyromagnetic anomaly. S. J. Barnett, University of California at Los Angeles and California Institute of Technology.—This is an extension of the work presented at the June meeting, 1927 (Phys. Rev. **30,** 964 (1927)). Many additional measurements with the magnetizing solenoid wound upon the rotor have been made under improved conditions; also many with the solenoid fixed to the earth, as in most earlier work by others. The method used in the principal part of the investigation is essentially a null method, though two deflection methods have also been used. All are alternating current methods, involving the use of resonance and rectangular waves. The results of all are in excellent agreement. The mean (preliminary) value of ρ (ratio of angular momentum of elementary magnet to its magnetic moment) obtained is $m/e\times1.05+$, which agrees closely with the value ($m/e\times1.06$) obtained in the precise work on magnetization by rotation published in 1925. Systematic errors have been thoroughly studied. The total error is probably less than one percent. The magnetizing fields used in all the work have been weak, the intensities ranging approximately from 20 to 40 gausses. Rotor diameters have ranged from 1.5 mm to 3.2 mm; frequencies from 4.1 per second to 13.9 per second; and amplitudes of vibration (when not reduced to smaller magnitudes in the practise of the null method) from 4 cm to 16+ cm. The magnetic parts of all rotors are either 20 cm or 27.5 cm in length.

32. The Hall effect in single iron crystals. P. I. Wold, Union College.—Silicon steel, with about 3.8 percent silicon, has been obtained in the form of long single crystals about 1.5 cm wide and .3 cm thick. The crystal orientation is different for the various specimens. In some cases about half the specimen is monocrystalline and the remainder polycrystalline. The Hall effect has been measured on several of these and in various places. The Hall constant appears to be independent of the direction of orientation of the large crystals and does not differ substantially from that obtained in the polycrystalline portion. The results are in agreement with those obtained with single crystals of copper and it is believed that this is what should be expected for a metal of cubic lattice structure. The values obtained for the Hall effect in this silicon steel are about 15 times greater than for pure iron.

33. An x-ray examination of the anhydrous $Na_2SO_4-Al_2(SO_4)_3$ system. F. A. Steele, The Pennsylvania State College. (Introduced by Wheeler P. Davey.)—A series of mixtures of Na_2SO and $Al_2(SO\ )_3$ have been prepared by mixing solutions of the two in known ratios, evaporating to dryness, and heating to 400°C to give anhydrous crystals. X-ray diffraction patterns made by the powder method showed the presence of a definite compound of the composition represented by the formula $NaAl(SO_4)_2$. Specimens containing more $Al_2(SO_4)_3$ than the compound gave the patterns of $Al_2(SO_4)_3$ and $NaAl(SO_4)_2$ superimposed, with no observable change in the parameters of either. Specimens containing an excess of Na_2SO_4 gave the pattern of $NaAl(SO_4)_2$ with additional lines not due to Na_2SO_4, indicating a second compound. The composition of this compound has not yet been determined, but it contains more Na_2SO_4 than represented by the formula $Na_3Al(SO_4)_3$. None of the compounds involved gave patterns similar to soda alum.

34. The crystal structure of strontium-oxide. Thomas A. Wilson, General Electric Co and Union College.—Powder photographs of samples of SrO were made with Mo K radiation. All the material examined contained $SrCO_3$ as shown by the presence of the spectrogram of the latter. By comparing the spectrograms of $SrCO_3$ and the mixture of SrO and $SrCO_3$ for both position and intensity of the lines, the pattern of SrO was isolated. The lattice is of the NaCl type. The length of the cube edge is $5.073 \pm .01$A, the density is 5.235. Gerlach's values are $5.104 \pm .01$ and 5.143 respectively. (Zeit. f. Phys. **9**, 184 (1922).) All these x-ray values of the density are much higher than those obtained by direct measurement. (Groth gives 4.750.)

35. The oxidation of ferrous sulphate in aqueous solution by x-rays of different wave-lengths.—A determination of the Compton absorption. Hugo Fricke, Cleveland, Ohio.—The amount of ferrous sulphate oxidized by x-rays to ferric sulphate is determined, the rays being measured in terms of the ionization of 1 cc of air, and is found independent of the concentration of ferrous sulphate (1/100 to 1/25000*n*). It is concluded that the transformation is due to a primary production of activated water molecules and using Duane and Scheuers determination of the number of water molecules transformed to hydrogen and oxygen by α-rays, it is found that in solutions containing dissolved oxygen, for each such "activated" water molecule $8.2(\pm 2\%)$ ferrous ions are transformed, 2.05 oxygen molecules being simultaneously reduced; in gas free solutions 4.1 ferrous ions are transformed. To ferrous sulphate solutions are added salts of different light elements and for each solution a comparison is made of the amounts of transformation produced by a constant dose of x-rays of different wave-lengths (.20 to .80A). The amount of transformation is independent of the wave-length when the mass coefficient of photo-electric absorption of the solution is equal to that of air, but when larger the effect of the shorter wave-lengths becomes increasingly smaller. This is due to the Compton effect and for $\lambda = .204$ the mass coefficient of absorption due to the production of Compton electrons is for light elements found equal to .0158; the value derived theoretically by Compton is .0156.

36. Reflection of soft x-rays from aluminum. S. D. Gehman and C. B. Bazzoni, University of Pennsylvania.—Non-characteristic soft x-rays, of voltage range 40 to 300, were passed through a slit system and then reflected from a polished aluminum mirror in a high vacuum. The reflecting power of the mirror was measured by a photo-electric method as a function of the voltage for a given grazing angle and as a function of the angle for a given voltage. The reflecting power-voltage curve shows a broad maximum between 68 and 140 volts accelerating potential and falls off rapidly as the voltage increases. It is hoped to resolve this maximum to give critical potentials of aluminum by filtering or otherwise. For a fixed voltage the reflecting power falls off rapidly as the grazing angle increases. With a plate voltage 102, for example, the reflecting power for a grazing angle 9 degrees 30 minutes was 0.460, while for an angle of 12 degrees 30 minutes it was 0.140. The form of the reflecting power-grazing angle curve is practically independent of the voltage.

37. Refractive indices of silver in the wave-length range of two to seven Angstrom units. Elmer Dershem, University of California.—The indices of refraction of silver have been measured at short wave-length intervals in this region, using the same methods previously reported (Phys. Rev. **31**, 305 (1928) and Bull. Am. Phys. Soc. Vol. **3**, No. 2, Feb. 18, (1928)). The dispersion curve thus obtained shows a marked depression in the values of δ on both sides of the L_I absorption limit wave-length. A much greater depression is noted mid-way between the L_{II} and L_{III} absorption limit wave-lengths. Further work is being done to definitely determine whether this effect is caused by the depressions due to latter levels not being resolved or is due to these two levels functioning as one in dispersion phenomena as might easily be expected. While the shorter wave-lengths give values of δ which are in agreement with classical theory if not too near an absorption limit it may be noted that in all substances thus far examined that δ rises rapidly with increasing wave-length between 6 and 7 Angstrom units. δ for platinum increases 51% in this range while δ for silver increases 54%, δ for silver having a value of 666×10^{-6} at 7 Angstrom units.

38. X-ray diffraction in liquids—isomers of normal heptane. G. W. Stewart, University of Iowa.—An examination was made of the diffraction of monochromatic .712A radiation with the following liquids: 2-3, 2-4, 2-3 and 3-3 dimethyl pentane, 2 and 3 methyl hexane, 2-2-4 trimethyl pentane, 2-2-3 trimethyl butane, and 3 ethyl pentane. The general conclusion is that the isomers differ from the normal compounds in a manner similar to that occurring in the alcohol chains. The effect upon the "diameter" of the molecule of the group CH_3 in a branch depends upon the number of groups and the points of attachment. The "straightness" of the chain itself is modified by the attachment of branches. With 3 ethyl pentane where the molecule is a union of three like branches, a symmetrical form is indicated. The length of the normal paraffin chains is expressed with less than one percent accuracy by $1.24n+2.70$ Angstroms wherein n is the number of carbon atoms. The comparison of all data from this laboratory on the x-ray diffraction in liquids indicates that the use of Bragg's law and the interpretation of the liquid condition as the cybotactic state is justified.

39. K-electron ionization by direct impact of cathode rays. David L. Webster, Stanford University.—Investigations reported at the Reno meeting (Proc. Nat. Acad. Sci., **13**, 445 (1927)) on the ratio of direct and indirect characteristic rays of silver, have been improved and extended. Between 35 kv and 80, although the rays increase in intensity by factors of 18 or 19, this ratio changes very little, the data giving 1.83 to 1.96, each ±10%. The probability that a cathode ray will ionize a K electron by direct action, i.e., action all within one atom, bears a ratio of 0.90 to the probability that it will emit a corresponding quantum of continuous spectrum radiation; this ratio is constant with change of voltage, and therefore applies to thin targets also. The absolute probability of direct K ionization can be calculated by combining present data with total x-ray efficiency data, with results confirming Thomas' theory. This and other evidence indicates that the direct process of K-electron ionization is not an internal photo-electric effect so often as it is a repulsion, much like ordinary electrostatic force.

40. Atomic structure factor and Fourier analysis. G. E. M. Jauncey and W. D. Claus, Washington University, St. Louis.—Compton (X-Rays and Electrons, p. 164) gives a formula for the radial distribution (U) of electrons in an atom. When $D \rightarrow \infty$, U takes the form of the Fourier integral

$$U(r) = 8\pi r \int_0^\infty x F(\lambda x/2) \sin 2\pi r x dx \qquad (1)$$

where F is the atomic structure factor expressed as a function of $\sin\theta$. For the case of Z electrons moving in a circular orbit of radius c in an atom and the atom vibrating thermally so as to give a Debye temperature factor of $\exp(-b\sin^2\theta)$ we obtain

$$U(r) = (Z/ac\sqrt{\pi})r\{\exp[-(r-c)^2/a^2] - \exp[-(r+c)^2/a^2]\} \qquad (2)$$

where $a = (\lambda\sqrt{b})/2\pi$ = the most probable displacement. Using the experimental value of b at room temperature for rocksalt, $a = 0.175$A in good agreement with James and Firth's value of 0.20A (Proc. Roy. Soc. A, 117, 62). We have compared a U curve obtained from (1) with a U curve obtained from Compton's formula for a model Cl^- atom and we find that the positions of the maxima agree. A U curve gives the electron distribution relative to a lattice point of the crystal and not relative to the center of the atom.

41. Fine structure in the K-series of copper and nickel. Harris Purks, Columbia University.—High resolving power was obtained by means of the double x-ray spectrometer with crystals set so as to increase the angular displacements. The method was the same as that previously described by Davis and Purks (Proc. Nat. Acad. Sci. June, 1927, and Feb., 1928). With both crystals set for first order reflection there appeared bulges on the long wave-length sides of the $K\alpha$ lines of copper and nickel. It was found that these bulges could be explained as weak lines at displacements of .42 X.U. and .35 X.U. to the long wave-length sides of Cu $K\alpha_1$ and Cu $K\alpha_2$, respectively, and .45 X.U. and .38 X.U. to the long wave-length sides of Ni$K\alpha_1$ and Ni$K\alpha_2$ respectively. These results were checked by placing both crystals at second order. At second order there appeared evidence of other structure nearer the center of the principal lines. The $K\beta$ doublets of these elements were investigated. They were not resolved but the rocking curves by their shape permitted solutions of the problem of displacements and intensities of components. The separations graphically determined from the curves were CuKβ .32 X.U., Ni Kβ .29 X.U. It was found that the widths of the lines were dependent upon the voltage across the tube. Near the excitation voltage the widths were about two-thirds that at 40 kv.

42. **Effect of chemical combination on the structure of the K absorption limit of silver and molybdenum.** BERGEN DAVIS AND HARRIS PURKS, Columbia University.—The proper arrangement of crystals in the double x-ray spectrometer has multiplied the resolving power of ionization spectrometer many times. By its use fine structure in the K series of Mo, Cu and Ni have been discovered. The structure of the absorption limit was investigated by the same method. The limit of the pure metal is quite sharp. Its total spread (Ag and Mo) is less than .5 X-units. The limit for Ag_2S and Ag_2O was broader than for the pure metal. Also Ag_2S showed traces of structure and Ag_2O showed marked evidence of structure. The Ag_2S turned black indicating dissociation by the x-rays. The limit for MoO_3, MoS_2 and Mo_2O_3 was investigated. All of these compounds showed marked broadening at the limit. Marked evidence of structure was observed in Mo_2O_3. The center of gravity of the limit is not much shifted. The K limit of copper was also taken. It was much wider than in the case of Ag and Mo. In general the absorption limit broadens toward lower atomic numbers. The copper compounds were not investigated as energy available was too small. The measurements were all made with both crystals at first order.

43. **Fine structure of scattered x-rays.** DANA MITCHELL AND BERGEN DAVIS, Columbia University.—By means of a double x-ray spectrometer with calcite crystals the fluorescent radiation from a sheet of molybdenum was observed. The Kα doublet was resolved into two lines less than .5 X.U. wide at their half maximum. The Mo Kα_1 scattered at approximately 90 degrees by a piece of carbon was then investigated. Five lines attributable to Mo Kα_1 were found. One is in the position of the fluorescent Mo Kα_1, and three are displaced by 1, 2, and 10 X.U. from the unmodified in the long wave-length direction. The width at half maximum of each of these is .6 X.U. or less. The fifth line about 4 X.U. wide at half maximum and displaced about 22 X.U. seems to be the modified line in the Compton effect. Assuming the impulse of the deflected quantum to be absorbed by the atom and the scattering electron to be removed from one of the L positions of carbon the displacements of 1 and 2 X.U. are each about twice that predicted by the expression $\Delta\lambda=\lambda^2/(\lambda s-\lambda)$. The displacement of 10 X.U. is a little less than similar assumptions predict for the case of a K electron in carbon.

44. **X-rays from thin targets.** WARREN W. NICHOLAS, National Research Fellow, Cornell University.—Very thin metal foils are mounted as anticathodes in x-ray tubes. The thickness of the foils is such as neither to slow up nor to deflect the cathode rays appreciably at the voltages used. Thus the x-rays produced in the foil result from the bombardment of atoms by cathode rays of uniform speed and direction. The spectra of these x-rays are examined photographically by means of small Seeman spectrographs placed inside the x-ray tube. The continuous spectra in different directions relative to the cathode stream differ markedly as to spectrum energy distribution. Due to the simplicity of the photographic blackening laws for the x-ray region, quantitative results are obtainable by the method, and on account of the simplicity of the present conditions as compared with the conditions in the ordinary thick target x-ray tube, it is expected that these results will yield to a more direct theoretical interpretation. Spectrographs and densitometer curves are reproduced for a comparison of thick and thin target spectra, as well as for comparison of thin target spectra in different directions, and these are discussed in the light of present theories.

45. **The scattering of x-rays from gases.** CHARLES S. BARRETT, University of Chicago.—Using apparatus previously described (Proc. Nat. Acad. Sci., **14,** 20 (1928)) with unfiltered Mo rays from a Coolidge tube at 62000 volts, the azimuthal distribution of intensity of scattering from gases was measured. The scattering from helium coincides with that from hydrogen (proportional to $1+\cos^2\theta$) from 60° to 100° but is slightly greater from 20° to 60°. The deviation at the small angles is of the type that could be explained as due to a small amount of nitrogen

as an impurity. Nitrogen shows excess scattering, though at somewhat smaller angles than oxygen. Argon exhibits excess scattering over the whole range investigated, 20° to 100°. Reduced to equality with hydrogen at 100°, its intensity at 40° is over twice that of hydrogen. This does not confirm Mark and Schocken's finding of $(1+\cos^2\theta)$ for argon. The scattering from argon at angles less than 100° increases with increasing wave-length giving further evidence of coherent scattering. These experiments with argon show the existence of excess scattering from atoms spaced at random. Scattering which follows the $(1+\cos^2\theta)$ formula may be considered as modified, as this formula expresses the predictions of the quantum theories within experimental error.

46. The polarizing angle for x-rays. G. E. M. Jauncey and Gerald Hassler, Washington University, St. Louis.—The classical theory of x-ray scattering and the theory based on the new quantum mechanics predict 90° for the polarizing angle, while the quantum theories of Jauncey and Compton give a polarizing angle of less than 90° and dependent upon wave-length. Jauncey and Stauss found a polarizing angle of less than 90° for an effective wave-length of 0.25A scattered by paraffin (Phys. Rev., **23**, 762 (1924)) while later Bearden and Barrett (Phys. Rev., **29**, 352 (1927)) find a polarizing angle of 90° or slightly greater than 90° for a wave-length of 0.215A. We have repeated the experiments of Jauncey and Stauss with a wave-length of 0.27A and we find a polarizing angle of 90°20′ thus supporting the findings of Bearden and Barrett.

47. The diamagnetic layer of the earth's atmosphere and its relation to the diurnal variation of terrestrial magnetism. Ross Gunn, Naval Research Laboratory, Washington, D. C. (Introduced by Lynde P. Wheeler.)—An examination of the phenomena existing in the upper layers of the earth's atmosphere shows that ions or electrons in motion spiral about the earth's magnetic field producing certain electrical and magnetic effects which modify greatly present ideas regarding this layer. Maintained ionization of the layer is great only in the regions where the free paths of the ions or electrons are long. Under the condition of long free paths the electrical conductivity is anisotropic. Large circulating currents in the upper atmosphere of the type assumed in present theories of the diurnal variation are shown to be highly improbable. A new theory of the diurnal variation of the earth's magnetic field is proposed which appears to be free of objectionable assumptions and explains quantitatively the major features of the observed facts. As a consequence of the theory and experimental data it appears that an appreciable fraction of all molecules in the upper atmosphere having long free paths are ionized.

48. Capacity of aluminum anodes. J. E. Lilienfeld, Washington Square College, New York University.—Two different theories have been advanced in order to explain the action of the aluminum cell. Both agree that aside from the oxide layer formed on the aluminum anode there is also a gas layer (or some other invisible layer, Slepian) present. They differ with respect to the question whether exclusively the gas layer is responsible for the observed phenomena (Gunther-Schulze); or whether the influence of the oxide layer upon the electrical characteristic is to be considered alongside with that of the gas layer. (Guthe; Fitch; Meserve.) The idea of a gas layer has been introduced—among other reasons—because it is being assumed that the visible oxide layer by itself may not account for the capacity of the cell. However, it has to be mentioned that with respect to the resistance of the cell there is on the part of Fitch and Meserve a tendency to consider the oxide layer as the determining factor. The present investigation adds to the knowledge of this class of phenomena by showing that the dielectric dry oxide layer as formed in the electrolytic cell upon application of a definite maximum voltage will, if properly brought into contact with a metal, form a specific capacity controlled to a large extent by that voltage and checking within close limits some of the figures of Gunther-Schulze. For instance: for a 325V layer Gunther-Schulze quotes 0.018μF while 0.017μF have been measured in the present case.

49. Measurement of the charge of positive ions by the shot effect. N. H. Williams and W. S. Huxford, University of Michigan.—Following somewhat similar methods to those used by Hull and Williams in measuring the electronic charge in thermionic and photo-electric emissions, the charge of the positive ion in high vacuum has been measured. The amplifier consists of five stages in which shielded grid tubes are used with tuned plate circuits. The source of positive ions was a fused mixture of potassium and iron oxides. A formula developed in a paper by Williams and Vincent expresses the electronic charge in terms of the impedance, Z, of the circuit and the area, A, under the resonance curve of the amplifier. This equation is $e=v^2/2Z^2i_0A$, where v is the high frequency voltage which produces the same effect upon the amplifier as the shot voltage and i_0 is the space current through the tube as read from a microammeter. This equation was used in computing the positive ionic charge. The measurement of Z is accomplished by an improved method of considerable precision. The result is a numerical value equal in magnitude to the charge of the electron within the limit of error of the frequency standard used.

50. The refraction of electrons by a crystal of nickel. C. J. DAVISSON AND L. H. GERMER, Bell Telephone Laboratories, Inc.—New electron diffraction measurements, made by a method entirely analogous to the Bragg method of x-ray spectroscopy, have shown a selective regular reflection of electrons from a $\{111\}$ face of a nickel crystal for a series of different critical electron speeds. These selective reflections correspond to various orders of the Bragg reflection of x-rays. The electron wave-lengths do not, however, coincide with the critical wave-lengths for the corresponding x-ray reflections, but at high voltages they approach these wave-lengths. We have found two angles of incidence (10° and 46°) for which adjacent orders occur at the same electron wave-length (1.07A). These observations allow us to determine the orders of the electron reflections, and to show that the differences between critical electron and x-ray wave-lengths can be accounted for by attributing to the crystal a refractive index varying regularly from 1.13 at 1.6A to 1.01 at 0.5A. The differences cannot be accounted for by assuming a superficial spacing factor or a refractive index less than unity. This assignment of orders corresponds to the second of the two possible associations of electron beams with x-ray beams considered heretofore (Phys. Rev., **30**, 705 (1927)). This seems now to be established as the correct association.

51. Interaction of electron and ion space charges in cathode sheaths. IRVING LANGMUIR, General Electric Co.—The usual space charge problem for electrons from a plane hot cathode to a parallel plane anode is modified by assuming positive ions emitted from the anode. Single ions emitted with negligible velocity permit $0.378(m_p/m)^{1/2}$ additional electrons to pass. An unlimited supply of ions gives an electron current 86.05 percent greater than with no ions, the field is symmetrically distributed between cathode and anode, and the electron current is $(m_p/m)^{1/2}$ times the ion current. These conditions apply to a cathode emitting a surplus of electrons surrounded by uniformly ionized gas. The cathode sheath is a double-layer with an inner negative space charge and an equal outer positive charge, the field being zero at the cathode and at the sheath edge. The electron current is limited to $(m_p/m)^{1/2}$ times the rate at which ions diffuse to the sheath edge and is independent of voltage if the source of ions is constant. Experiments with oxide cathodes in mercury vapor agree with this theory. The theory has been extended to take into account initial velocities of ions and ultimate electrons and also to deal with cylindrical sheaths.

52. Some characteristics of the discharge between cold electrodes in vacuum. ALBERT W. HULL AND E. E. BURGER, General Electric Co.—*Heavy discharges* from a transformer or charged condenser were passed between well-exhausted solid tungsten electrodes 2 mm apart in a good vacuum. *Current-time* and *voltage-time characteristics*, taken with a cathode ray oscillograph, show that the current starts as a pure electron discharge, but soon changes to a tungsten vapor arc. The arc voltage is less than 1000 with discharge currents as high as 20,000 amperes. Condenser charges of 5000 joules energy (1 microfarad at 100,000 volts) can thus be discharged through the tube repeatedly, with no appreciable heating of the electrodes. As soon as the discharge ceases the tungsten vapor condenses, and the breakdown voltage returns to its original value. The *time-lag* in passing from pure electron discharge to arc is less than 10^{-7} sec. The time lag in passing back again from arc to pure electron discharge depends on the depth of penetration of the heat. With heavy discharges it is between 1 and 10 microseconds. The *voltage gradient* necessary for breakdown is about 500,000 volts per cm for tungsten, and 100,000 for carbon.

53. Heats of condensation of electrons on platinum in ionized He, Ne and A. C. C. VAN VOORHIS AND K. T. COMPTON, Princeton University.—The heat liberated by the absorption of electrons at the surface of a Pt electrode was measured by the method previously described (C.C.V.V., Phys. Rev., **30**, 318 (1927)). Platinum is notoriously difficult to obtain with a clean surface, hence extreme measures for purifying the metal and gases were employed. The results obtained are: ϕ (Pt in A), 5.20 volts; ϕ (Pt in Ne), 5.00 volts; ϕ (Pt in He), 4.77 volts. These are relatively accurate to within a small fraction of a percent, but the absolute values may be high by not more than five percent owing to possible loss of weight of the electrode during an over-strenuous positive ion bombardment for cleansing purposes preceding the series of measurements. Correction for this error will be made later. Contrary to general belief, the work function of the metal in these inert gases varies with the gas used. This had been suspected in the earlier work with molybdenum but was not then thoroughly investigated. Experiments in mixtures of these gases at different voltages prove that it is the *ions* rather than the neutral atoms which influence the work function—a result suggestive of the halogen-like character of the rare gas ions.

54. The reflection of hydrogen atoms from crystals. THOMAS H. JOHNSON, Bartol Research Foundation of Franklin Institute.—Recent theories, as well as the experiments of Davisson and Germer suggest a wave of length $\lambda = h/mv$ associated with a freely moving particle. Evidence for the existence of such waves associated with the hydrogen atom has been sought by reflecting atomic hydrogen from a Wood tube from various crystal surfaces. Diffraction lines from a powdered crystal surface of ice, if present, were masked by scattered atoms although these were less than 1/300 as intense as the incident beam. Freshly cleaved rock salt, heated to degasify, reflects intensely with angle of reflection equal to the angle of incidence. Prismatic and hexahedral faces of crystal quartz, and freshly cleaved calcite reflect in no preferred direction. First order surface grating beams from rock salt were looked for but if they existed they were masked by the general reflection.

55. Phenomena at the cathode of a mercury arc. THOMAS J. KILLIAN, Princeton University. —The region close to the cathode in a mercury arc was investigated by the use of small cylindrical collectors after the method of Langmuir (G. E. Rev. (1924)). The space potential at distances of from 0.2 cm to 3 cm from the cathode spot was found to vary from 10.1 volts to 11.6 volts above that of the cathode. The cathode drop is therefore probably very close to 10 volts. The only previous determination of the cathode drop made by Stark (Ann. d. Phys. (1905)) was 5.27 volts. However, this is not the space potential but that at which equal numbers of electrons and positive ions are collected. The random positive ion currents were between 1.5 and 40 milliamps cm^{-2}. Random electron currents of from 1.3 to 18 amperes cm^{-2} and temperatures of from 5000°K to 16,500°K were also measured. The cathode is covered by a thin positive space charge sheath which seems to be punctured at the cathode spot due to the large electron emission at this point. Evidence is presented that these electrons are not of thermionic origin. An attempt is being made to conduct the investigation even closer to the cathode spot.

56. Ionic oscillations in the glow discharge. J. S. WEBB AND L. A. PARDUE, Lehigh University. (Introduced by C. C. Bidwell.)—In an effort to correlate Whiddington's work on moving striae and Appleton's work on ionic oscillations from a striated discharge, it was found that the ionic oscillation phenomenon was sufficiently involved to warrant a detailed study. The discharge tube was of the hot cathode type, 3 centimeters in diameter and 26 centimeters long. The oscillations were detected in three ways; first, by means of curved plates on the tube which were connected in parallel with the tuning condenser of the receiver; second, by direct inductive "pick-up" from the tube itself; third, by inductive "pick-up" from a coil in series with the tube. By these methods frequencies from 240000 to a few hundred cycles were obtained, the higher frequencies being detected on an auto-dyne receiver, the lower frequencies, on a straight low frequency amplifier. Characteristic curves obtained show an increase of frequency with filament current, an increase of frequency with anode potential, and a decrease with pressure except at the highest and lowest pressures where decided minima and maxima respectively occur. Without plates on the tube oscillations do not occur in sharply defined striae but begin just as striae commence diffusing, decreasing in frequency and become audible when a uniform glow fills tube.

57. Electrical breakdown of spark gaps at atmospheric pressures. J. Slepian, West. Elec. and Mfg. Co., East Pittsburgh.—As shown by Rogowski, the classical Townsend theory applied to breakdown of spark gaps at atmospheric pressures leads to time of breakdown greater than 10^{-5} sec. for gaps 1 cm or more in length, whereas experiments show times of the order of 10^{-7} sec. It may be shown by calculation, using values of ionizing constants derived from low pressure experiments, that the initiating electron, in its motion towards the anode accompanied by the electrons generated by collisions will so raise the temperature of the gas that the path left behind will be thermally ionized. In this way the need for the repeated traversal of the path by positive ions is obviated, and the short time for breakdown accounted for. Taking the effect of space change into account, and assuming that the critical gradient for sparkover is that at which thermal ionization first appears, a satisfactory agreement is found with the observed critical gradient as a function of gap length at atmospheric pressure. The formation of streamers during breakdown as disclosed by Torok is also explained.

58. The formation of atomic negative ions in mercury vapor. Walter M. Nielsen, Duke University.—A beam of electrons was projected along the axis of a discharge tube, coaxially placed inside a solenoid which produced a magnetic field of 250 gauss. Negative and positive ion currents produced in a definite length of the beam were measured for different driving potentials by applying suitable potentials to electrodes on opposite sides of the electron beam. The total current was absorbed by an end plate, placed perpendicularly to the magnetic field. Secondary electron effects were eliminated by a 115 volt accelerating potential on the end plate. The curves giving the relationship between the ratio of negative ion to total current as a function of the driving potential show that: At a vapor pressure corresponding to saturation at 14°C, the probability of the capture of a slowly moving electron by a normal atom is small compared with the probability of the attachment of an electron to an excited mercury atom. The following critical potentials for negative ion formation were observed: 4.7, 5.3, 6.0, 7.3, 8.8, 9.3, and 11.4 volts. Under the above conditions, a relatively small number of negative ions was observed at 2.3 and 2.7 volts. They are believed to be due to the mercury molecule and will be discussed in another paper.

59. Platinum term values and classification. Paul J. Ovrebo, University of Chicago. (Introduced by H. G. Gale.)—Forty new intermediate and upper levels together with three new low levels have been found for platinum. Combinations of these and of levels previously known give 142 lines. A. C. Hausmann's classification of the old low levels from the Zeeman effect is taken as the basis for prediction of classification of some of the new levels and of the unclassified old intermediate and upper levels. These assignments agree with Hausmann's assignment of *j* values for the old levels. The number of platinum lines classified now total 500. This leaves about 200 lines to be classified, excepting the lines of very low intensity. The work on these lines is in progress. This work assumes that Kayser's wave-lengths are accurate to .05A.

60. The spectra of cadmium II, arsenic IV, arsenic V, and selenium V. R. A. Sawyer and C. J. Humphreys, University of Michigan.—Extrapolation of the screening constant data for the $^2D(d^9s^2)$ term in 47 electron spectra, and the $^3D(d^9s)$ term in 46 electron spectra has permitted the prediction and location of the analogous ^2D term in the spark spectrum of cadmium. New vacuum-spark data in the extreme ultra-violet has been obtained for arsenic and selenium. By aid of previous classifications in 29 and 30 electron spectra of copper, zinc, gallium, and germanium, it has been possible, by aid of extrapolation of the Moseley diagram the irregular doublet law, screening constant data, and the triplet interval ratios, to predict the location of and to identify the multiplets arising from the lowest levels in the spectra of arsenic IV, arsenic V, and selenium V. The power of these methods is again demonstrated by the accuracy of the predictions. The 4^2S term of arsenic V is determined as about 505100 corresponding to an ionization potential of 62.4 volts.

61. The spectrum of quadruply ionized tin, Sn V. R. C. Gibbs and H. E. White, Cornell University.—It has been shown in passing from element to element in certain sequences of iso-electronic systems that when an electronic transition takes place between two levels having the same total quantum number, the resulting lines are displaced to higher and higher frequencies by very nearly a constant value. Applying this general rule to the spectra of Pd I, Ag II, Cd III, and In IV, and guided by the Moseley type of diagram for the values of $(\nu/R)^{1/2}$ of the terms, by term separations, and by relative intensities, we have been able to identify most of the strong lines in the spectrum of Sn V. The lines arising from the transitions $^3PD'F$ and $^1PD'F(4d^95p)$ into ^3D and $^1D(4d^95s)$ are found in the region 1000 to 1500A. The lowest energy level of the spectrum $^1S_0(4d^{10})$ has been identified by transitions from $^1P_1$, $^3P_1$, and $^3D_1'(4d^95p)$. These three lines were found in the region of 360A, each within one Angstrom of the wave-length predicted from an extrapolation of the $^1S_0$ and $^1P_1$ lines on a Moseley diagram for the Pd I-like sequence.

62. An analysis of the arc and spark spectra of yttrium. William F. Meggers, Bureau of Standards, and Henry Norris Russell, Princeton University.—An analysis of the arc and spark spectra of scandium was reported by the authors last year (Phys. Rev., **29**, 606 (1927)); a similar analysis of the analogous spectra of yttrium has now been completed. Both spectra of yttrium were entirely remeasured, a satisfactory separation of the Yt I and Yt II lines was obtained, and many new lines were recorded. Practically all of the lines in both spectra have been classified and series forming terms have been identified in each. The spectral series give an ionization potential of 6.6 volts for the neutral Yt atom, and 12.3 volts for the Yt^+ atom. Although a striking similarity exists between the yttrium spectra and the corresponding spectra of scandium, there are some important differences. For example in the Yt II spectrum, a singlet-S term $(5s)^2$, not observed in Sc II, is slightly lower in energy than $^3D(5s\cdot 4d)$. The analysis is supported by measurements of Zeeman effects photographed for this purpose by the late B. E. Moore. All details of the Yt I and Yt II spectra are in accord with Landé's theory of Zeeman effects and with Hund's theory of spectral terms.

63. The application of the x-ray laws to optical spectra of higher rank, and the classification of Ga IV and Ge V. J. E. Mack and Otto Laporte, University of Michigan, and R. J. Lang, University of Alberta.—X-ray energy levels are ionization energies of neutral atoms, whereas in isoelectronic sequences the net charge increases with the atomic number Z. The first order screening number σ_1, for a given electron, increases with Z in x-ray spectra but decreases to an asymptote in isoelectronic spectra; the difference is probably due to outer screening. Exact representation of isoelectronic optical spectra on a Moseley diagram, generally, requires knowledge of series limit correlation of individual levels. If σ_1 for a certain electron is plotted as a function of Z in several isoelectronic sequences, the initial slopes of the resulting curves depend only slowly upon the total number of electrons, and for a given total number of electrons the slope is substantially independent of the configuration; this implies that the lines on a Moseley diagram representing the addition of a given n_l electron to different isoelectronic sequences containing nearly the same number of electrons, are parallel, to a second approximation. The irregular doublet law applied to isoelectronic sequences in the neighborhood of a closed d-shell (d^{10}) is valid for $\sqrt{p}-\sqrt{s}$ but not for $\sqrt{d}-\sqrt{p}$ or for $\sqrt{f}-\sqrt{d}$. By application of the x-ray laws the $(3d^94s)$ and $(3d^94p)$ levels of Ga IV and Ge V have been found. From a comparison of the spectra Ni I to Ge V, it appears that $^3D_2(3d^94s)$ should be correlated with the series limit $^2D_3(3d^9)$, contrary to the theory of Hund.

64. Disagreements with the predictions of the Hund theory of series limits. A. G. Shenstone, Princeton University.—The Hund theory includes a prediction of the individual levels of an ion to which component sequences will converge. The theory is reasonably confirmed in the case of spectra determined by less than half-filled electron groups. For spectra determined by almost complete groups, there are, in addition to a large amount of adverse though inconclusive evidence, two definite cases of disagreement. The first case is the ^3P, $^1P(p^5s)$ sequences of NeI. The four component series actually converge to the ^2P limit in pairs $^3P_2$, $^3P_1$; $^3P_0$, $^1P_1$: theoretically $^3P_2$, $^1P_1$; $^3P_1$, $^3P_0$. The second case is the ^3D, $^1D(d^9s)$ sequence in

PdI where the convergence is actually in pairs $^3D_3$, $^3D_2$; $^3D_1$, $^1D_2$: theoretically $^3D_3$, $^1D_2$; $^3D_1$, $^1D_2$. The nature of these terms was fixed by intensities from McLennan and Smith's analysis, and the terms agree only partially with their identifications. The disagreements between the Hund theory and the experimental results are a real difficulty since the predictions of the theory are definite and there seems no part of the argument where ambiguity may enter.

65. Zeeman effect of hyperfine structure and magnetic moment of the bismuth nucleus. E. Back, University of Tuebingen, Germany, and S. Goudsmit, University of Michigan.—The analysis of the hyperfine structure of the bismuth lines and energy levels has shown that the bismuth nucleus very probably possesses a mechanical moment of momentum and a magnetic moment. The Zeeman effect in strong fields (43000 gauss) gave for the *mechanical* moment of the nucleus the value $9/2 \cdot h/2\pi$ (Zeit. f. Phys., **43,** 321 (1927) and **47,** 174 (1928)). The *magnetic* moment can, however, not be derived from those Zeeman effects, as its value just cancels out in the results. Preliminary observations of the Zeeman effect of λ4121 in weak fields (8000 gauss) were made by E. Back. The magnetic moment could not be detected, meaning that the ratio between magnetic moment and mechanical moment (Landé g factor) must be smaller than 1/10 in quantum units. Thus the nuclear moment is very probably not produced by moving or spinning electrons in the nucleus (expected $g \sim 1$), but by positive particles ($g \sim 1/10000$). This result is in agreement with the order of magnitude of the natural hyperfine structures in bismuth without magnetic field.

66. Multiplet separations. S. Goudsmit and C. J. Humphreys, University of Michigan.—Formulas for the separations of normal multiplets, arising from general configurations, are derived by reasoning from the fundamental assumption that they are due to the interaction energy between spin and orbital magnetism of the electrons. The separations are known for multiplets arising from groups of equivalent electrons, from considerations given in another abstract. It can be shown by a simple treatment of the vector model that the interaction energy for other configurations may be found in terms of that of the equivalent group and the interaction energy of the electron or group of electrons added, provided the quantum vectors of the original configuration remain unchanged. Our treatment applies only to multiplets showing reasonably close agreement with the interval rule, and which are therefore accounted for by the Russell-Saunders coupling. Applications to known spectra indicate the validity of our formulas to the extent permitted by agreement of data with the interval rule. The formulas also can be used to determine the electron configuration from the observed multiplet separations.

67. The comparison of the long and short arcs as an aid in the analysis of spectra. Keivin Burns, Allegheny Observatory, and F. M. Walters, Jr., Carnegie Institute of Technology.—Any data which aids in sorting the lines into different groups is of assistance in finding regularities in a spectrum. In iron a comparison of the long and short arcs enables one to pick out spark lines, lines which are broadened in the short arc, groups of lines shifted to the red and lines shifted to the violet. Self-reversal is far more pronounced in the short arc than in the long arc. The advantages of this method are that it may be used for the study of weaker lines than are usually observed and that it does not require the use of special equipment other than a large grating in a stigmatic mounting.

68. A type of variation from Beer's law and some of its implications. C. V. Shapiro and R. C. Gibbs, Cornell University.—Deviations from Beer's Law ordinarily occur if chemical reactions take place in a solution upon changing the concentration. Hydrolysis is a typical equilibrium reaction dependent on concentration and occurs in the case of solutions of the salts of weak acids and bases. Data is presented to show the effect on absorption spectra of diluting alkaline solutions of weak acids of the phthalein and fluorescein series while maintaining the ratio of alkali to acid constant. In the light of this data, the interpretation of absorption spectra and their bearing on chemical constitution are discussed. Fluorescence is also affected under these circumstances, since the phenomenon of luminescence is dependent both on the nature of the active ions in solution under the particular conditions of concentration of alkali and active substance employed and on their absorption under these conditions.

69. Active nitrogen. JOSEPH KAPLAN, National Research Fellow in Physics, Princeton University.—It was observed in the present experiments that the fourth positive group of nitrogen was excited in a weak discharge through active nitrogen. The passage of a weak discharge through active nitrogen, as Strutt has found, results in the partial destruction of the afterglow. The above bands were observed whether the active nitrogen was made from air or from commercial nitrogen. Strutt observed that the main difference between a condensed and an uncondensed discharge in nitrogen was the presence of the fourth positive group in the former. The same observation has been made by the author for discharges through air. It is suggested that the fourth positive bands in the condensed discharge and in the weak discharge through active nitrogen are excited in the same manner. The fourth positive group corresponds to the transition D–B in the nitrogen molecule, where the D level is the highest electronic level of the molecule. The excitation of these bands under the present conditions may indicate the presence of metastable molecules in the afterglow.

70. The excitation of oxygen by active nitrogen. JOSEPH KAPLAN, National Research Fellow in Physics, Princeton University.—A green line of oxygen of wave-length 5578A, which is now thought to be the Aurora green line, and a red line of oxygen at wave-length 6655A have been observed in the afterglow of active nitrogen. Preliminary experiments on the excitation of the green line show that an N_2 mixture containing about 4% oxygen is best for the excitation of the line. Active nitrogen produced in this manner shows an unusual development of the α bands of N_2. In addition to the prominent after-glow bands many of the remaining α bands are strongly emitted under these conditions. The appearance of these two oxygen lines alone, without the presence of the strong arc lines, suggests that they are excited in a simple process. Further experiments are necessary, however, before a definite process of excitation can be proposed.

71. The rotational structure of the blue-green bands of Na_2. R. W. WOOD AND F. W. LOOMIS, the Alfred Loomis Laboratory, Tuxedo Park, N. Y.—Owing to the theoretically impossible structures of these bands as reported by previous observers the writers have measured them, in absorption, in the third order of a seven inch plane grating mounted in the forty foot spectrograph. Each band is found, quite definitely, to consist of only one P, one Q and one R branch. This accords with Mulliken's theory that the electronic transition is ${}^1P-{}^1S$, and with the evidence of the fluorescent series. The combination relations have been applied to all measured bands and found to hold, rigorously, within the experimental error, except for the expected P,Q,R defect. This can be represented by values of B' which differ slightly in the P and R branches from those in the Q branches. The more important constants of this band system are: $B_0''=0.15431$ cm, $r_0''=3.08\times10^{-8}$ cm, $\alpha''=0.00082$, $B_0'=0.12541$ cm, $r_0'=3.41\times10^{-8}$ cm, $\alpha'=0.00094$, $B_{PR}'-B_q'=0.000013$. These extremely large internuclear distances correspond to very weak molecular binding, which is in accord with the low heat of dissociation previously reported.

72. Thermoelectric power of selenium crystals. R. M. HOLMES AND A. B. ROONEY, University of Vermont.—Crystals were formed by slow condensation of the vapor in a tube evacuated to .008 mm, one end of the tube being in an oven with automatic temperature control while the other end was in open air. The best crystals grew on a fine thread of pyrex glass situated in the center of the tube. Thermal e.m.f. measured against copper follows the equation: $E=1.10t+.00017t^2$ in millivolts and between 0°C and 180°C. This is the largest thermal e.m.f. so far reported for any substance and since it is about 800 times the value for a copper-lead couple, the above equation holds equally well for selenium against lead. Thermal e.m.f. is nearly a linear function of t, one junction being at zero, showing that the Peltier effect is responsible for nearly all of the thermal e.m.f. An e.m.f. is developed in some crystals by the absorption of light when the circuit is at a uniform temperature. This actino-electric effect, which is new for single crystals of selenium, amounts to as much as 10 millivolts for a 100 watt lamp at 50 cm and is not due to heating.

73. The thermal e.m.f. and resistance of single crystals of non-cubic metals. P. W. BRIDGMAN, Harvard University.—An improved method of casting single crystals has permitted the production of crystals with a wider and more uniform distribution of orientations than hitherto, and a reexamination, with greater accuracy, of the way in which thermal e.m.f. and resistance varies with direction. The metals studied were zinc, cadmium, tin, bismuth, and antimony. Except for small, but distinct effects in tin and bismuth, the thermal e.m.f. is a linear function of $\cos^2\theta$, where θ is the angle between the axis of the crystal and the length of the rod. This is the relation of Kelvin and Voigt, about which I have previously expressed doubt. I still can see no theoretical method of deriving the relation. The new results on resistance verify the discrepancy between my former results and those of other observers, in that I find a smaller difference between the resistance parallel and perpendicular to the axis. This can be explained by the difficulty of avoiding slight flaws or slip on the cleavage or slip planes.

74. Thermionic activity, evaporation, and diffusion of barium on tungsten. J. M. EGLIN, Bell Telephone Laboratories, Inc.—When a tungsten filament is being coated with barium in a vacuum, the thermionic electron emission increases at first, reaches a maximum with a definite amount of coating, and then decreases again. The Richardson line for the maximum emission has been determined quite closely. The constants corresponding to this line are $A = 2.5$ amps/cm^2 deg^2 and $\phi = 1.66$ volts. The line was observed many times: (1) in covering a tungsten filament with barium; and (2) in uncovering it from a coating of more than that giving maximum emission. The rate of evaporation of barium from the surface increases rapidly as either the relative amount of coating or the temperature are increased. At a given temperature, the logarithm of the rate is approximately a linear function of the amount of barium. The rates for the thickness giving maximum electron emission are of the order of one billionth of values from the literature for barium in bulk. For temperatures up to 1250°K, and possibly beyond, the penetration of barium into the interior of the tungsten by diffusion is slight.

75. The voltage current relation in central cathode photo-electric cells. THORNTON C. FRY and HERBERT E. IVES, Bell Telephone Laboratories, Inc.—This paper presents a theoretical basis for the interpretation of the experimental results described in the paper which follows. It considers a source of photo-electrons located on the inner of two concentric spheres; derives the trajectory of an electron shot off at any angle with any speed; and then makes use of this information to compute the current which would be received by a small collector located anywhere on the outer sphere upon very general assumptions as to the directional distribution and velocity distribution of the photo-electrons. This theoretical study is followed by graphical presentation of results computed for several typical cases of special interest in connection with the experimental study.

76. The distribution in direction of photo-electrons from alkali metal surfaces. HERBERT E. IVES, A. R. OLPIN AND A. L. JOHNSRUD, Bell Telephone Laboratories, Inc.—An experimental study of the distribution in direction of photo-electrons emitted from alkali metal surfaces irradiated by light incident at various angles and polarized in different planes. The alkali metal surfaces used were of two sorts: (1) Liquid alloys of sodium and potassium; (2) thin films of potassium or rubidium on polished platinum. In all cases the alkali metal surface was at the center of a large spherical enclosing anode, provided either with collecting tabs at various angular positions or with an exploring finger. It is found that the emission closely obeys Lambert's law, but that the ellipse by which the emission is represented, in polar coordinates, is more elongated normally to the surface for perpendicularly incident light than for obliquely, when the direction of the electric vector is in both cases parallel to the surface, and still more elongated for obliquely incident light with the electric vector in the plane of incidence. The distribution curves are all perfectly symmetrical about the normal to the surface, showing no tendency to follow the direction of the electric vector.

77. The nature of the sensitive surface of the point in a Geiger electrical counter. L. F. CURTISS, Bureau of Standards.—The metal of the point must be in a *catalytic* condition to hold the gaseous surface layer responsible for the sensitive condition. This is shown by the following observations: 1. Points of platinum black and palladium black work as well as the usual oxidized steel or glowed platinum points. 2. *All* sensitive points are "poisoned" by the usual catalytic poisons such as mercury vapor, sulphur dioxide and hydrogen sulphide. As soon as these substances are admitted to the counting chamber the point instantly ceases to function. Only when the point is *negative* is it necessary to provide it with a sensitive surface. Any sufficiently sharp metal point will work when the point is *positive* with proper voltage. This gaseous layer therefore plays an important role in releasing the electrons from the point when negative. Two tentative explanations are proposed, one assuming an ionization of the gas layer to release the electrons after which it recombines; the other an evaporation of the gas layer with free electrons from the metal which have entered into the structures of the gas layer followed by a readsorption of the gas. Since both recombination and readsorption occur very quickly at the pressures usually used either process would restore the counter soon enough to count particles entering with any rapidity within the limitations imposed by ordinary methods of registration.

78. A close collision between an alpha-particle and a nitrogen nucleus. L. F. CURTISS, Bureau of Standards.—Approximately 83,000 α-ray tracks in air have been photographed by the method developed by Shimizu (Proc. Roy. Soc., **99**, 425 (1921)), and modified by Blackett (Proc. Roy. Soc., **102**, 294 (1922)). Many forks and bends of minor interest have been recorded. One fork involving a close collision between the α-particle and a nitrogen nucleus seems particularly important. An analysis of the photographs yields the following results: A nitrogen and not an oxygen nucleus was struck. The α-particle was deflected through an angle $\phi=110°$ with its initial direction and travelled 10.5 mm after the collision. The nitrogen nucleus traveled 4.7 mm at an angle $\theta=26\frac{1}{2}°$ to the original direction of the α-particle. From the equations developed by Darwin (Phil. Mag., **27**, 500 (1914)) one computes that at the moment of closest approach the α-particle was only $.5\times10^{-12}$ cm from the center of the nucleus. The velocity of the α-particle at the moment of impact was 1.1×10^{9} cm/sec and after the impact 8.7×10^{8} cm/sec. Although the α-particle has penetrated into the nuclear structure with sufficient energy to eject a proton there is no evidence from the photograph that this has occurred. This indicates that other factors than nearness of approach and energy of the impinging α-particle are involved in determining whether a disintegration occurs.

79. Increase in conductivity of glass under electron bombardment. W. R. HAM, M. W. WHITE AND H. R. KIEHL, Pennsylvania State College.—In a continuation of the study of the reflection of electrons from the target of a Coolidge x-ray tube (Ham and White, Phys. Rev., **27**, 510 (1926) and Ham, Phys. Rev. **29**, 908 (1927)) the effect of their impact upon the walls of the tube was examined. Upon connecting to the anode a metal coating shellacked to the outer walls of the tube, a current was found to flow through the glass during operation of the tube. This current varied in magnitude and direction as the retarding potential applied to the coating was varied, and was of such magnitude as might be expected from the potential applied and the resistance of the glass. Thermocouple measurements indicated at the same time the presence of a current to the anode along the inner surface of the glass, of greater magnitude than might be expected with the potential applied. Application of a retarding potential sufficient to prevent the reflected electrons from reaching the glass, caused this current as well as that through the glass to disappear. At this point the heat developed in the anode became equal within 0.2 percent to the energy input to the tube. The results indicate that during normal operation of the tube, the reflected electrons greatly increase the conductivity of the inner surface of the glass.

80. An application of vacuum tubes in measuring small alternating currents of any frequency. R. E. MARTIN, Lehigh University.—Four three-electrode vacuum tubes and a D'Arsonval galvanometer are connected in such a manner that, on passing an alternating current into the system, the tubes will function as a full wave rectifier and pass a direct current through the galvanometer. Calibration can be accomplished by passing either a known direct current or alternating current through the arrangement. The accuracy of the device has been checked by comparing the deflections of the galvanometer with the current as determined from observations made on a Duddel thermal galvanometer through which the same current is passed. In this manner alternating currents down to the lower limit of the current sensitivity of the D'Arsonval galvanometer have been measured. The deflection of the galvanometer has been proven to be independent of the frequency up to 3,000,000 cycles and should be for any frequency. Since the deflection of the galvanometer is a linear function of the current, very small currents can be determined very accurately. For the same reason the arrangement can be calibrated by using known currents of several milliamperes.

81. The variation of effective capacity of an air condenser due to humidity and pressure changes. George D. Rock, Catholic University of America.—The variation of effective capacity of an air condenser due to humidity change was determined by means of a heterodyne method tuning the beat note to a 1000-cycle frequency and noting balance by means of phones and a thermo-galvanometer. The condenser was placed under a bell jar and in contact with air of various degrees of dryness secured by exposure to H_2SO_4 solutions and balance restored for each case by means of a compensating condenser. Capacity change due to pressure variation was then noted and compared with that caused by humidity.

82. The positive ray analysis of ammonia. James H. Bartlett, Jr., Harvard University. The ammonia molecule has been investigated by Dempster's electromagnetic method of positive ray analysis of gas ions. Two principal ions occurred, with approximately the same intensity at low pressures. These are identified as $(NH_3)^+$ and $(NH_2)^+$, respectively. At higher pressures, secondary positive ions appeared with m/e ratios of 14, 15, and 18, which are probably $(NH)^+$, N^+ and $(NH_4)^+$, with the first the strongest and the second the weakest in intensity of the three. No negative ions and very few, if any, hydrogen ions were observed. The ionization potentials of $(NH_3)^+$ and $(NH_2)^+$ were observed to be 11.2 ± 1.5 volts and 12.0 ± 1.5 volts, respectively, these values being the means of several observations. The above results furnish evidence tending to show that in ammonia electron impact with 60-volt electrons may result either in the formation of the molecular ion $(NH_3)^+$ or in the formation of the $(NH_2)^+$ ion. The primary processes probably occurring are $NH_3 = (NH_3)^+ + \epsilon$ and NH_3 $(NH_2)^+ + H + \epsilon$.

83. Structure of the violet bands of silicon nitride. F. A. Jenkins. New York University.—The spectrum of the glow produced by the reaction of $SiCl_4$ vapor with active nitrogen has been photographed with the Harvard 21-ft. grating. The structure lines of ten bands in the violet system ascribed to SiN have been measured. As predicted by Mulliken, the band structure is that characteristic of a ${}^2S \rightarrow {}^2S$ electronic transition, since no Q branch is observed and there is one missing line between the P and R branches. The latter show a narrow doubling for higher values of m. This doubling decreases in each sequence as n increases, but shows certain irregularities; in the (1,1) band it begins abruptly at $R(12)$ and $P(14)$. Various other perturbations are found. The combination principle is applied, and from the resulting term-differences the following molecular constants are obtained: $B' = 0.7189 - 0.01045n$; $B'' = 0.7291 - 0.00594n''$. Measurements of the heads of the (2,2), (3,3), (4,4) and (5,5) bands of the isotopic systems due to $Si^{29}N$ and $Si^{30}N$ give conclusive evidence in favor of the quantum mechanics formulation of the vibrational energy as a function of $(n + \frac{1}{2})$. The observed values for the isotopic displacements of the heads differ from those calculated with half-integral numbers by -0.031 ± 0.035, whereas they differ from those calculated with integral numbers by -0.894 ± 0.112.

84. On infra-red spectra: hydrogen chloride; the methyl halides. C. F. Meyer, A. A. Levin, and W. H. Bennett, University of Michigan.—The fundamental absorption band of hydrogen chloride has been examined with narrower slits than it has been possible to use heretofore. Each line of the band hitherto observed has been separated into two lines which arise from the existence of the isotopes Cl_{35} and Cl_{37}. The wave-number separation of these lines increases in passing across the band in the direction of higher wave-numbers. A study of the spectra of the methyl halides is under way. Most of the principal regions of absorption have been located. Some of these are shown to comprise several bands. All bands which have thus far been examined in detail fall into one of two groups. One group shows well separated fine structure. There is a three-fold succession of intensity of the maxima, in accordance with the three-fold symmetry of position of the hydrogen atoms. The other group of bands has *P*, *Q*, and *R* branches. The lines are closely spaced, but those of the *P* and *R* branches have been separated in some cases.

85. Beryllium hydride band spectra. William W. Watson, University of Chicago.—With an arc between beryllium electrodes in a hydrogen atmosphere as a source, two new band groups were photographed in the first order of the 21-foot grating. One group consists of an isolated set of twelve branches in the region 4800–5120A, with a common origin at 20031 cm^{-1}. This band, which undoubtedly belongs to the $^2P_{1,2}-{}^2S$ class due to MeH molecules, exhibits some unique features: the usual doublet separation at the origin is not detected since it is probably about 0.3 cm^{-1} as for the Li atom; the series all shift markedly towards the red for $j>30$. The other spectrum stretches from λ3700 into the ultra-violet and consists of a number of bands with simple *P* and *R* branches only, degraded to the red. These bands are therefore of the $^1S-{}^1S$ type with BeH^+ as the probable emitter. The quantum analysis gives $\nu=39059+1460.5n'-14.5n'^2-2182.0n''+41.0n''^2$ as the equation for the zero-points, and $I_0'=3.85\times10^{-40}$ gm.cm^2, $I_0''=2.50\times10^{-40}$ gm.cm^2, $\alpha'=0.1360$, $\alpha''=0.3075$, r_0(final state) $=1.29\times10^{-8}$ cm.

86. Beryllium hydride bands. Max Petersen, Lehigh University.—In the spectrum of a beryllium arc run in a low pressure (5 to 15 mm) of hydrogen a strong band group is found near 5000A. Spectrograms in the second order of a 21-foot grating show that the group consists of several overlapping sets of three-branch bands, of which the earliest lines are narrow doublets. The group apparently embraces the 0,0; 1,1; 2,2; etc. parts of a band system which seems attributable to BeH. If this analysis is correct the origin of the band system is about 20032 cm^{-1}, the head of the strongest *Q* branch. As many as six *P* and *R* branches can be traced, the stronger of which show so great deviations from a parabolic wave-number formula that while the band is degraded toward the violet and the strongest *P* branch is followed to its head, the corresponding *R* branch is also found nearly to a convergence. From the earlier lines of the strongest *P* and *R* pair a moment of inertia of 3.53×10^{-40} and, assuming BeH origin, an internuclear distance of 1.54×10^{-8} cm are obtained. Precise measures of these bands are under way and it is planned to get useful plates of two other groups of bands which appear on small plates and may belong to the same system as the 20032 group.

87. Zeeman effect in the calcium hydride A band. P. S. Delaup, University of Chicago. (Introduced by William W. Watson.)—The calcium hydride A band at λ7000 was photographed in the first and second orders of the 21-foot grating with field strengths from 9000 to 23,000 gauss. At low field the $Q_1(1)$, $Q_1(2)$ and $P_1(4)$ lines were found to be split into doublets having a separation twice that of the normal Zeeman separation. This is in agreement with Van Vleck's formula for the case of loose coupling of the spin axes (Phys. Rev. **28**, 1009 (1926)). The separation was found to increase linearly with the field, at least for low and medium fields. At high fields the separation of the components becomes comparable with the distance between the lines, and accurate measurements could not be made. For high magnetic fields there seems to be a tendency for the distance between the Q_1 and Q_2 branches to contract.

88. Magnetic rotation lines in the red sodium bands. W. R. Fredrickson, University of Chicago.—The heads of the red absorption bands of sodium have been remeasured and can be represented by the formula $\nu=15006.68+(115.22n'-0.384n'^2)-(157.14n''-0.423n''^2)$. The magnetic rotation lines in this region have been photographed at high dispersion. Practically all the lines given by Wood (Astrophys. Jour. **30**, 364 (1909)) are obtained and in addition it is found that many strong lines are accompanied by weak lines close to the strong lines. The lines in all cases are very close to absorption lines. A correlation between the absorption and magnetic rotation data has been made—assigning lines to some hundred bands. The magnetic rotation lines for the n'' progressions appear to agree more closely with the n'' progression given by Loomis (Phys. Rev. **31**, 225 (1928)) for the blue-green lines than with the

n'' progression given above—showing that the green and red systems have the same final state. It is found that the bands group themselves along several parabolas of the same curvature and not along one as predicted by the Franck-Condon theory.

89. New absorption bands in nitrogen. J. J. HOPFIELD, University of California.—The absorption spectrum of pure nitrogen was observed in the gas in amounts equivalent to .06 to 19 meters at atmospheric pressure. The well known bands at λ1450 occurred strongly, and besides these two new band systems or a system of double bands (the measurements are not sufficiently accurate to decide this) also occur in absorption. Taking the latter point of view, five double bands were observed. They are in pairs:

(0,0) λ1742.4, or 7.09 volts, intensity [10], and λ1728.4 [10];
(0,1) λ1701.4 [10], and λ1688.3 [10];
(0,2) λ1666.3 [7], and λ1650.2 [7], etc.

Two prominent isolated bands occur at λ1518.8 and λ1437.2. The bands are of a diffuse nature and hardly look like bands of a diatomic molecule; neither do they fit into the scheme of nitrogen bands. They seem, however, to be due to some modification of nitrogen and may account for some of the small critical potentials observed in nitrogen at points corresponding to this region of the spectrum.

90. The excited states of the H_2 molecule. E. C. KEMBLE, Harvard University.—Recent experimental work discloses five excited states of H_2 which dissociate adiabatically into a normal H atom and a two-quantum excited H atom. The complete problem of two such atoms interacting at large distances as 16-fold degeneracy. Half of the sixteen solutions of the problem are antisymmetric in the coordinates of the electrons and according to London give purely repulsive forces between the atoms. Triplet terms should not appear in the molecular spectrum. Four of the remaining eight solutions are symmetric in the coordinates of the nuclei, and four are antisymmetric. There is one double (degenerate) state in each group, so that there should be six distinct two-quantum states in all of which only three will combine with the normal one-quantum state. One of these has yet to be discovered. The B and C states associated with the Lyman and Werner bands may be identified with fair certainty. A theoretical calculation of the expected law of force for these states is in progress.

91. Intensities of lines in the ammonia band at 2μ, and the form of the ammonia molecule E. F. BARKER, University of Michigan.—Two types of bands have been observed in ammonia, arising from vibrations parallel to and perpendicular to the symmetry axis respectively. The former sort yield the moment of inertia A about an axis normal to the line of symmetry. The latter determine the second moment of inertia C and the distance between H atoms only to within two possibilities depending upon whether the molecule is prolate ($C=(2/3)A$) or oblate ($C=2A$). Intensity computations for the band at 2μ now reveal the latter choice as the correct one. Employing transition probabilities derived by the new mechanics, relative intensities are obtained, using both prolate and oblate cases, for each of the components of the 24 observed lines. The intrinsic spins of the H nucleii must be considered, since those molecules in which all three are similarly oriented possess a perfect threefold symmetry which excludes many transitions otherwise permitted. Satisfactory agreement between observed and computed intensities is obtained only for the oblate molecule. The distance from the N atom to the plane of the three H atoms is apparently from 1/16 to 1/10 of the distance between H atoms. The double character of the 10μ band may now be explained.

92. Fine structure of the absorption bands of crystals. H. M. RANDALL AND H. H. NIELSEN, University of Michigan.—The band at 3.5μ of $CaCO_3$ has been examined by an infra-red spectrograph of high resolving power and a fine structure developed with the lines spaced about 23A apart. The first results were found in January, 1927, in the band $Mg(OH)_2$ at 2.4μ.

93. Near infra-red absorption in certain organic liquids. JAMES W. SAPPENFIELD, Ohio State University.—The near infra-red absorption spectra of the following alcohols: methyl, ethyl, n-propyl, iso-propyl, n-butyl, iso-butyl, secondary butyl, tertiary butyl and butyric acid, cyclohexanone, pyridine, and methyl acetate have been observed in the region from

0.8μ to 2.5μ with an accuracy of about $.002\mu$. Although the absorption of these substances has been studied by Weniger and others for the region between 2μ and 15μ, no previous observations have been made in the near infra-red except by Abney and Festing, who by the photographic method located approximately the bands at 0.915μ and 1.020μ. A glass prism spectrometer with a linear thermopile was used. The following table gives results for iso-butyl alcohol and tertiary butyl alcohol:

Iso-butyl: .915 1.020 1.192 1.395 1.509 1.562 1.682 1.873 1.919 1.955 2.039 2.089 2.370μ
Tert butyl: .910 1.023 1.179 1.241 1.402 1.477 1.515 1.550 1.670 1.712 1.809 1.867 2.104μ

Similar sets of values were obtained for the other substances investigated. Six of these bands can be fitted into an anharmonic series $\nu_n = \nu_0 n(1-nx)$ as was suggested by Ellis. The band at 1.5μ seems to be the harmonic of the band at 3.0μ found by Weniger in the same alcohols. The investigation is being extended to certain aldehydes, ketones and other acetates.

94. Combination frequencies in the infra-red spectrum of quartz. E. K. Plyler, University of North Carolina.—Many observers have studied the infrared absorption bands of quartz and have found regions of intense absorption at about 9μ, 12.5μ, and 20μ and 26μ. The writer has considered these regions of absorption as the fundamental frequencies for the ordinary ray of quartz. By combining the fundamental frequencies six bands in the region from 3μ to 9μ are accounted for. Two bands not previously observed have been found at 2.72μ and 3.18μ. The frequencies of these two bands correspond to two combinations of the fundamental frequencies. This gives a total of twelve absorption bands for the ordinary ray of quartz extending from 2.72μ to 26μ. The frequencies of the observed bands correspond with only small differences to the calculated values.

95. The effect of x-rays on the infra-red absorption of kunzite and hiddenite. P. L. Bayley, Lehigh University.—The range of measurement of the spectral transmission of kunzite and hiddenite, before and after exposure to x-rays, has been extended to 4.5μ to cover the entire region of transmission of the samples (0.3 to 4.5μ). Previous measurements (Phys. Rev. **29**, 353, 1927) with a glass prism showed absorption bands in radiated kunzite at 0.625, and 0.910. Hiddenite had bands at 0.625 and 1.0μ and 1.67μ. Measurements on the same samples with a rock salt prism confirm the presence of those bands and absence of the one at 1.67μ in radiated kunzite. Although both have much the same absorption from 0.45 to 1.3μ, there is little similarity beyond 1.3μ. Beyond the band at 1.67μ the transmission of hiddenite rises to a maximum at 2.1μ, drops rapidly to a low value, rises slightly at 4.0μ and decreases sharply toward zero beyond 4.4μ. Kunzite shows more absorption after radiation than before radiation but this difference decreases steadily to zero at 3.7μ. Throughout the region where there is a difference, both show the same slight absorption bands at 1.4, 1.85, 2.15, 2.5, 2.65 and 3.1μ. Beyond 3.7μ their identical values decrease rapidly, increase slightly at 4.0μ, and decrease sharply toward zero beyond 4.3μ.

96. Multiplet separations for equivalent electrons and the Röntgen doublet law. S. Goudsmit, University of Michigan.—Expressions can be derived for the separation of multiplets arising from configurations of equivalent electrons. Those explain why the Röntgen doublets obey the Sommerfeld formula, although this formula was derived formerly for one single electron only. The separations of more complicated multiplets are connected also with the Sommerfeld formula. According to Landé the multiplet separations can be characterized by factors, designated by Γ, which give the displacement of each level from the center of gravity of the whole multiple level. The properties of these Γ factors can be shown to be quite analogous to the well-known properties of the magnetic separation factors, g, introduced by Landé for the explanation of the Zeeman effect. There exist a Γ sum rule, corresponding to the well-known g sum rule, stating that, for given quantum numbers of the electrons, the sum of the Γ values belonging to a certain total moment j is a constant, independent of the type of coupling of the electrons. This rule is important especially because it makes it possible to obtain expressions for the multiplet separations in general cases.

97. The natural resonant frequencies of a quartz sphere. K. S. VAN DYKE, Wesleyan University.—By means of the piezo-electric property of quartz a number of spheres of different sizes are driven as resonators and the principal natural frequencies of the sphere determined. The cathode-ray oscillograph is used (as previously described (Phys. Rev. **31,** 302 (1928)) to make certain that the sphere is vibrating at the fundamental frequency of the driver and not at some harmonic. For the spheres used (diameters about 1 cm and 5 cm), the characteristic frequencies are found to be in the ratios 1, 1.47, 1.61, 1.83, 2.12, 2.18, 4.12, etc., where the lowest frequency corresponds to a radio wave-length of about 108 meters per mm diameter. While the elastic moduli of crystalline quartz are known for any direction in quartz, the mathematical problem of using these constants to determine the vibration frequencies for a sphere of crystalline quartz is hopelessly complex. The attempt has been made to identify the geometry of the mode of vibration by observing the Giebe and Scheibe type of glow discharge around the sphere in vacuum. The glow is characteristic of the mode and for some modes has shown nodal lines in easily recognizable patterns.

98. The force equation and some related theorems in wave mechanics. ARTHUR EDWARD RUARK, Mellon Institute, University of Pittsburgh, and Gulf Production Company.—Ehrenfest (Zeit. f. Phys., **45,** 455 (1927)) gave a generalization of Newton's force equation which holds for conservative systems in wave mechanics. Let Ψ be the wave function; Ψ^*, its complex conjugate; V, the classical potential energy function; x_n, a Cartesian coordinate of a particle of the system; $\bar{x}_n$, the corresponding coordinate of the centroid of the $\Psi\Psi^*$ distribution; m_n, the mass of the particle in question; and $d\tau$ the element of volume in the coordinate space. The generalization of Newton's law is $m_n d^2\bar{x}_n/dt^2 = \int \Psi\Psi^*(-\partial V/\partial x_n)d\tau$. A proof of this relation is presented for systems obeying the wave equation $\Delta\Psi - 8\pi^2 V\Psi/h^2 - (4\pi i/h).\ \partial\Psi/\partial t = 0$. From this relation theorems analogous to the virial theorem, and other laws of ordinary mechanics, are easily obtained.

99. On the origin of the Aurora Borealis. E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—It has been assumed by Birkland, Strömer, Vegard and others that the aurora is caused by charged particles from the sun which are diverted to the polar regions by the magnetic field of the earth. There are possible objections to this; namely, if the charged particles are α-particles or ions of some sort they do not combine a sufficient penetrating power with a sufficient magnetic deflectibility to explain the height and structure of the aurora, and if they are electrons their penetrating power may be too great. It is therefore suggested that the aurora is due to ultraviolet light of the sun which produces ions and electrons in the high atmosphere of the earth, above 200 km or so. These diffuse along the magnetic lines of force, concentrate at the magnetic poles of the earth, recombine and in some way yield up their energy to form the aurora. The aurora illumination during the strong display of August 20, 1927, was observed to be somewhat weaker than the light of the crescent moon, and from this the total energy of the aurora was estimated to be 10^{15} erg $\sec^{-1}$. This is in rough agreement with the energy of the upper spray of photo-electric ionization in the high atmosphere indicated by wireless telegraphy, according to some recent calculations.

100. Wave-length measurements in the arc and spark spectra of hafnium. WILLIAM F. MEGGERS, Bureau of Standards.—Using samples of hafnium salts presented by Professors Bohr and Hevesy, the arc and spark spectra characteristic of this element were photographed with concave-grating and quartz-prism spectrographs. Wave-length measurements were made on about 2100 lines, but 609 of these were discarded as impurities, identified mainly as columbium, zirconium, and titanium. Nearly 1500 lines remain to describe the hafnium spectra between the wave-length limits 2155.72A in the ultraviolet and 9250.27 in the infrared. In this investigation an attempt has been made to improve upon an earlier description of these spectra (1) by extending observations to shorter and to longer waves, (2) by increasing the precision of the wave-length measurements to 0.01A, and (3) by making a more critical differentiation between lines characterizing neutral atoms (Hf I) and those ascribable to ionized atoms (Hf II). Comparison of these results with the earlier measurements of zirconium spectra proves that hafnium was invariably present as an unrecognized impurity. The most sensitive Hf I and Hf II lines for spectrochemical identification are tentatively selected. The stronger Hf II lines are identified with faint Fraunhofer lines in the sun's spectrum.

101. Poisson diffraction on disks of colloidal dimensions. R. A. WETZEL AND GEORGE NEEDHAM, College of the City of New York.—In a dark field ultra-microscope we have observed images of colloidal gold, rubber latex, silver and rutile with a more or less sharp dark spot in the middle of a bright disk of light. For macroscopic objects Arkadiew (Phys. Zeit. **14**, 832 (1913)) records similar images. The effect has been photographed for silver and rutile particles as small as one-half the wave-length of yellow light.

102. The dielectric constants of silver sols when diluted with varying amounts of ethyl alcohol. GEORGE D. ROCK AND SIMON KLOSKY, Catholic University of America.—In order to determine the charge on colloid particles, it is customary to measure the velocity at which they migrate under the influence of a known difference of potential. In the formula which shows the relation between these two quantities, the dielectric constant appears. It is usual to consider the dielectric constant of the sol equal to the dielectric constant of the medium; but as this is not always true (for example, vanadium pentoxide) it was thought desirable to measure it in the case of silver sols especially in the presence of varying amounts of alcohol. The dielectric constants were then determined by means of a heterodyne method and found to be substantially equal to the dielectric constants of the dispersion media.

103. Critical potentials below 4.7 volts for negative ion formation in mercury vapor. WALTER M. NIELSEN, Duke University.—The experimental apparatus and procedure is given in another paper presented at this meeting. At higher vapor pressures, the following critical potentials below 4.7 volts were observed: .4, .8, 1.4, 1.8, 2.3, and 2.7 volts. They are believed to be due to the mercury molecule. The magnitude of such negative ion currents increases more rapidly than the first power of the vapor pressure. Only those formed at about 2.3 and 2.7 volts are measurable at low vapor pressures such as in the paper referred to above. There is evidence that the number of negative ions formed per unit electron current increases more rapidly with increase of vapor pressure for driving potentials of .4, .8, and 1.4 volts than for those formed at 2.3 and 2.7 volts and all of the atomic critical potentials discussed in the former paper. The negative ions formed at the lower voltages are especially prominent when liquid mercury is present in the tube. It is probable that critical potentials lower than .4 volt may be found as the pressure is further increased.

104. The electron wave theory of electrical conductivity. WILLIAM V. HOUSTON, Institut für Theoretische Physik, Munich.—The quantum statistical treatment of an electron gas is justified by the picture of an electron as a standing wave; consistently to use this idea in a conduction theory it is necessary to treat the interaction between the electron waves and the metallic ions as an interference phenomenon. This can be done by using the results of the work on x-ray diffraction. This treatment, in connection with Sommerfeld's work on the electron gas, gives directly the dependence of the electrical conductivity on the temperature in very close agreement with experiment. With a reasonable assumption as to the field of an ion, it is possible to compute roughly the magnitude of the conductivity, the sudden drop of conductivity and change of temperature coefficient at the melting point, the effect of pressure, the dependence of the conductivity upon direction in a single crystal, and the thermoelectromotive force in a single crystal. The advantage of this treatment, however, lies not only in the number of phenomena which it correlates, but in the fact that all the assumptions involved have already been found necessary for other purposes.

105. A discussion of the fraction of mass of a spring that is accelerated in simple harmonic motion in the case of various types of conically wound springs. O. B. ADER, Duke University. (Introduced by G. D. Collins.)—A determination of the extension of a conically wound spring under a given load in terms of the constants of the spring is necessary to the solution. The equations in Cartesian coordinates for a curve which conforms to our definition of a conically wound spring are used in this determination. Our result is, $Z=2Wa^2L^3/3\pi nb^4$ where Z is the extension under the load W, L is the length of the wire, n the modulus of rigidity, b is the radius of the wire, and a is a constant approximately equal to R/L for springs of the type treated, R being the maximum radius of the conically wound spring. (The corresponding equation for the helical spring is, $Z=2WR^2L/\pi nb^4$.) This same equation is developed by a second method from energy considerations. Now using the formula, $K.E.=\frac{1}{2}\int_0^L \dot{x}^2\rho ds$ where $\dot{x}$ is the velocity of the ith particle of the spring, ρ is the mass per unit length, and ds is an element of length measured along the wire, we can readily calculate that one-seventh of the mass of the spring enters into the equation for its kinetic energy,—as compared to one-third for the helical spring. Solutions have also been obtained for the inverted conically wound spring, truncated, inverted truncated, and double conical, each of which presents various degrees of complication.

106. The dielectric constant and electric moment of CO, CS_2, COS, and H_2S. C. T. ZAHN AND J. B. MILES, JR., Princeton University.—In view of the interest in the structure of CO with reference to its infra-red spectrum, it was thought important to obtain the electric moment of CO and associated molecules from the variation of dielectric constant with temperature as given by the Debye Equation. The improved heterodyne null method previously described, was used to measure the dielectric constants of carefully purified gases over various ranges of temperature. The results are represented very well by the Debye Equation $(\epsilon-1)vT=AT+B$, where ϵ is the dielectric constant and T the absolute temperature, and v the specific volume. The values for A are .000670(CO), .002790(CS_2), .001970(COS), .001223(H_2S); and for B .0078(CO), .089(CS_2), .352(COS), .722(H_2S). These values of B give for the electric moment in c.g.s.e.s. units$\times 10^{18}$; .10(CO), .326(CS_2), .650(COS), .931(H_2S). The moment of CS_2 indicates a different structure from that of CO_2 whose moment is probably zero. H_2S was measured in order to make a comparison with the recent work of Braunmuehl.

107. New features of the red band system of Na_2. F. W. LOOMIS AND S. W. NILE, JR. New York University.—On photographing the Na_2 absorption spectrum with a neocyanine plate it was found to terminate in a sharp edge at 12400 cm^{-1}. This represents an unusual feature of the Franck-Condon intensity distribution and is shown to be due to the fact that $\omega_0''>\omega_0'$ and $B_0''>B_0'$ but $D''<D'$, D being the heat of dissociation. B_0' and α' were estimated from Birge's semi-empirical rules that B_0/ω_0 and $2xB_0/\alpha$ are nearly constant during a transition, by comparison with the green system. The potential energy curves could then be drawn and the Franck-Condon locus of maximum intensity plotted. The calculated infra-red edge came at 12000 cm^{-1}. The same calculation shows that the red system should also have a short wave-length edge in the green, and this is apparent in the spectrum when the vapor is dense. The form of the potential energy curves shows that although $\omega_0''>\omega_0'$ and $B_0''>B_0'$, the reverse is the case when n is high, and $\omega_n''<\omega_n'$ and hence $B_n''<B_n'$. Consequently, as one proceeds away from the system origin, the R heads separate from the Q heads and the latter become prominent. Finally the bands even degrade to the violet. This accounts for the observed discrepancy between magnetic rotation and absorption data, since magnetic rotation lines should occur at R heads, but not at Q heads.

108. Voltage-intensity relations of twenty-nine lines of the mercury spectrum. PAUL B. TAYLOR, University of Pennsylvania.—Data are given for the variation in intensity with voltage of 29 lines of the mercury spectrum between 2378 and 4108A. A photographic method of measurement was used. It is to be noted from the graphs that at lower voltages the curves for members of the same series have very different slopes which increase with m number. Indeed, for low values of m the intensity may even decrease with rising voltage. At higher voltages the curves of one series approach parallelism. As the m numbers increase the distance between curves grows less approaching a limiting position corresponding to the limit of the series. Curves of the same triplet lie close together; in some cases they are identical within the precision of measurement but in other cases they are distinctly different, for example 3341 and 2894, 2803 and 2482. Athanasiu reported that 2652, 2967 and 3025 all maintained the same relative brightness under conditions quite similar to those of the present experiments. This is in disagreement with the present results.

109. Dielectric losses by a calorimetric method. G. E. Owen, University of Pennsylvania.—Small condensers of fibre, rubber and fused quartz, were put into an oscillating circuit and the dielectric losses measured by a differential calorimeter. In a vulcanized fibre condenser one centimeter square, .03 centimeter thick, with plates applied by the Schoop pistol process, the losses bear a linear relation to the frequency from 250 to 600 kilocycles: and are proportional to the voltage squared up to 50 volts. Above 50 volts the results are not consistent. At 30 volts the losses vary from .013 watts at 250 kilocycles to .021 watts at 600 kilocycles. A condenser kept at 70 percent relative humidity shows about twice as much loss as one kept for two days in a bottle containing phosphorous pentoxide. If the condenser is kept in this drying atmosphere, the losses diminish slowly for several weeks. For a condenser of soft rubber, similar results were obtained, which are consistent up to 85 volts. A clear fused quartz tube gave small but measurable losses. It will be used as a standard. The voltages were measured with an electrostatic voltmeter. A peak vacuum tube voltmeter did not seem to be independent of frequency. The work is being continued with glass, mica and celluloid.