PROCEEDINGS
OF THE
AMERICAN PHYSICAL SOCIETY

MINUTES OF THE WASHINGTON MEETING, APRIL 22–23, 1927

The 145th regular meeting of the American Physical Society was held at the National Academy of Sciences in Washington, D. C. on Friday and Saturday, April 22 and 23, 1927. 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 R. A. Millikan, Dr. E. E. Slosson, and Professor P. M. Debye.

At the regular meeting of the Council held on Friday, April 22, 1927, three were transferred from membership to fellowship and nineteen were elected to membership. *Transferred from Membership to Fellowship*: F. S. Brackett, J. J. Hopfield, and R. de L. Kronig. *Elected to Membership*: Charles S. Allen, Howard H. Brinton, C. J. Campbell, C. C. Cole, W. E. Curtis, Ralph K. Day, Milan W. Garrett, Newell S. Gingrich, Philip C. Jones, S. C. Lind, Noel C. Little, H. E. Marsh, Wm. Crawford McKissack, Jr., J. Howard McMillen, John G. Moorhead, Charles A. Rinde, Harry Rolnick, Henry Semat, and Lloyd P. Smith.

The regular program of the American Physical Society consisted of 94 papers, numbers 12, 14, 21, 35, 37, 43, 44, 46, 61, 72, 87, 88, 91, 92, 93, and 94 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. A thermo-magnetic effect on gases. NOEL C. LITTLE, Bowdoin College.—If a temperature gradient is maintained in a gas completely enclosed by a metal box placed between the poles of an electro-magnet, the isothermal surfaces in the gas are warped upon the excitation of the field, provided the field is non-uniform. That the effect varies with the nature of the gas was shown by a thermo-couple placed midway between the ends of the pole pieces where the temperature gradient was 15 degrees per centimeter. When a field of 15 kilograms was excited, drops in temperature were observed as follows: in air 16 degrees, in oxygen 18 degrees, in nitrogen and carbon dioxide none, in hydrogen 6.6 degrees, in propane 16 degrees.

2. Critical potentials of copper. RICHARD HAMER and SURAIN SINGH, University of Pittsburgh.—Critical potentials of copper have been investigated in the region up to 30 volts. The method adopted was to search for repeatedly occurring breaks in the current potential curves when a copper cylinder and insulated central copper rod suspended in a highly evacuated quartz tube were heated to about 700°C. The measurement of the potentials was made to depend on the determination by a potentiometer of the e.m.f. across a standard resistance in the same portion of the series of standard resistances as that across which the applied potentials were taken. This permits the measurement of critical potentials to be made as accurately as desired. The breaks or changes of slope were taken to indicate the critical potentials and were checked by plotting the differential curves from the observed deflections for the applied equal changes in potential. The preliminary results for copper are as follows: 3.3, 7.9, 14.2, 19.5 and 25.3 volts for the range mentioned.

3. The significance of photo-electric conduction in crystals. A. M. MacMahon, University of Chicago.—The numerous successes of the Rutherford-Bohr atom model suggest interesting possibilities which the conception may have when applied, with appropriate modifications, to the phenomena of the solid state—e. g., the conduction of electricity. An explanation of the light-sensitiveness of certain crystalline substances, particularly selenium, follows at once. Simultaneous differential equations, whose solution leads to an expression of the same form as the empirically determined one (Phys. Rev. **29**, 219 (1927)) relating the change in current through a specimen to the time of illumination, are readily obtained upon the assumption of a shift to either of two distinct configurations of the outer electrons when light is absorbed. The picture seems more plausible than those of molecular changes, proposed by previous investigators to account for the exposure and recovery characteristics of selenium, and is in agreement with x-ray analyses which show that the crystal lattice is not perceptibly disturbed even under strong illumination. An explanation of the effect of previous illumination is afforded, and the transmitted action discovered by Brown and Sieg (Phil. Mag. **28**, 497 (1914)) interpreted. This view of the conduction of electricity gives physical meaning to electrical resistance in agreement with the approach to perfect conductivity found for the metals at very low temperatures.

4. Relation between light intensity and photo-current in selenium. R. J. Piersol, Westinghouse Research Laboratory, East Pittsburgh.—This is a continuation of work previously reported (Phys. Rev. **29**, 362 (1927)) in which the variation of photo-sensitivity with temperature pointed to the theory that selenium conductivity is photo-electric. Present work on white light and ten spectral frequencies shows a linear relation within experimental error between the light intensity and the square of the photo-current. This data is shown in the form of curves for the various colors of light. The results are further substantiation of the photo-electric theory of selenium conductivity.

5. Photo-electric threshold of bismuth crystals. T. J. Parmley, Cornell University.—Single bismuth crystals were grown according to Bridgman's method. The apparatus was mounted in a bell jar and evacuated to a pressure of 10^{-6} mm. Then a razor blade as the effective edge was used to open the crystal along a plane and the specimen was moved into position in a Faraday cylinder where readings were taken, the mechanical operations being controlled by external electromagnets. The light source included a quartz mercury vapor lamp and quartz monochromator. Saturation currents were measured by means of a Dolezalek electrometer of 1500 mm per volt sensitivity connected directly to the crystal. The photo-electric threshold of a freshly prepared surface was found to lie between 2804 and 2894 A. Fatigue curves extending over approximately an hour's time were obtained.

6. Effect of oxygen on photo-electric emission from potassium. L. R. Koller, General Electric Co.—Some measurements were made to determine the effect of adsorbed oxygen on the photo-sensitivity of a potassium photo-electric cell. Sufficient oxygen was admitted to form an adsorbed layer one atom deep. This cleaned up almost at once and no change in sensitivity was observed. Oxygen was then admitted in doses of about 100 microns. There was no appreciable change in photo-sensitivity until after 355 microns had been adsorbed. The next 800 microns resulted in a three-fold increase in sensitivity. After this, each dose resulted in an immediate drop in sensitivity followed by a gradual recovery, but for each successive dose, the drop was to a new low level and the recovery less complete. The explanation of these phenomena lies in the absorption of oxygen by the potassium. Small quantities diffuse in so that no oxide is left on the surface. After the potassium is nearly saturated, the diffusion in is slowed down so that the effect on the surface can be observed. The gradual recovery takes place as the oxide diffuses in and a fresh potassium surface is formed. Eventually the potassium is all converted to oxide and the sensitivity is completely destroyed.

7. Electron emission and diffusion constants for tungsten filaments containing various oxides. S. Dushman, D. Dennison and N. B. Reynolds, General Electric Company.—In general the emission phenomena observed for these filaments are similar to those observed by I. Langmuir with tungsten containing thoria. Reduction of the oxide occurs at a very high temperature and activation at a lower temperature. None of the monatomic films produced in this manner are as stable as those obtained with thoria, owing both to more rapid diffusion and evaporation. This makes it difficult to obtain accurate emission data for completely covered films. Using the equation $I = AT^2\epsilon^{-b/T}$, the values of A and b obtained for different films are as follows:

Metal	Yt	La	Ce	Zr	U	TH
A	7.0	8.0	8.0	5.0	3.2	3.0
B	31,300	31,500	31,500	36,500	33,000	30,500

Measurements have also been made on diffusion constants (d) and rates of evaporation (E) for these films. The following table gives a summary of results obtained for 4 mil filaments at T = 2000. The values for Th are taken from Langmuir's paper.

Atom	$d\times 10^{11}$(cm^2 sec.$^{-1}$)	Heat of Diffusion	$E\times 10^9$(atoms/cm^{2}sec.)	Atomic Weight
U	1.3	100,000	>Th	238.5
Th	5.9	94,000	1.53	232
Ce	95.	83,000	1450	140.3
Zr	324	78,000	68	91.
Yt	1820	62,000		89.

8. Theory of the shot effect. Harold A. Wheeler, Johns Hopkins University.—The shot effect, described by Schottky, is the phenomenon of current fluctuations in a stream of electrons limited by random emission, as from a hot filament. Previous derivations of the magnitude of the shot effect have been based on equations derived in the abstract by the theory of probability. In the present paper, a simple derivation of the equation, $(I_0^2)_{\text{mean}} = eI_a/2RC$ (I_a = average space current), is given in terms of the familiar discharge current in a simple series circuit (R, C, L). This is followed by a Fourier integral derivation of the continuous frequency spectrum of the current fluctuations: $d(I^2)_m/d\omega = eI_a/\pi$. The simple derivation is thereby linked with former work and the correctness of the assumptions verified.

9. A study of the lag of the Kerr effect for several liquids as a function of the wave-length of the light. J. W. Beams, National Research Fellow, and Ernest O. Lawrence, National Research Fellow, Yale University.—We have shown that an upper limit to a possible lag of the Kerr effect in carbon bisulphide is 3×10^{-9}sec. However, measurable lags have recently been observed for various liquids (method described in J. O. S. A. & R. S. I., **13**, 597(1926); also paper by Beams and Allison in press). The differences between the lags of the Kerr effect for several liquids have now been investigated as a function of the wave-length of the light. The results indicate that the lag differences are independent of the light wave-length. The following are the excess lags over a possible lag in carbon bisulphide: Bromoform 3.3 10^{-9}sec: Chloroform 3.8 10^{-9}sec: Ether 6.0 10^{-9}sec.

10. The instantaneity of the photo-electric effect. Ernest O. Lawrence, National Research Fellow, and J. W. Beams, National Research Fellow, Yale University.—The grid and potassium coated plate of a three electrode photo-electric cell were attached in series with a bias battery accross one of two condensers which in turn were connected in parallel with a spark gap. The arrangement was such that when the potential across the spark gap was nearly a maximum the field between the photo-cell plate and grid was such as to draw electrons to the grid and on to the collecting electrode. A definite time after the discharge of the spark (equal to the wire path connecting photo-cell to spark gap divided by the velocity of light) the field reversed, thereby preventing electrons from leaving the plate. By varying the wire path this device permitted a study of the times of ejection of electrons by short flashes of light from the spark, produced by an earlier described method. Our experiments indicate that electrons start coming off a potassium surface the instant light falls on the surface and cease being emitted the moment the illumination is cut off, within a possible experimental error of 3×10^{-9}sec.

11. Polarization of resonance radiation in strong magnetic fields. Breadth of spectral lines. A. Ellett, University of Iowa.—The polarization of resonance radiation excited by the D lines has been measured for various states of polarization of the exciting light and for magnetic fields up to 3500 gauss. With the electric vector of the exciting light parallel to the magnetic field the polarization reaches a value of 49 ± 1 percent in a field of 500 to 600 gausses and does not change with further increase of the field. With the electric vector perpendicular to the field the polarization reaches a value of $32.8\pm.5$ percent at 500 gauss and remains constant to 1200 to 2000 gauss depending on the breadth of the exciting line. This line breadth may be made so small that first one and then both of the perpendicular components of D_2 fall outside the exciting line. D_2 excited by the inner perpendicular component alone is completely polarized. From the magnitude of the fields at which these components cease to be excited it is evident that the line breadth is about what one expects from Deppler shift alone, though it may exceed this slightly.

12. The magnetic moment of helium and molecular hydrogen. Irvin H. Solt, University of Cincinnati.—A narrow beam of molecules or atoms was produced by means of two slits, $.03\times2.2$ mm, three centimeters apart. The space between the slits was connected to a mercury vapor pump. The beam passed through a non-homogeneous magnetic field produced by a pair of pole pieces, one wedge shaped and the other slotted, after the manner of Stern and Gerlach. The beam was explored by a platinum wire .017 mm in diameter and 2.5 mm long which formed one arm of a Wheatstone bridge. No influence of the magnetic field on the beam was observed for a gradient of about 1.5×10^5 gauss per cm. The experiments are being continued with a view toward increasing the sensitivity of the apparatus so that other gases can be investigated.

13. The magnetic moment of atomic iodine. John B. Taylor and T. E. Phipps, University of Illinois.—The magnetic properties of atomic iodine have been investigated in an apparatus which is a modification of that used by the authors in the determination of the magnetic moment of the hydrogen atom. The iodine was dissociated in an electrically heated tiny quartz tube furnace and the ray of atoms received on a liquid air cooled glass target, which had been first coated with a thin film of mercury. This was a very sensitive detector. A multiple separation of the ray in a magnetic field, corresponding to a magnetic moment of two, has been predicted spectroscopically for the iodine atom. The rather imperfect images thus far obtained show a distinct deflection of the ray, and apparently such a multiple separation into more than two lines corresponding to a magnetic moment greater than one. This latter point and the relative intensities of the lines cannot yet be decided with certainty.

14. Method of measuring the distribution of magnetic fields. J. Tykocinski-Tykociner and J. Kunz, University of Illinois.—The following method has been developed for the determination of field inhomogeneity between pole pieces as used in the magnetic moment measurements of atomic rays. Two bronze ribbons carrying a mirror and stretched on a frame move between the poles of an electromagnet whose field distribution in the air gap has to be determined. By means of two micrometer screws the frame can be moved either along or across the field. From the deflection of the mirror produced by direct currents passing through one of the wires and then through the other and then through both of them the magnetic field intensity and its gradient can be determined from point to point. Satisfactory results were obtained when currents of equal intensity flow through both wires simultaneously. For a current i_1, flowing through both wires in the same direction the angular deflection is tan $\alpha_1/2=c(H_2-H_1)i_1/d$ for a current i_2 flowing in opposite direction tan $\alpha_2/2=c(H_2+H_1)i_2/d$ where H_1 and H_2 are the magnetic field intensities, c is a constant and d the distance between the wires. For small angles α the following relations are obtained $H_1=d(a_1/i_1+a_2/i_2)/4cD$ $H_2=d(a_1/i_1-a_2/i_2)/4cD$ and $\partial H/\partial x=(H_2-H_1)/d=a_1/2ci_1D$, where D is the distance between the scale and mirror, and a_1, a_2 are the scale readings corresponding to the angles α_1 and α_2.

15. The origin of the magnetic fields of sun spots. W. F. G. SWANN, Yale University.—Recently the writer has developed a modification of the laws of electrodynamics according to which among other things, a neutral rotating sphere should give rise to a magnetic field which at the pole is proportional to Dv^4 where D is the density and v the peripheral velocity. A sun spot is usually regarded as a U-shaped structure with appreciable rotation confined to a depth of the photosphere comparable with the diameter of the spot. As regards order of magnitude we should thus expect that the magnetic field of a sun spot would be comparable with that of a sphere rotating with the same peripheral velocity. According to this, if subscript s refers to the sun spot and e to the earth $H_s/H_e=(D_sv_s^4)/(D_ev_e^4)$. Taking H_e as 0.5 for the poles, $D_e=5.5$, $v_e=0.5$ kilometer per second, $D_s=4\times10^{-5}$, we find that the value of v_s necessary to account for a value of H_s equal to 2000 gauss is 80 kilometers per second. This value is not unreasonable for a sun spot. On applying the theory to the planet Jupiter we calculate a magnetic field of the order 50,000 gauss for that planet.

16. Magnetic susceptibility of single-crystal metals. C. NUSBAUM, Case School of Applied Science.—The magnetic susceptibility of single-crystals of bismuth and antimony has been measured by a modified form of Terry torsion balance. The single-crystals of these metals are characterized by a three-fold axis of rotational symmetry, with the cleavage planes perpendicular to the principal axis. The crystals are rotated around an axis perpendicular to the principal axis of the crystal. The mass susceptibility (x) for bismuth in a direction parallel to the principal axis is 1.13×10^{-6} and in a perpendicular direction 1.32×10^{-6} dyne-cms. Corresponding values for antimony are 0.497×10^{-6} and 1.38×10^{-6}, respectively.

17. Results of earth-resistivity surveys in connection with the study of earth-currents at Watheroo, Western Australia and Ebro, Spain. W. J. ROONEY and O. H. GISH, Department of Terrestrial Magnetism, Carnegie Institution of Washington.—To supplement the potential registrations and so ascertain the earth-current density, earth-resistivity surveys have been made at the Magnetic Observatory of the Carnegie Institution of Washington, Watheroo, Western Australia, and at Ebro Observatory, Tortosa, Spain. At Watheroo, situated on a sandy plain, the resistivity at the surface varies with position from 90 to more than 4,000,000 ohms per centimeter cube. The mean values for the region are extremely low, the average to depths of 60 to 100 meters being 700. Beyond this depth the values increase slowly, reaching 5,000 for 600-meter depths, the greatest explored. At the Ebro Observatory, located in the valley of the river Ebro the resistivity, although generally low near the surface, is always higher than that at Watheroo when depths beyond 30 meters are included in the measurements. The average value to 100-meter depths is 9,600 and increases to a little over 12,000 for 300 meter depths, the greatest explored there. Records of potential gradient for a number of years give values approximately one magnitude higher at Ebro than at Watheroo. The resistivity results, therefore, indicate that the current density is of about the same magnitude at both places.

18. The Hall effect and resistance of sputtered tellurium films. F. W. WARBURTON, Cornell University.—According to Eldridge and Page the Hall coefficient should be proportional to resistance, but Mackeown's experiments with thin films have shown that the Hall e.m.f. remains constant when the resistance changes by aging. The present experiment was undertaken to find the relation of the Hall coefficient to resistance when the latter is changed by temperature or by means other than aging. Preliminary results show that the Hall e.m.f. in very thin films of tellurium is directly proportional to resistance, both when the temperature coefficient of resistance is positive, as well as when it is negative but is independent of change in resistance due to absorbed gas.

19. Magnetic properties of iron in high frequency alternating current fields. John R. Martin, Case School of Applied Science.—A number of investigators have studied the losses due to eddy currents and hysteresis in iron when placed in high frequency alternating current fields, but the results obtained are in wide disagreement. Using a new method, the author has investigated the variation of this loss with the frequency for several areas of cross section. The total loss is considered as the equivalent of an absorbing resistance and by measuring the value of this resistance at resonance, the loss may be determined from the I^2R relation. With magnetizing currents of 3, 4 and 5 ampere-turns per cm, the measurements are made on short iron cylinders of various cross sectional areas, at frequencies ranging from 5.20×10^6 to 9.08×10^6 cycles per second. The loss is found to increase with frequency in the small samples and to decrease with frequency in the larger. At any particular frequency the loss is an inverse function of the area. This is due to the magnetic shielding effect of eddy currents in the large samples and the disagreement between previous investigations may thus be explained.

20. On refraction in moving media. N. Galli-Shohat, University of Michigan.—For light passing from vacuum to a moving medium it is customary to construct a "relative ray" with the help of Fresnel's drag coefficient $(1-1/n^2)$. If one applies Fermat's principle both to this ray and to the wave normal, it may be shown that only one of them obeys Snell's Law. The variation of one path affects the other in such a way that it would be necessary to neglect first order terms in v/c in order to preserve Fresnel's form of the drag coefficient. It is possible however to preserve Snell's law for both rays by a modification of the drag coefficient so that it depends on the angle of incidence and assumes the customary form for normal incidence.

21. The theory of the magnetic nature of gravity and electrons. Cornelio L. Sagui, Castelnuovo dei Sabbioni, Italy.—In a preceding paper Balmer's series were derived from equation $(x^2+x)/2=y$ and other possibilities as to their behavior were investigated. The attempt is made to give a physical meaning to those mathematical results by considering the structure of an atom as an assembly of protons and electrons. Electrons are considered as an assembly of a large number of electromagnetic quanta and reasons are given for their negative electric charge. Again, a proton would result from an assembly of electrons and its positive charge is considered as due to a symmetrical difference in its structure, resulting in the opposite to an electron. The Einstein's equation $eV=h\nu$ was considered in the light of the theory and frequencies ν were supposed to be due to the splitting up of the electrons themselves into smaller units of energy. The effect would be wholly a mechanical one. The atomic fluorescent absorption, the Compton effect, the phenomena of absorption of light by atoms and their reradiation, as well as the Brownian movements are all investigated from the point of view of the electromagnetic quantum theory.

22. Ionization by collisions of the second kind in mixtures of hydrogen and nitrogen with the rare gases, Gaylord P. Harnwell, Princeton University.—The behavior of ionized mixtures of hydrogen and of nitrogen with helium, neon, and argon separately have been investigated by means of a positive ray analysis. (See abstract No. 24, New York Meeting, Feb. 26, 1927.) Due to the secondary products of ionization the variation with pressure of the types of ions present was found to be more complicated than in the rare gas mixtures previously studied. However, in all cases so far investigated the results are in agreement with those predicted on the basis of a type of collision of the second kind resulting in ionization of atoms by collisions with ions of atoms of higher ionizing potentials. These processes are represented by the following equations:

$$\begin{array}{ll} He^{+}+H_2=He+H_2^{+} & He^{+}+N_2=He+N_2^{+} \\ Ne^{+}+H_2=Ne+H_2^{+} & Ne^{+}+N_2=Ne+{}^{17}N_2^{+} \\ & Ne+{}^{24}N_2^{+}=Ne^{+}+N_2 \\ A\ +H_2^{+}=A^{+}+H_2 & A\ +N_2^{+}=A^{+}+N_2 \end{array}$$

In these cases as in pure rare gas mixtures the interchange was found to be most probable when the difference between the ionizing potentials was least.

23. The dissociation of hydrogen chloride by positive ion impact. WALTER M. NIELSEN, Duke University.—Positive ions from a heated sodium phosphate source were projected between two electrodes, P_1 and P_2, towards a third electrode, P_3. The hydrogen chloride, fed into the tube through a fine capillary, was generated by dropping H_2SO_4 onto NaCl. With a mean free path of about 2cms, and with a potential on P_1 such as to prevent positive ions from reaching it, and with a small drawing out potential for positive ions on P_2 and P_3, currents were measured for increasing values of the driving potential, V_F. No negative current to P_1 was observed below 34 volts. Above this value of the driving potential the ratio of negative current to total positive ion current increased rapidly with increase in the driving potential. The positive currents were of the order of 1×10^{-9}amperes, the negative of the order of 2×10^{-10}amperes. A magnetic field of about 500 gauss was applied so as to prevent secondary electrons from leaving any of the accelerating or collecting electrodes. The driving potential at which a negative current is first observed is lowered by an increase in the drawing out potential of P_2 and P_3, but is not affected by an increase in the retarding potential of P_1. The experiment does not indicate the products of dissociation.

24. Combination of hydrogen and oxygen by electric discharges and x-rays. ROGERS D. RUSK, North Central College.—A study has been made of the combination of hydrogen and oxygen in the Geissler tube discharge, low-voltage arc, electrodeless discharge and by exposure to x-rays. Rates of combination were measured at pressures varying from 1mm to .01mm and with different proportions of the gases. In the low-voltage arc, the rate of combination per milliampere of arc current was abnormally small after making due allowance for the catalytic action of the coated platinum filament, which set in quite regularly with the filaments used at 65°C (thermocouple measurement.) This suggests that in the low-voltage arc combination occurs mostly at or near the cathode. The logarithmic decrease in rates of combination in the other cases indicates that combination is a matter of gaseous collision. The results agree with the notion that combination is proportional to number of ions present, and in the Geissler tube discharge approximately 0.12 molecules of water per ion were formed at a pressure of .1mm in equivalent volumes.

25. The dissociation of hydrogen by electrons. A. L. HUGHES and A. M. SKELLETT, Washington University.—The dissociation of hydrogen, through which electrons are driven, may be the direct result of a collision between an electron and a hydrogen molecule, or it may be due to a secondary process, in which the dissociation actually results from a collision between a neutral hydrogen molecule and an ionized (or excited) molecule which itself had been produced by an electron impact. At sufficiently low pressures, the number of molecules dissociated should be proportional to the pressure if the effect be a direct one, but proportional to the square of the pressure if the effect be a secondary effect. Using the yield of dissociated hydrogen molecules at different pressures as a criterion, the experiments are decisively against the effect as being a secondary effect. Investigation shows that if the mean free path of the ionized (or excited) molecule be abnormally small, the above criterion may not be able to distinguish between the two possible processes at pressures available. Provided that the mean free path is not less than one three hundredth of that of the normal molecule, these experiments are decisively against the interpretation that dissociation is a secondary process.

26. Some observations on the nature of the nitrogen afterglow. A. G. WORTHING, Nela Research Laboratory and University of Pittsburgh.—Three 6-inch spherical glass bulbs symmetrically joined by large glass tubing were filled with nitrogen (1 to 5mm). Discharges in one bulb caused sudden visible streamings to the other bulbs. After the filling of the bulbs, the afterglow stream, which was produced by a single impulsive discharge, was completely stopped near the exit. It formed an umbrella-shaped luminous cloud which was many times as bright as the afterglow elsewhere in the bulb. After many discharges, the resistance to the passage of the afterglow broke down, and the afterglow carriers seemed to pass unhindered to the other bulbs. The most probable explanation suggests either that the afterglow carriers or that some of the agents active in the production of these carriers are electrically charged.

Some experiments with a tube (approximately 200mm of A, 0.4 mm of N_2) seem to indicate that this effect is limited to the early stages following a discharge. These observations do not seem to support the view that the afterglow has its origin in impacts of neutral unexcited nitrogen atoms and molecules.

27. The scattering of electrons by a nickel crystal. C. DAVISSON and L. H. GERMER, Bell Telephone Laboratories, Inc.—In bombarding a $\{111\}$ surface of a single crystal of nickel with a beam of electrons of uniform speed it has been found that, for certain definite bombarding speeds, there are beams of scattered electrons leaving the crystal in perfectly sharp directions. A simple correlation between these directions and the directions taken by diffracted beams of x-rays can be stated as follows. If the known crystal structure of nickel were contracted by a factor of 0.7 in a direction parallel to the incident beam then among all the diffracted x-ray beams those ten sets of beams which correspond to the longest x-ray wave-lengths would coincide in position with ten observed sets of electron beams. The wave-lengths of the wave disturbances which could give rise to these beams are quite accurately given by $\lambda = h/mv$, in accordance with the wave mechanics. In addition to these ten sets of electron beams there are three other such sets for electrons below 200 volts. These three sets seem not to observe the symmetry required by the known structure of the nickel crystal, and they offer strong evidence that there exists in this crystal a structure which has not been hitherto observed for nickel.

28. O- and N-energy levels in the secondary emission of hot tungsten. HERMANN E. KREFFT, General Electric Company, Nela Park.—While critical potentials found by Richardson and Chalklin in the soft x-radiation of tungsten agree fairly with computations of its O and N-energy levels from x-ray data, there does not seem to be such a relation between these levels and breaks found by Petry on the secondary emission curve. If, however, the secondary emission is measured with the tungsten at about 1200° K, a number of breaks are easily obtained at primary velocities of $v_p = 5$ to 750 volts on the curve showing the number of secondary electrons per primary as a function of v_p. The electrode arrangement is similar to the one described by Petry. A very considerable break occurs at a primary velocity of 70.5 volts (corrected), this one also being the most prominent break above 25 volts. With cold tungsten only a slight indication of this break is obtained. This break is undoubtedly due to the O_I-level of the tungsten atom, the value 70.5 volts, or $\nu/R = 5.2$, being in excellent agreement with the value given by Bohr and Coster. The greater part of the other breaks agree well with measurements of Richardson and Chalklin and with the values for the N_I, N_{II} and N_{III} levels computed by Nishina. The secondary emission of other metals near tungsten will have to be studied before a definite interpretation of these breaks can be made. This work is being continued.

29. Reflection of electrons from molybdenum. W. R. HAM, Pennsylvania State College.—The apparatus in use consists of: (1) a source of steady direct current; (2) water-cooled Coolidge tubes with molybdenum anti-cathodes; (3) a constant flow calorimeter for measuring the heat developed at the anti-cathode; (4) a method of applying retarding potentials varying from zero to full impressed p.d. to the outside surface of the glass of the tube, while the tube is being run at a particular impressed voltage. (1000–22,000 volts). Since the power input, the heat generated at the anti-cathode, and the velocity distribution of reflected electrons are all measured, the percent of reflected electrons relative to incident electrons may be plotted against velocity of reflected electrons. A large percentage of reflection occurs at velocity corresponding approximately to 2900 volts. Peaks of reflection seem to occur as the impressed p.d. passes the critical potentials for the L levels and also probably the K level of molybdenum. The total number reflected is in general more than 100 percent of the incident electrons but much the larger part of this number have relatively slow velocities. Different tubes behave much alike and there is little evidence that residual gas has any effect on the results.

30. Velocity distribution and 180° scattering of low velocity electrons from iron. H. E. FARNSWORTH, Brown University.—The curve expressing ratio of secondary to primary electron current as a function of accelerating potential for both iron and copper show prominent maxima and minima in the low velocity region. If these are due to atomic inelastic collisions one might expect to find evidence of this from a measure of the velocity distribution of the secondary electrons. Such measurements for iron show no evidence of inelastic collisions. These results, together with the fact that the above mentioned maxima and minima are obtained only after heating the metal at a critical temperature, are interpreted to mean that sudden changes in slope in the low velocity region of the secondary electron curve for metals are not an atomic phenomenon but are characteristic of the arrangement of atoms at the surface. The apparatus was such that those electrons leaving the iron target nearly normally, fell on an insulated disk concentric with the primary beam thus giving a measure of the fraction leaving approximately normally. This fraction, for primary velocities of a few volts, is much greater than that to be expected from the cosine distribution law, and decreases rapidly with increasing primary velocity to about 30 volts. Observations subsequent to baking the target at 350° C but previous to heating at red heat did not show this distribution.

31. A theory of the normal cathode fall. K. T. Compton and P. M. Morse, Princeton University.—Use is made of the experimental value of the cathode fall of potential V_n and Townsend's empirical equation for the number of ionizing collisions α per unit path by an electron, together with the principle that the potential drop is distributed throughout the fall space so as to give maximum current. Thence is deduced the law $pd_n=A$ for the product of the pressure p and cathode fall space d_n, and acceptable values of the constant A are calculated for various gases. Certain dependence of d_n on cathode material is predicted, in conformity with observations. Distribution of ionization throughout the fall space is also calculated, and the results prove that a cathode in an ionized gas must be a much more copious emitter of electrons under positive ion bombardment than is a degassed metal. Introduction if Poisson's equation leads to the known law for normal current density $(j/p)^{1/2}=B$, and gives values of B which are approximately correct. At several points second order corrections are neglected, and the boundary conditions are not very satisfactorily known. Yet the theory seems to be distinctly promising in this field, in which there has been no previous tenable theory.

32. Heats of condensation of electrons and positive ions on molybdenum. C. C. Van Voorhis and K. T. Compton, Princeton University.—A small molybdenum sphere was supported in a region of intense gas ionization by three fine wires, two of which formed a thermocouple to measure its temperature, while the third carried the current of the incoming ions. Space potential and mean electronic energies $\bar{\mathrm{V}}$ were found by using the sphere as an exploring electrode. Its rate of heating due to an increment Δi in the electron current reaching it against a small retarding field was measured and equated to $\Delta i(\bar{\mathrm{V}}+\phi)$, whence the heat of electron condensation ϕ was found to be 4.76 volts in argon; 4.77 or 5.01 volts in nitrogen; and 4.04 or 4.35 volts in hydrogen. The double values follow different treatments of the surface. The probable error of measurement is less than 1 percent, but uncertainty regarding the specific heat of molybdenum causes some uncertainty in the absolute values. Similar measurements of the heating effect of a positive ion of argon gave about one volt, which indicates that less than half of the energy of neutralization of the gas ion at the surface, is absorbed by the metal. ϕ_- and ϕ_+ are involved in the theory of gas discharges. Incidentally, confirmatory evidence was found for Langmuir's "high speed electrons."

33. The method of least squares vs. the arithmetic method of obtaining the slope of a straight line. R. C. Spencer, Westinghouse Lamp Company, Bloomfield, N. J.—This discussion applies particularly to the case where the abscissas are spaced equidistantly. To illustrate: Let $t_1, t_2, \cdots, t_r, \cdots, t_s, \cdots, t_N$ be the times of N transits of a torsion pendulum. Let the difference, $(t_r-t_s)=T(r-s)$, have a weight of unity. Then the period, $T=(t_r-t_s)/(r-s)$, will have a weight of $(r-s)^2$ because the error in (t_r-t_s) has been divided by $(r-s)$. In general we will use only n observations, discarding the inner ones. The weight of the period as calculated by the method of least squares is $(N-1)^2+(N-3)^2+(N-5)^2\cdots$ to $\frac{1}{2}n$ terms. The weight of the arithmetic solution is $\frac{1}{2}n(N-\frac{1}{2}n)$. The arithmetic method has a maximum weight when the inner third of the observations are discarded. Tables are given comparing the two methods.

The arithmetic method can be used on a standard motor driven calculating machine by pressing the numbers 1, 2, 3 etc. up to $n/2$ and down again to 0. The sum will give the period, T, in fifths of seconds times $\frac{1}{2}n(N-\frac{1}{2}n)$. A mechanical spring model is described. The potential energy at equilibrium is a minimum, and is proportional to the sum of the squares of the spring displacements. Therefore, the equilibrium position gives the least square solution of the system.

34, Log, semi-log, and uniform coördinator. II. R. A. Castleman, Jr., Bureau of Standards.—A log, semi-log, and uniform *coördinator*, (a combination of plotting instrument and computing instrument) has been designed with special reference to its usefulness in the physics or physical engineering laboratory. The device employs a drawing board, a T-square, two slide rules and certain machined accessories. One rule is attached along one edge of the drawing board, while the other is attached to the T-square, whose shoe is arranged to bear on a straight-edge of the former slide-rule. Indices attached to the T-square and a suitable slider make possible: (a) coordination of the three kinds mentioned above; (b) quick and easy change from plotting to computing; (c) quick and easy change from one side of the T-square blade to the other. Each rule carries three sizes of log and one of uniform scales, thus furnishing practically all needed combinations. The use of a somewhat similar device in the special cases of power and exponential-finding has been pointed out in previous articles.

35. Shielding from vibrations. R. C. Hartsough, Western Electric Company, Inc.—The shielding of sensitive apparatus from vibration by the use of thin inflated rubber bags has been found to approach 100 percent. Three bags are generally used and interconnected so that they all have exactly the same pressure. A pressure of 50cm of water and approximately four pounds mass on each bag gave perfect shielding for all ordinary vibrations. An interferometer mounted on a quartz fibre was shielded so effectively that the fringe system was quiet, even with persons walking in the room.

36. A redetermination of the Newtonian constant of gravitation. Paul R. Heyl, Bureau of Standards.—The present accepted value of the Newtonian constant of gravitation rests upon the independent work of Boys and Braun done thirty years ago. It is 6.66×10^{-8}, with an uncertainty of one unit in the third significant figure. About three years ago the Bureau of Standards undertook a redetermination of this constant with the object of obtaining another decimal place. The results so far obtained confirm the present accepted value and add the desired figure 6.664. The method was that of a torsion pendulum in a vacuum, as used by Braun.

37. A resonance method for the determination of the universal constant of gravitation. Jacob Kunz, University of Illinois.—Two comparatively large spheres placed on a table are made to carry out undamped simple harmonic motion. Between these spheres there are suspended two small spheres, connected by a light bar, in a vacuum. The harmonic motion of the outer spheres induce forced oscillations of the inner spheres, which become large when their natural frequency coincides with the impressed frequency. The differential equation of the motion has been developed. It is much more complicated than the classical differential equation of resonance. The present differential equation has been solved by a method of successive approximations.

38. Variation of gold plated screw-knob weights with atmospheric humidity. A. T. Pienkowsky and E. S. Fowle, Bureau of Standards.—Many gold plated weights of the common screw-knob type have been found to change by excessive amounts with changes in the humidity of the air. Measurements were made on the sum of the weights from 1 gram to 50 grams inclusive, from each set. When the relative humidity changed from 30 percent to 70 percent, the worst set yet noted changed nearly 3 mg in 8 days, and was still gaining rapidly. When the humidity was lowered to 30 percent again, these weights promptly returned to their original value. In the 18 sets first tested, more than half the sets changed more than 0.5 mg for the same conditions, while about 0.1 to 0.2 mg seems to be the smallest change that occurs with such sets. These weights were from both American and foreign makers. Several variable sets were boiled in water with the knobs out and with the adjusting material removed so far as practicable. The variations then dropped to about 0.2 mg. Weighings were made without removing the sets from a box in which the humidity was controlled, but the standards and balance were outside this box, and therefore not affected by the changes in humidity.

39. Thermal expansion of some nickel steels. Peter Hidnert and W. T. Sweeney, Bureau of Standards.—Data on the linear thermal expansion of some nickel steels containing from 36 to 42 percent nickel, have recently been obtained for various temperature ranges between room temperature and 500°C. The expansion curve of each steel showed a critical point by an abrupt increase in the rate of expansion. The nickel steels containing from 38.4 to 42.2 percent nickel expand less than invar for the temperature range from 20° to 500°C. Additional alloys having a greater range of coefficients are being tested. The following table gives a comparison of the results obtained.

		Average Coefficient of Expansion per Degree Centigrade	
Nickel Content Per cent	Critical Point °C	20° C to Critical Point $\times 10^{-6}$	Critical Point to 500° C $\times 10^{-6}$
36.4	260	3.1	14.4
36.9	260	3.3	14.7
38.4	300	3.5	14.4
41.0	340	5.1	14.2
42.2	340	5.5	13.6

40. The resolving power of the ears. Arthur Lowell Bennett, Union College. (Introduced by P. I. Wold.)—The resolving power of the ears will be defined for use here as the shortest time interval between two successive sound impulses, the first occurring in one ear and the second in the other, for which interval the observer can distinguish in which ear the first impulse occurred. When the interval becomes quite small the sounds merge into each other but, through the binaural sense, one is still made aware of the difference in time of arrival. A rotating disc with two brush contactors, one of which could be displaced angularly, made it possible to send two impulses separated by a small time interval measurable to a hundred thousandth of a second. Data taken on eleven observers show that every observer was able to distinguish with certainty at one one-thousandth of a second and that the limit for the average observer is one tenth of this or less. One exceptional observer was found whose limit was less than one millionth of a second.

41. The surface tensions of the molten elements as functions of the temperature. I. Copper. E. E. Libman, National Research Fellow, University of Illinois.—Copper is melted in a square box with a capillary side tube by means of a high vacuum, water cooled, molybdenum wound furnace of special design. The temperature is measured by means of the resistance of the molybdenum furnace winding. An x-ray photograph is taken through the entire furnace and the capillary depression and depression of the surface at the walls of the square box is measured on the photographic films. This gives two observations for the two unknowns, surface tension and angle of contact. The method, as usual, gives not the surface tension directly but the capillary constant" (twice the surface tension divided by the product of the density of the molten material and the acceleration of gravity) from which the surface tension can be obtained when the density of the molten material is known. In this way the capillary constants of copper have been determined over a range of temperature from the melting point 1083°C to about 1400°C, and the error is estimated not to exceed 2 percent. The capillary constant of copper at its melting point is .301 cm^2 and decreases linearly with rise in temperature to .269 cm^2 at 1375°C.

42. Variation of surface tension of oils with the temperature. George Winchester, Rutgers University.—The surface tension of several high flash point oils has been measured at temperatures up to 550°F during the last two or three years by the maximum bubble pressure method. The densities of the oils were linear functions of the temperature up to 450°F. Between 300° and 550°F Mendelejeff's equation for an ideal liquid is verified within the limits of experimental error, estimated at about 0.4 of a dyne. Below 300°F the surface tension decreases faster than the temperature rises. The critical temperature is calculated from the formula, $T=a-bt$.

43. Influence of electrolytic ions upon moisture of steam. (Analogue of Wilson cloud experiment.) Arthur W. Ewell, Worcester Polytechnic Institute.—Bubbles of vapor, breaking at the free surface of a liquid, inevitably throw some liquid into the vapor space and, if the vapor is continuously drawn away, some of this liquid will accompany the vapor—a phenomena known technically as "priming." An apparatus was designed, which permitted quite accurate measurements of the priming of pure water, and of various solutions. It was found that priming increases with the density and viscosity of the solution, and decreases with the number of electrolytic ions present. The addition to water of such a salt as sodium or potassium chloride, which highly dissociates, and increases the density and viscosity but little, reduces the priming. As gaseous ions in a vapor facilitate the formation of liquid bubbles, so electrolytic ions in a liquid (probably by reduction of surface tension) facilitate the formation of vapor bubbles, and thus produce quieter boiling and less priming. Slightly dissociated salts, such as lead acetate, increase the priming on account of the large increase which they produce in the density, and solutes showing no dissociation, such as cane sugar, increase the priming still more.

44. Relations in connection with the reversible mixing of substances in the condensed state at the absolute zero of temperature. R. D. Kleeman, Union College.—The properties of the quantities associated with the reversible mixing of substances in the condensed state, initially under the pressure of their vapors at the absolute zero of temperature, have been investigated on the basis of the theoretical results previously communicated (Phys. Rev. **29**, 369 (1927)). It is shown that: $H_m=0$, $(\partial H_m/\partial T)_v=0$, $(\partial^2 H_m/\partial T^2)_v=0$, $(\partial H_m/\partial T)_p=0$, $(\partial^2 H_m/\partial T^2)_p=0$, $dH_m/dT=0$, $d^2H_m/dT^2=0$, $p_m=0$, $(\partial p_m/\partial T)_v=0$, $(\partial^2 p_m/\partial T^2)_v=0$, $(\partial p_m/\partial T)_p=0$, $(\partial^2 p_m/\partial T^2)_p=0$, $dp_m/dT=0$, $d^2p_m/dT^2=0$, $A=0$, $(\partial A/\partial T)_v=0$, $(\partial^2 A/\partial T^2)_v=0$, $(\partial A/\partial T)_p=0$, $(\partial^2 A/\partial T^2)_p=0$, $dA/dT=0$, $d^2A/dT^2=0$, where H_m denotes the heat absorbed during the process of mixing the substances, A the external work done, p_m the increase in internal energy, p the pressure, v the volume, and T the absolute temperature. A total differential coefficient indicates that the substances are kept under the pressures of their vapors during a change in temperature. Accordingly the mixing of substances, including different forms of the same substance, is under these conditions not attended by a change in entropy and internal energy. The formulas: $T\Delta S=H_m=p_m+A=\Delta U+A$, $\Delta U=T(\partial A/\partial T)_v-A$, $\Delta U=T(\partial A/\partial T)_p-A$, $\Delta U=T(dA/dT)-A$, it can then be shown, hold for all temperatures, where S denotes the *controllable* entropy and U the *controllable* internal energy.

45. The vacuum tube oscillator. D. G. Bourgin, Lehigh University.—The functional dependence of total filament emitted current on grid and plate voltages is formally approximated by $i_p+i_g=A[1-\exp\{-(E_p+\mu E_g)^2\}]$ for $E_p+\mu E_g>0$ where A is the saturation value of the current and the other symbols are standard notation. (The approximation may be improved by considering this to be the initial term in an expansion in terms of Hermite polynomials). This relation is made the basis for the "second order" treatment of the Hartley oscillator. By applying Kirchoff's laws to the equivalent network, three simultaneous differential equations of the third order are derived connecting the variable grid and plate voltages and currents, and the current in the oscillatory circuit. These equations are restricted to the case that the phase difference between E_p and E_g is closely 180° and that the general conditions for efficiency indicated by Prince are satisfied. Only the fundamental is considered. By tabulating the values of the Fourier series coefficient for the fundamental in the expansion of $\exp\{-(a+b\sin x)^2\}$ it becomes possible to use a combined analytical and graphical method to determine the amplitudes, phase relationships and fundamental frequency. The approximation for the grid current is, as yet, not wholly satisfactory.

46. A device to draw characteristic curves of vacuum tubes automatically. G. C. Campbell and G. W. Willard, University of Minnesota.—The usual circuit for obtaining characteristic curves was used. The grid-potential was varied continuously throughout the desired range by a modified W. G. Pye drum rheostat of the potentiometer type driven by a synchronous motor through speed reducing gears. A Leeds & Northrup recording pyrometer of the potentiometer type, connected across a standard resistance in the plate circuit, automatically drew the grid-potential plate-current curve in rectangular coordinates. The paper roll of the recording instrument was driven by the same motor that varied the grid-potential in order to insure uniformity. The instrument worked well with currents as low as 0.5 milliampere for full scale deflection which interpreted graphically means the maximum ordinate permitted by the width of the coordinate paper which was ten inches. Obviously, smaller currents require a larger resistance in the shunt to give sufficient potential drop for full scale deflection which reduces the sensitivity of the instrument and fixes the low current limit for satisfactory operation with any given glavanometer in the recording instrument. Characteristic curves of a higher order of accuracy than are usually obtained by plotting points were drawn in from five to ten minutes depending on the reducing gears used.

47. Space charge as a cause of negative resistance in a triode. Lewi Tonks, General Electric Co.—Oscillations occurring in a tuned circuit connected to grid and plate of a triode have been obtained by Gill (Phil. Mag. **49,** 993, (1925)) when the grid potential was 40 volts and plate potential 8 volts. These were ascribed to unstable space charge in the tube. In the present paper the mathematical theory for the case of plane parallel electrodes is first presented and later applied qualitatively to the case of cylindrical electrodes. The existence of a virtual cathode may cause negative resistance in both plate and grid circuit under emission limited operation, but for the case of space charge limited operation negative resistance is at most very small. The theory has a possible bearing on very short wave generation by the method of Barkhausen and Kurz (Phys. Zeit. **21,** 1 (1920)).

48. Electric absorption currents in solid dielectrics. Hubert H. Race, Cornell University. (Introduced by F. K. Richtmyer).—The lower electrode of a guard-ring condenser containing specimen under test was connected, either (A) to constant potential or (B) to ground. The upper electrode was connected to a quadrant electrometer and an adjustable air condenser. This insulated system was maintained at ground potential by controlling voltage on the air condenser. Thus charge, (A) and discharge, (B), curves were obtained as functions of time (t). Using plates in intimate contact with specimen, potential was applied until current became constant at I_g, the true conduction current. Then potential was removed and the following relation was observed for certain materials: $i(\text{charge})-I_g=-i\ (\text{discharge})=i_a$ (1). For these materials, of which hard rubber is a good example, an approximate straight line was obtained between log i_a and log t, so that the current i_a, due to absorption, may be represented by the equation: $i_a=(c/t)^b$ (2) where b and c are determinable constants. Tests were also made with an air gap between specimen and upper plate. Eq. (2) was still found true but eq. (1) was not.

49. Effect of temperature on polarization capacity and resistance for gold and platinum electrodes in different concentrations of sulphuric acid and at different audible frequencies. E. E. Zimmerman, Cornell University.—Measurements of polarization capacity together with corresponding values of cell resistance have been made for gold and platinum electrodes in sulphuric acid solutions at temperatures varying from 0°C to about 90°C. Measurements were made by means of an a.c. bridge using frequencies from 650 to 3900 cycles. For platinum electrodes in a 12.7 percent solution of H_2SO_4, the temperature coefficient is positive and has a value of about 0.37 of a microfarad, for one electrode of unit area, per degree rise in temperature. The value decreases at the upper range of temperatures and also with decreasing concentration. For gold electrodes, the average value of the temperature coefficient is about one-tenth of that for platinum. In contrast to the results with platinum, the value of temperature coefficient increases at the upper part of the temperature range. Cell resistance, with platinum electrodes, decreases with increasing temperature while with gold electrodes the resistance, especially at higher temperatures, increases with temperature. For both metals, the temperature coefficient of capacity decreases with increasing frequency. Incidentally, studies of variation of capacity and cell resistance with varying frequency have been made at constant temperature. Also, decay curves have been obtained for gold electrodes after hydrogen polarization. No such decay curve could be obtained using platinum electrodes.

50. Analysis and applications of wave filter determinants. FRANCIS D. MURNAGHAN and HAROLD A. WHEELER, Johns Hopkins University.—In the study of the electric wave filter comprising a finite line of recurrent sections, the simultaneous equations in currents and voltages yield determinants of a known type. By the method of difference equations, various typical determinants are evaluated and expressed in terms of convenient substitutions. Special attention is given to the finite cases involving (1) terminal conditions and (2) two recurrent sections in alternating succession. Procedures are given and simple formulas developed applying the determinants to (1) free oscillation frequencies of finite, conservative lines and (2)steady state response of finite, non-dissipative Campbell filters, terminated by any values of resistance, as a function of the frequency of the applied alternating voltage. Proceeding to the infinite line by a novel method, the iterative impedance and propagation exponent are derived. The definition of complex electric impedance is outlined to show the fundamental differential equations involved and thereby make the work equally applicable to other systems with similar differential equations.

51. Formal unification of gradient, divergence, and curl, by means of an infinitesimal operational volume. VLADIMIR KARAPETOFF, Cornell University.—Besides the usual definitions of gradient, divergence, and curl, familiar to physicists, some German writers on Vector Analysis (Runge, Spielrein, von Ignatowsky) define these quantities as ratios of certain integrals of a scalar or vector function, taken over a small closed surface, to the volume comprised within the surface, when both tend to the limit zero. By properly choosing the *shape of an infinitesimal operational volume*, around the point under consideration, and its *position with respect to the lines of force, integrations can be done away with, and it is not necessary to reduce the results to the limit zero.* The above operators thus become symbols for certain forms of *space derivatives*, independent of fixed axes of coordinates. The results throw additional light on the *physical nature* of divergence and curl. The operational volume may be so chosen and placed as to give the *total magnitude of the curl vector*, and not only its components.

52. Surface layers produced by activated nitrogen. CARL KENTY and LOUIS A. TURNER, Princeton University.—A one mil tungsten wire at about 450°C placed in a stream of nitrogen shows a large decrease in resistance when the active nitrogen produced by a condensed discharge reaches it. The same effect is produced by bombarding still nitrogen in the neighborhood of the filament with electrons. In a tube having a large nickel anode the minimum accelerating voltage for producing a detectable effect is 10.8 volts but it is considerably higher (about 21 volts) in a tube having a hot tungsten filament anode. The decrease of resistance is attributed to the formation of a surface layer which increases the emissivity of the filament, thereby lowering its temperature. The effect increases with the pressure in the range from 0.04 to 5 mm. The film is removed by flashing the filament or pumping out the gas. The effect is apparently produced by a neutral substance, being independent of the potential of the test filament. Active nitrogen also causes a large reduction of the thermionic current from a tungsten filament. Such an effect is obtained with ordinary nitrogen in the hot anode tube, a saturation current reached at 15 volts being reduced at voltages above 21.

53. Simultaneous ionization and excitation of molecules on collision with foreign ions. O. S. DUFFENDACK and H. L. SMITH, University of Michigan.—The spectrum of a low-voltage arc in a mixture of 90 percent helium and 10 percent CO contains the Comet Tail, First Negative, and Baldet-Johnson bands of CO^+ strongly developed. In neon and CO the Comet Tail bands are strong, the First Negative weak, and the Baldet-Johnson absent. None appear in an argon-CO mixture. The introduction into the discharge of twice as many electrons from an auxiliary filament as from the cathode failed to increase the intensities of the bands if their accelerating voltage was less than the ionizing potential of the rare gas, even though it was above the excitation potential of the bands. Hence these bands were not excited by electron impacts either upon the CO^+ ions or upon the CO molecules. To determine whether excited atoms or ions were effective in producing these bands, nitrogen was substituted for CO. Its negative bands appeared strongly in helium and in neon mixtures. As their excitation potential is above the strong radiating potentials of neon, their excitation must be due to the ions. We conclude that an ion may ionize a molecule and excite the resulting ion to the degree the ionizing potential of the one exceeds that of the other.

54. Residual ions and critical restriking potential in mercury arcs. M. L. Pool, University of Chicago. (Introduced by A. J. Dempster).—Using as a collector for electrons a 4 mil wire and for positive ions an anode which completely surrounds a hot cathode the rate of removal is given by $n = n_o e^{-kt}$ where $k = 240$ for all voltages during the first 1/75 sec. After 1/300 sec the space charge sheaths about the anode and wire are 2 mm in thickness and 1 mm in radius respectively. These sheaths rapidly expand in size and within 1/50 sec. fill the entire arc space. Replacing the wire by a larger collector the arc space has been swept free of ions within 1/500 sec. The restriking of a mercury arc at the lowest radiating potential is explained by means of the large concentration of electrons and ions which exist near the filament. There electrons will have energies up to 5 volts. When the arc is stopped these electrons will diffuse into the filament and in order to repel them the filament must be made 5 volts negative with respect to the gas. If the filament is made still more negative electrons can leave the filament and the arc restrikes through ionization of the metastable atoms formed by continual recombination.

55. The fine structure of the mercury line 3650 A. W. H. McCurdy, National Research Fellow, Johns Hopkins University.—The fine structure of the Hg line 3650 A has been studied by means of crossed Lummer-Gehrcke plates of quartz. The results show that this line consists of five components within the limits of the observations. The separations are -45, -32, -20, 0, $+102$ mA. The main component is found to be single within the limits of the plates but under certain arc conditions it is found to appear reversed. Nagoaka, Siguira and Mishima have studied all the strong lines of the mercury arc spectrum and they give as the structure of the main component a group of three lines with weaker ones on each side. The structure of the main component in their results may be due to broadening of the line and partial reversal due to the type of arc used. It is possible that their results on the line 2967 A may also be incorrect for the same reason, as the main component of this line also shows absorption under some conditions. This shows the importance of the source in fine structure work.

56. Zeeman-effect of the fine structure components of λ 2536 of mercury. Walter A. MacNair, National Research Fellow, Bureau of Standards.—Preliminary results of an extended study of the Zeeman-effect of λ2536 of mercury show that the five fine structure components split into triplets, the perpendicular components of which behave as the perpendicular components of 322 normal triplets with no Paschen-Back effect in fields up to 5000 gauss, the present limit of the magnet being used. The parallel or central components of the five triplets show some pecularities in fields of 3000 gauss and over.

57. H_3 as a possible emitter of the secondary hydrogen spectrum. Charles J. Brasefield, Princeton University.—Positive ray analysis of the ions in a discharge in hydrogen show that H_3^+ is by far the predominant ion, except at very low pressures. In an attempt to correlate the proportion of H_3^+ with the intensity of the lines of the secondary spectrum, photographs were taken of the discharge operated under two different conditions; (1) In which no H_3 ions were detectable and (2) in which the number of H_3 ions was quite appreciable. The second type discharge showed marked enhancement of the Fulcher bands in the red and blue, which was at first attributed to H_3. However, when the electron velocities were determined by the Langmuir exploring electrode method, and the results compared with the curves obtained by Lowe showing the variation of intensity of the secondary lines with the energy of the exciting electrons (Trans. Roy. Soc. Canada, **20,** 217 (1926)) it was found that the observed change in intensity could adequately be accounted for by change in electron velocity. Very little evidence was found to support the bands recently found by Allen and Sandeman which they ascribe to H_3.

58. Theory of the Stark-effect in the arc spectra of helium. J. Stuart Foster, McGill University, Fellow of the International Education Board (in Copenhagen).—In this application of the perturbation theory of the quantum mechanics of Heisenberg quantitative displacements and intensities replace the less definite qualitative explanation afforded by the correspondence principle in the earlier Bohr theory. Following Kramers, the hydrogen atom is considered to be perturbed by (1) an inner and entirely central field which effectively replaces the time mean position of the inner helium electron as well as its resonance action, and (2) a uniform external electric field. As a first approximation, the perturbation matrix H_1 (n, m, k) therefore contains, within a region of given n and m, (1) diagonal terms which denote the differences (at zero field) between the hydrogen and the parhelium (or the orthohelium) spectral terms identified by the various k values, and (2) terms due to the applied field, and identical with those recently given by Pauli and by Schroedinger in the theory of the Stark-effect in hydrogen. The various Stark patterns as well as great variations in the displacements and intensities previously observed by the writer over a wide range of field strengths are faithfully reproduced in the theory. An interesting feature in accord with the observations is the vanishing of a few components at certain field strengths and their reappearance at higher fields. Displacements of the following line groups have been calculated at seven field strengths: $\lambda\lambda$ 4922, 4388, 3965, 3614, 4472, 4026, 3188, and 2945. The intensities have been calculated at 10, 40, and 100 kv/cm.

59. The light absorption of liquefied gases. F. G. Brickwedde and W. A. MacNair, Bureau of Standards.—For the study of the absorption of liquefied gases, the continuous spectrum of hydrogen was used for wave-lengths 2000–3700 A, a bromine cell cutting out wave-lengths greater than this, and the light from an incandescent bulb was used for wave-lengths 3400–6500. The absorption spectra were photographed with a Hilger E2 quartz spectrograph. The liquefied gases were contained in a cylindrical, quartz Dewar flask—inside diameter 22 mm—mounted in front of the slit of the spectrograph. The results obtained with liquid oxygen were found to be in essential agreement with the results published by W. W. Shaver (Trans. Roy. Soc. of Canada, **15,** 7 (1921)), except for a number of new bands not previously recorded. Three of these obviously belong to the system of broad bands found by Shaver, extending between wave-lengths 2600 and 2800. No absorption was found in liquid nitrogen between wave-lengths 2000 and 6500, and no absorption in liquid hydrogen between wave-lengths 2000 and 3800.

60. Reproducible liquid filters for the determination of the color temperatures of incandescent lamps. Raymond Davis and K. S. Gibson, Bureau of Standards.—A series of filters has been devised, reproducible from specification, by means of which any Planckian energy distribution from 2300° to 4000°K may be converted to the color of mean Washington sunlight. Given a simple photometer, a lamp standardized at some one temperature in the above range, and the proper filter, a second lamp may then be calibrated at as many temperatures as is desired by preparing the respective filters. The solutions required for any given filter are contained in a two-chamber glass cell, one chamber containing a one-centimeter thickness of an aqueous solution of copper sulphate, pyridine, and mannite, the other, a one-centimeter thickness of an acidified aqueous mixture of copper sulphate and cobalt ammonium sulphate. Careful spectrophotometric measurements from 350 to 750 mμ were made on medium concentrations of the three component solutions, and the validity of Beer's law studied over the range of concentrations necessary. The respective concentrations were then varied until the color characteristics of the source-and-filter combinations were, by computation, all identical with that for mean sunlight.

61. The fluorescence of sodium vapor. R. W. Wood and E. L. Kinsey, Johns Hopkins University.—Sodium vapor contained in a Wood sodium tube was excited by monochromatic radiation in the blue-green region obtained by sunlight and a monochromater. Although the exciting radiation corresponded only to a molecular absorption band group in the blue-green region and to no absorption lines in the sodium atom, the "D" lines appeared in the fluorescence spectrum when the pressure of the residual gas was around 4 mm. The phenomenon was not obtained at lower or higher pressures. Bands appearing in the region surrounding the "D" lines in the fluorescence spectrum under white light excitation were studied. They have been definitely determined to appear only at pressures of the residual gases (hydrogen and nitrogen) around 6 mm. Approximate monochromatic excitation shows them be to excited only by wave-lengths in their own region. Absorption spectra obtained with both a two meter and twenty foot spectrograph so far fail to reveal these bands. The introduction of small quantities of potassium failed to effect the appearance of these bands.

62. Spark spectrum of nickel. A. G. Shenstone, Princeton University.—The following terms of Ni II have been identified:—1. Low set in order $^4F'$, $^2F'$, $^4P'$, $^2P'$, $^2\mathrm{D}$ all from the structure d^8s. 2. Intermediate set (d^8p) $^4\mathrm{D}'$, $^2\mathrm{D}'$, $^4G'$, $^2G'$, ^4F, ^2F; $^4S'$, ^4P, $^4\mathrm{D}'$ and a large number of levels unidentified. 3. A high $^4F'$, $^2F'$ (d^8, s). These terms account for about two-thirds of the lines including practically every strong line. Zeeman effects indicate that the g-values of $^4F'$, $^2F'$ and the corresponding intermediate triad are probably regular. The g-values of $^4P'$ etc., are certainly irregular as are also the intervals. All terms are inverted except that $^4G_6$ is higher than $^4G_5$. The predicted lowest term $^2\mathrm{D}$ (d^9) would give lines outside the present observed region and has not been found. The two $^4F'$, $^2F'$ terms belong to a sequence (d^8, s) and give a calculated I. P. of about 17.4 volts. The same peculiarities of convergence and interval are present in this $^4F'$, $^2F'$ series as were evident in the corresponding series of Cu II, Ni I and Pd I (d^9s).

63. Terms arising from similar and dissimilar electrons. D. T. Wilber, H. E. White and R. C. Gibbs, Cornell University.—Following the scheme of Hund for similar s, p and d electrons, the terms arising from similar f electrons have been worked out and tabulated. Tables have also been prepared for one and two electrons, where in the latter case these electrons are dissimilar, i. e., have either different total or different azimuthal quantum numbers, and also for three electrons two of which are similar. In the tables for similar electrons we have indicated, in parenthesis, the total number of possible configurations of p (=number of possible values of m_a times the number of possible values of m_s) things taken q (=total number of electrons in consideration) at a time. These tables are found not only to be of frequent use but also to bring out certain rules that may be applied in determining spectral terms arising from any electron configuration.

64. Multiplets in the spectra of Cr(III) and Mn(III). R. C. Gibbs and H. E. White, Cornell University.—Following the method previously reported by us for the identification of multiplets in other isoelectronic systems of the first long period it has been found possible to extend the multiplet designated as $^5F-{}^5G$ for four electron systems (involving the transition $4p3d^3 \rightarrow 4s3d^3$) from Ti(I) and V(II) to Cr(III) and also the multiplet designated as $^6\mathrm{D}-{}^6F$ for five electron systems (involving the transition $4p3d^4 \rightarrow 4s3d^4$) from V(I) and Cr(II) to Mn(III). The twelve lines of the ^5FG multiplet of Cr(III) and the fourteen lines of the ^6DF multiplet of Mn(III) all follow the usual rule of relative intensities. These and other data enable us to extend further the systematic arrangement of radiated frequencies arising from the transition of an electron from a $4p$ to a $4s$ orbit in the presence of 0, 1, 2, 3 etc. $3d$ electrons, for elements in the first long period from K to Cu. The Moseley diagrams for the deepest lying terms arising from $d^{n-1}s$ and $d^{n-1}p$ configurations for these elements not only give very straight lines but also reveal a regular and systematic displacement in passing successively from one iso-electronic system to another.

65. The sodium and potassium absorption bands. W. R. Fredrickson, William W. Watson, and J. Rinker, University of Chicago.—The blue-green Na_2 and the red K_2 absorption bands have been photographed with a dispersion of 1.3A per mm. Vibrational quantum numbers have been assigned, with the following formulas giving the frequencies of the heads:

$$\begin{aligned} \mathrm{Na}_2{:}\,v &= 20301.62+(123.84n'-0.79n'^2)-(157.57n''-0.57n''^2)\\ K_2{:}\,v &= 15368.63+(74.46n'-0.21n'^2)-(91.94n''-0.39n''^2) \end{aligned}$$

Using Wood's resonance series data, the lines in the Na_2 bands are arranged into singlet P, Q, R branches, a result in accord with Mulliken's prediction of a ${}^1S-{}^1P$ electronic transition. The resonance doublets have one component on the R, the other on the P branch, with $\Delta j=2$; most of the singlets fall on Q branches. All of Wood's magnetic rotation lines lie on P and R branches. The usual P, Q, R combination principle holds. The band origins are very close to the heads; B_0' is 0.17 cm^{-1}. The K_2 bands appear to have four branches, indicating doublet P, R arrangement. If weak Q branches are present near the heads, they cannot be detected. The K_2 bands might involve a ${}^1P-{}^1P$ transition (suggested by Mulliken) and it is shown that both ${}^1S$ and ${}^1P$ initial molecular states are plausible.

66. The rotational and vibrational specific heat of a diatomic gas, the molecules of which have a doublet P normal state. Enos E. Witmer, National Research Fellow, Harvard University.—As is well known, the rotational and vibrational specific heat of a diatomic gas, the molecules of which have a single electronic state as the normal level, when plotted as a function of the temperature, shows the following characteristics. The curve rises more or less abruptly from zero at the absolute zero to a value in the neighborhood of R, after which the curve is almost flat until the vibrational energy begins to add its contribution. R is the gas constant in calories per degree (1.986). If, however, the normal electronic level is double, the specific heat curve presents in general in addition to this initial rise in the neighborhood of the absolute zero a secondary rise at the temperatures at which molecules begin to exist in the upper component of the doublet in appreciable numbers. After this second rise, which carries the curve above the value R, the curve again declines, tending to the value R, until vibration begins to add its contribution. A good example of the doublet type is nitric oxide. The specific heat of this gas was computed from the band spectrum data of Jenkins, Barton, and Mulliken. At 50°K. its specific heat is $1.33R$.

67. Recoil electrons from aluminum. A. A. Bless, Cornell University.—On the Compton theory of scattering the maximum energy of the recoil electrons is given by $E=h\nu_0 2\alpha/(1+2\alpha)$. On the assumption made by C. T. R. Wilson that x-rays on scattering spread in spherical waves the maximum energy of recoil electrons would be about 1/4 that given above. Experiments on recoil electrons have been made with a molybdenum water cooled tube and aluminum as the scattering substance. Preliminary results using the magnetic spectrometer method show the presence of a band the high velocity edge of which agrees fairly well with the value predicted by Compton. The band shifted properly with the change of the field.

68. X-ray absorption formulas. S. J. M. Allen, University of Cincinnati.—Wetzel, using the new wave mechanics of Schroedinger, and applying it to photo-electric effect, has recently developed a formula for the absorption of high frequency x-rays for the K series. By the aid of Moseley's law the formula can be put in such form that it can be compared with experimental data. For a single element this formula is:

$$(\mu/\rho)_{\mathrm{K}}=k_1\lambda^3+k_2\lambda^{3.5}+k_3\lambda^{2.5}+\sigma/\rho$$

Using the same exponents of λ, empirical formulas can be found which agree, within experimental error, with existing data. The elements, Al, Fe, Cu, Ag, Sn, and Pb, have been considered from $\lambda=.081$ to $\lambda=1.934$ A, and it has been found that such a formula fits the experimental data quite well through the entire range of λ for the K series. It also appears that such a formula fits the L series of Fe, Cu, and Pb, but that the L series of Ag and Sn, and the M series of Pb can be best expressed by two parameters. The complete formula for Ag is: $(\mu/\rho)\mathrm{total}=(400\lambda^3-30\lambda^{3.5}+80\lambda^{2.5})_{\mathrm{K}}+(97\lambda^3-35\lambda^{3.5})_{\mathrm{L}}+(1/6.5)\ (\tau/\rho_{\mathrm{L}})_{\mathrm{M}}$ etc. $+\ \sigma/\rho.\sigma/\rho=.35$ at $\lambda=.08$ A, and increases slowly with λ. From this formula, $J_k=(\tau/\rho_{\mathrm{K}}+\tau/\rho_{\mathrm{L}}+\tau/\rho_{\mathrm{M}}$ etc.) $(\tau/\rho_{\mathrm{L}}+\tau/\rho_{\mathrm{M}}$ etc.) is not a constant but varies with λ.

69. Molecular space array in liquid primary normal alcohols: the cybotatic state. G. W. Stewart and Roger M. Morrow, University of Iowa.—Examination of liquid normal primary alcohols, methyl to lauryl, by Mo Kα x-radiation, gives diffraction curves which are readily and consistently interpreted by the following: (a) There is a fluid molecular space array, called the "cybotatic" rather than "crystalline" state. (b) The alcohol molecules are parallel and separated by the most probable distance of 4.6 A. (c) The length of the molecules increases in equal amounts with each addition of CH_2; this increase is 1.3 A or approximately the distance between C atoms in crystalline form. (d) The above interpretations are in full accord with all known facts and especially to be noted is the agreement with the surface film molecular arrangement of similar compounds studied by Adam. The experiments and discussion refer to liquids that are optically isotropic. They are an extension of the work of numerous observers on the well known x-ray diffraction x-ray halo in liquids. The general conclusion is that *the cybotatic state or cybotaxis, is common in liquids and lends itself readily to a better understanding of the nature of a solution and solution phenomena, such as osmosis.*

70. X-rays of long wave-length from a ruled grating. F. L. Hunt, Bureau of Standards.—By the use of a grating ruled on glass (200 lines per mm), at grazing incidence (20′ to 40′), in vacuum, the following lines have been obtained: Mα of platinum, (6A); Kα of aluminum, (8.3A); Lα of copper, (13.3A), all in the first three orders; the Lα of iron, (17.7A) and of chromium, (21.5A), in the first order; and the Kα of carbon, (45A), in the first two orders. A water-cooled metal x-ray tube with a hot lime-coated platinum cathode, which permitted the use of an unprotected photographic plate, was connected directly to the spectrometer with no absorbing film between the anti-cathode and the plate. Two 0.5 mm steel slits 20 cm apart were mounted between the tube and the grating. The distance from the grating to the plate was from 10 to 30 cm. The voltage applied to the tube was 10 kilovolts, the current 10 milliamperes, and the time of exposure from 20 minutes to 1 hour. The wave-lengths were determined with reference to the first order Lα of copper which was used in computing the zero position of the direct beam. The angle of incidence on the grating and the effective distance from the grating to the photographic plate were determined experimentally. These preliminary measurements agree within approximately 0.1A with the values determined by reflection from crystals.

71. An explanation of Whiddington's rule for x-ray electrons. E. C. Watson, California Institute of Technology.—In Whiddington's pioneer work on the velocities of electrons ejected by x-rays, the very remarkable observation was made that the incident radiation was able to eject an electron only when its frequency was double the value corresponding to the energy level of the electron concerned. Robinson, however, in his extensive study by the same method was unable to confirm this result. Robinson worked with electrons ejected approximately at right-angles to the x-ray beam, while Whiddington studied those leaving the radiator in the forward direction of the x-ray beam, and it can be shown that his rule resulted from this procedure together with the fact that x-ray plates become relatively insensitive to electrons whose HP velocity is less than 300. β-ray spectra have been taken at various angles with the x-ray beam, and lines which are forbidden by Whiddington's rule appear when the electrons leave the radiator approximately at right-angles to the x-ray beam but disappear when electrons leaving in the direction of the x-ray beam are studied. This is in agreement with the work reported at the Los Angeles Meeting (Abstract no. 24, March 5, 1927) and also with the work in gases by the expansion chamber method.

72. On a gyromagnetic electron-theory of the Compton effect. Louis Vessot King, McGill University.—In the following classical theory of the Compton effect, it is supposed that electrons are carried forward in a beam of monochromatic radiation of high frequency. The equations of motion of the electron, taking into account the variation of mass with velocity, may be solved by successive approximation. The electron describes a trajectory of sinusoidal form whose period differs slightly from that of the incident radiation, while the resultant velocity depends on the magnitude of the electric intensity in the electromagnetic wave. The disturbing couples on the gyromagnetic electrons are provided by couples arising from the corresponding magnetic field. On inserting these conditions in the gyromagnetic equations of line radiation (*Gyromagnetic Electrons and a Classical Theory of Radiation and Atomic Structure*, Louis Carrier, Mercury Press, Montreal), it is found that a certain group of electrons (whose velocities give rise to a natural precessional frequency synchronizing with that of the disturbing couple) will precess by resonance, emitting line radiation of frequency differing slightly from that of the incident beam. Since the precessing electron moves forward while radiating, the application of the classical Doppler principle gives the well-known complete formula for the Compton effect.

73. Iron crystals. L. W. McKEEHAN, Bell Telephone Laboratories, Inc.—It has been found possible to grow long crystals in iron wire by making use of the allotropic transformation which occurs at about 900°C. The method is to heat, in an inert atmosphere, a portion of the wire between two mercury contacts by passing direct or alternating current through it and then to cause the heated portion to travel along the wire either by moving the support carrying the contacts or by moving the wire itself. The hottest part of the wire should be at 1400°C or higher. Under these conditions a very steep temperature gradient exists at the point where face-centered cubic (γ) crystals, stable at high temperatures, are being replaced by body-centered cubic (α) crystals, stable at lower temperatures, and at a favorable velocity of travel a single α crystal will grow to a length of 20 centimeters or more in wire 1 millimeter in diameter. The chemical purity and previous mechanical history of the iron seem relatively unimportant. Irregularity in tension on the wire and torsional stresses in it result in twinning Twins may either appear as small inclusions or as complete changes in orientation with the twinning plane traversing the entire cross-section of the wire. The twinning plane is of the form $\{211\}$. The magnetic and magnetostrictive properties of the long crystals appear in some respects to differ from those of crystals prepared by others by the method of over-strain and annealing.

74. The purification of helium. J. WILLIAMSON COOK, Bureau of Standards.—Helium, containing 2.91 percent air (mostly nitrogen) plus a trace of hydrogen and neon, was passed at a slow rate and at atmospheric pressure, over activated cocoanut charcoal which had been thoroughly outgassed at from 300° to 400°C. With the charcoal cooled to -78°C. all air was adsorbed by the charcoal, leaving helium with only a trace of neon and hydrogen when observed spectroscopically. The charcoal was 100 percent efficient for removing air until its saturation limit was approached, when its efficiency failed almost instantly and completely. At lower temperatures, considerably more air was adsorbed but the saturation limit was not quite so abrupt. The amount of air, in cubic centimeters, which was adsorbed per gram of charcoal, up to the saturation limit, was 7 cc at -78°C; 152 cc at -182°C; 217 cc at -209°C. Relative observations, at liquid air temperature, indicated that if the hydrogen was first removed chemically, the charcoal would then adsorb more neon than when the hydrogen and neon were both present in the helium.

75. Duration of atomic hydrogen. JOSEPH KAPLAN, Johns Hopkins University. (Introduced by R. W. Wood.—A large bulb of 3 liters capacity was sealed to the middle of a Wood's hydrogen tube and the atomic hydrogen formed in the discharge tube was allowed to enter the bulb. It was found that atomic hydrogen could be detected, by means of a speck of Welsbach mantle, three seconds after the discharge was shut off. The piece of Welsbach was quite large which indicated that there was still probably considerable atomic hydrogen in the bulb even after three seconds. Certain other effects, such as small white infected spots on the glass, which were due to atomic hydrogen, were observed for as long as six seconds after the discharge was discontinued. There were indications that the atomic hydrogen lasted as long as 10 seconds, but, because of impurities in the tube, these indications may have been due to something else. It has also been shown that in the absence of water, a surface is a much better catalyzer than when water is adsorbed on it. The present experimental proof of the role of water has, however, been made away from the discharge tube, in which other complicated reactions might occur.

76. Structure and isotope effect in the alpha bands of boron monoxide. F. A. Jenkins National Research Fellow, Harvard University.—The α bands of BO excited by active nitrogen have been photographed with high dispersion. They are electronic doublets, each component having four branches designated R_1, (R_2+Q_1), (Q_2+P_1), and P_2, of which the two central ones are relatively more intense. This structure has been interpreted by Mulliken as due to a $^2P\rightarrow{}^2S$ transition. The missing lines support this designation, since there is one in the Q_1–Q_2 series for the higher frequency system, while there are three for the lower. The ^2P doublet is therefore *inverted*. Quantum analysis of the $(\frac{1}{2}, \frac{1}{2})$ and $(\frac{1}{2}, 1\frac{1}{2})$ higher frequency sub-bands shows that the rotational terms in the initial state are of the form $B'(j^2-\sigma^2)$, $\sigma=\frac{1}{2}$, and in the final state $B''(j-\epsilon)^2$, $\epsilon=\pm\frac{1}{2}$, with j integral. There is a close σ-type doubling in the initial state, but "crossing over" in the Q transitions allows the coalescence of R_2 with Q_1, and Q_2 with P_1. The origins of the $(\frac{1}{2}, \frac{1}{2})$ bands of $B^{10}O$ and $B^{11}O$ are separated by 1.547 A, exactly the amount required for half-integral vibrational quantum numbers. Analysis of this $B^{10}O$ band gives smaller moments of inertia than those obtained for $B^{11}O$, but identical internuclear distances, namely $r_0'=1.352\times10^{-8}$ cm and $r_0''=1.208\times10^{-8}$ cm.

77. Band structure and intensities, atomic and molecular electronic states, in diatomic hydrides. Robert S. Mulliken, New York University, Washington Square College.—Theoretical intensity formulas applicable to $^2P\rightarrow{}^2S$ and $^2S\rightarrow{}^2P$ molecular electronic transitions have been obtained, for Hund's case *b*. The observed branches (six intense branches), intensity relations, missing lines, etc., in the CaH, MgH ($^2P\rightarrow{}^2S$), OH, CH λ3900 ($^2S\rightarrow{}^2P$) bands agree well with the theory. As the ^2P separation increases, through ZnH, CdH, to HgH (all $^2P\rightarrow{}^2S$), and the ^2P state approaches Hund's case *a*, a gradual transition occurs to the HgH type, with twelve strong branches. In OH (as expected), apparently also in CH, the ^2P doublet is inverted; elsewhere it is normal. The intensity relations, probable missing lines, and occurrence of twelve strong branches (different from those in HgH), show that CH λ4300 is $^2D\rightarrow{}^2P$. Probably the three levels ^2P, ^2D, ^2S involved in CH λλ 4300 and 3900 are derived, by the addition of a normal hydrogen atom, from the lowest levels, ^3P, ^1D, ^1S of the carbon atom (the latter two metastable, unlike ^2D and ^2S of CH); the OH levels ^2P and ^2S similarly from ^3P and ^1S of oxygen; and the ^2P and ^2S levels of the metal hydrides from the lowest levels (^1S, ^3P) of the metal atoms.

78. Zeeman effect in AgH, AlH, ZnH, and MgH bands. William W. Watson and B. Perkins Jr., University of Chicago.—The AgH bands are absolutely unaffected by magnetic fields of any strength, thus verifying the assignment $^1S-{}^1S$ to these bands. The results for the λ4240 AlH band ($^1S-{}^1P$) are similar to those given by Kemble and Mulliken for the λ5610 CO band ($^1P-{}^1S$). The first R lines are broadened, the spread of the R(1) components being approximately half normal separation, in agreement with Van Vleck's "rigid-coupling" formula, if $j'=1$. The first P and Q lines are diffusely broadened. In the λ4326 ZnH band results at medium field strength are in agreement with Hulthen's except for the R_1 lines. These show a broadening for low *m's*, as do the R_2 lines. The P_1 and P_2 lines are unaffected at any field strength. Both the Q_1 and Q_2 lines split up into "loose-coupling" wide doublets ($\Delta v=2\times$normal separation for low *m's*.) A first order "rigid-coupling" effect on the Q lines at low fields apparently occurs, but measurements are uncertain. In the MgH bands the narrow doublets fuse into single lines more intense in the center and slightly narrower than the original doublets.

79. The excitation of the spectrum of CO_2. G. W. Fox, O. S. Duffendack and E. F. Barker, University of Michigan.—Pure CO_2 flowing continuously through a hot cathode discharge tube was excited by electron impacts at low voltages. The tube consists of two compartments separated by a diaphragm having a small aperture covered with platinum gauze through which the electrons from an oxide coated filament enter the impact chamber. The flow of gas was in the direction opposite to that of the electrons; thus dissociation products were swept out through the pump and no diffusion into the region of observation occurred. The gas pressure was controlled by regulating the rate of flow. Under these conditions the spectrum observed is altogether different from that produced in stagnant gas, and is attributed to the molecule of CO_2. The glow is violet and its spectrum consists of several systems of bands extending from 5000 A to 2850 A. Most of these bands are degraded toward the red. They have sharp edges, and occur in distinct groups. One group lying near 2880 A seems unique. It consists of two double edged bands each having oppositely degraded branches with a very narrow band between their edges. When the flow is stopped the familiar sky blue of CO appears at once, and the spectrum consists mainly of the positive bands of CO.

80. Ultra-violet absorption and emission spectra of carbon monoxide. J. J. HOPFIELD and R. T. BIRGE, University of California.—New emission and absorption spectrograms of CO have been measured and analyzed. Many irregularities in some previous data by others have been eliminated. By gradually varying the pressure of CO in the receiver of the spectrograph from 0.05 to 850 mm, nine absorption systems, between λ920 and λ2064.5 have been obtained. These represent transitions from the normal level to *all* of the previously known excited electronic levels (Phys. Rev., **28**, 1157 (1926)) and to four new levels at 58927, 92923,* 99730, and 105270 cm^{-1}. Other absorption systems are present but are too blended for certain analysis. The new data permit many satisfactory tests of the combination principle, and give as a direct evaluation of the previously known levels, 48438* to 48534,* 64765,* 83812* (poor) 86926,* and 91923* cm^{-1}. Band systems are found in emission also, for transitions from starred levels directly to the normal. The strongest absorption is to the highest levels. Three of the higher levels have a vibration frequency almost identical with that of the normal state, and this fact, coupled with the absence of a Q branch in the correlated bands, predicts unique features in the appearance of the bands which are experimentally verified.

81. A comprehensive form of energy level diagram for atoms. RAYMOND T. BIRGE, University of California.—A type of diagram is suggested which may include, at least theoretically, all energy levels of an atom and its singly, doubly, etc. charged ion, provided that not more than one electron is in an excited level. A general scheme is proposed for designating the levels in accordance with the present interpretation of complex spectra. Such a diagram exhibits all possible relations between the lines of ordinary spectral series, the enhanced series of the variously charged ion, the ordinary x-ray lines, the enhanced (spark) x-ray lines, the critical absorption limits, and the so-called discontinuities in the absorption limits. With emission represented as a downward transition, the x-ray energy levels appear inverted with the K level highest. All levels for the neutral atom are represented by parallel sets of vertical columns, grouped in one section. Similarly all levels of the singly charged atom, in an adjoining section. Transitions representing monochromatic radiation never cross the division between sections. All critical absorption limits do cross. Double electron jumps are not represented, as the number of types of possible levels, with more than one electron in an excited state, in prohibitively great for convenient representation.

82. The shift in a near infra-red absorption band of some benzene derivatives. JAMES BARNES, Bryn Mawr College.—By means of a grating spectroscope and plates sensitized with neocyanine absorption bands of benzene and of some of its derivatives have been photographed and their wave-lengths measured. The dispersion of the spectrometer as used was approximately 39.8 A to the millimeter. The results are believed to be accurate to ±5 A. The wave-lengths of the center of the absorption bands of the substances used are as follows:

	λ(A)		λ(A)
Benzene	8741	M-Xylene	8793
Toluene	8758	P-Xylene	8808
Ethylbenzene	8772	Diethylbenzene	8799
O-Xylene	8781	Mesitylene	8844

With an absorption cell 80 cms in length benzene shows an absorption band at 7134 A. Some interesting conclusions can be drawn from these results. Their explanation in the light of present theories regarding band spectra will be briefly discussed.

83. The infra-red absorption spectra of acetylene (C_2H_2), ethylene (C_2H_4), and ethane (C_2H_6). Charles F. Meyer and Aaron Levin, University of Michigan.—The absorption spectra of the above gases are being investigated by means of a grating spectrometer. The curves show fine structure of an interesting and, in some cases, an extremely regular nature. They are the first which show resolution of bands into ultimate lines for molecules containing more than one heavy atom. That is, all bands of the vibrational-rotational type which have hitherto been analyzed, originate from molecules which contain hydrogen and only one atom of another kind. Investigators have felt that the bands of other molecules, on account of the higher moment of inertia involved, and consequent closer spacing of the lines, were unresolvable. This is shown to be untrue for the gases under investigation. The measurements extend to nearly 15μ and have thus been carried to considerably longer wave-lengths than any previous work with high dispersion.

84. The infra-red spectrum of ammonia. W. F. Colby and E. F. Barker, University of Michigan.—The absorption band for ammonia at 10μ has been observed with high dispersion, and analyzed as two overlapping bands with zero branches at 10.3μ and 10.7μ. Each band has the same general structure. About twelve lines have been observed in each branch, the spacing being somewhat different in the two bands, about 18.9 cm^{-1} for one and 20.4 cm^{-1} for the other. There is very little convergence. It is suggested that these two bands result from the two transitions $1/2\rightarrow3/2$, $3/2\rightarrow5/2$ (or perhaps $1/2\rightarrow5/2$, $3/2\rightarrow7/2$) for the same normal vibration of the molecule. The slight change in line spacing is due to coupling. Other ammonia bands previously reported are interpreted in terms of two different types of transition, one in which the second rotational quantum number changes (1.9μ and 2.2μ) and the other where it does not change (6μ and harmonics). The band at 10μ belongs to the latter class. Possible values of the two moments of inertia for the symmetrical pyramid NH_3 are obtained.

85. The infra-red reflection spectra of some carbonates. E. K. Plyler, University of North Carolina.—A rock salt prism was used to examine the spectra of some carbonates. As the source of radiation a material called Globar was used. It was found to be about four times as intense as a Nernst glower in the region of 7μ. The structure of the band of selective reflection of calcium carbonate was studied by reflecting the radiation from the surface of a clear piece of calcite. The slit width was .07 mm. Maxima were found at 6.36μ 6.54μ, and 6.62μ. These different maxima are probably due to the isotopes of calcium. If the three maxima are caused by the isotopic effect, then calcium should have three isotopes rather than two. The reflection spectra for iron carbonate had two maxima. Dolomite also had two maxima.

86. Intensity relations and band structure in bands of the violet CN type. Robert S. Mulliken, New York University, Washington Square College.—Theoretical intensity formulas applicable to bands of the violet CN ($^2S\rightarrow{}^2S$) type are obtained, assuming Hund's case *b*. These predict two *Q* branches (*RQ* and *PQ*) which should appear as weak satellite series, one accompanying the familiar double *P* branch, the other, the *R* branch. These *Q* branches should decrease in intensity from their first members. The first *RQ* (or *PQ*) line should accompany the otherwise single first line of the *R* (or *P*) branch (all other *P* and *R* lines are truly double); this result is in agreement with Hulthén's results on the CaH "*B*" bands. In the *P* (and *R*) branches, the doublet component corresponding to the parallel orientation ($+\epsilon$) of the electron spin vector should be appreciably more intense than that corresponding to the antiparallel orientation ($-\epsilon$) for low *j* values. Treating the doublets (and their satellites) as unresolved single lines, the intensities should be exactly as in $^1S\rightarrow{}^1S$ bands (CuH, HCl). These predictions seem to be confirmed in the CaH, N_2^+, and violet CN bands. Thus the theory appears to afford a satisfactory explanation of the observed lines and intensity relations in $^2S\rightarrow{}^2S$ bands, removing previous difficulties and uncertainties in interpretation.

87. Some unclassified lines of oxygen in the ultraviolet. J. J. Hopfield, University of California.—Some of the ultraviolet lines of the arc spectrum of oxygen not yet fitted into series are $\lambda1152$ and a triplet $\lambda\lambda988.67$, 990.13, and 990.73. These are among the strongest lines and no doubt belong to OI. The triplet is perhaps an unresolved group similar to one in sulphur at λ1480 (unpublished work) which contains eight lines, the normal triplet separation occurring twice. The discrepancy of the separations of the above triplet of oxygen from the normal separation may be explained on this basis. λ1152 is always accompanied by a diffuse band or group on its ultraviolet side. Two single lines λλ1217.62 and 999.47, the latter measured with the carbon line λ1037.021 as standard, occur in the arc spectrum of oxygen with relative intensities of 5 and 7 respectively, the separation of these lines being 17925.6 cm^{-1}. The green aurora line attributed to oxygen has a frequency 17924.7 cm^{-1}. The difference between these two values is 0.9 cm^{-1}, so that the two numbers are identical to within limits of experimental error. This tends to indicate that this aurora line λ5577.35 I. A. is related to the two ultraviolet lines of oxygen, the most plausible relation being that the ultraviolet lines have a common initial or final state and the aurora line represents the transition between their respective final or initial states.

88. X-ray absorption and valence. W. B. MOREHOUSE, Westinghouse Lamp Company.—Experiments reported at the Washington Meetings, April, 1926, suggested that the absorption of heterogeneous x-rays by an element depends upon its valence. Results obtained from the same reactions using zirconium filtered beams indicate the same general results, but the magnitude appears to be somewhat greater, which suggests that the effect may be different for different wave-lengths. From a combination of Moseley's Law with the absorption law it can be shown that at the absorption limit, $d\tau_a/\tau_a=6db/(N-b)$ where τ_a=atomic absorption coefficient at the short wave-length side of the K limit, b=screening constant, and N=atomic number which indicates that if the screening constant changes the absorption coefficient will change. Existing data shows that the emission and absorption spectra depend upon the valence; in general the higher the valence the shorter the wave-length, which from Moseley's law indicates that the screening constant decreases, which in turn indicates qualitatively that the absorption coefficient should decrease with increase in valence. Calculations from the difference in wave-length of the L limits for iodine in the free state and iodine in sodium iodide gives a decrease in absorption of approximately 0.4 percent which is in agreement with experimental results. Hence with change of valence there must be a slight change in the electron configuration of the atom. (This work was done at Cornell University.)

89. Report on the ether-drift experiments at Cleveland in 1927. DAYTON C. MILLER, Case School of Applied Science.—The ether-drift interferometer which was used at Mount Wilson in California in the experiments of 1921–1926 has been mounted on the campus at Case School of Applied Science in Cleveland. Only minor changes, suggested by experience, have been made in the apparatus. Special precautions have been taken to obviate troubles caused by vibration from city traffic. A series of observations which will extend throughout the year, comparable with those made at Mount Wilson, is now in progress. The results for the first epoch of the series indicates an effect of the same order of magnitude as was obtained at Mount Wilson and consistent with the conclusions previously announced.

90. The photo-electromotive force in selenium. R. L. HANSON, Cornell University. (Introduced by F. K. Richtmyer.)—A detailed study was made of the e.m.f. developed in a selenium cell by illumination, an effect originally discovered by Adams and Day in 1876 and later observed by Fritts, Uljanin and others. Careful investigation has shown this not to be a thermal e.m.f. The results of the investigation up to date are the following: (1) For the same illumination the e.m.f. is independent of the current through the cell. (2) Over wide ranges the e.m.f. is directly proportional to the intensity of illumination. (3) For the same intensity of illumination the e.m.f. is a maximum in the region $\lambda=490$.

91. Charge Density in the new mechanics. R. M. LANGER, Naval Research Laboratory, Washington, D. C. (Introduced by G. Breit.)—The Schrödinger expression for the electric moment can be written $\mu^2-1=N_1/(\nu_1^2-\nu^2)+N_2/(\nu_2^2-\nu^2)+N_3/(\nu_3^2-\nu^2)+\cdots$. This is the form of the classical dispersion formula in which the N_i's indicate the number of oscillators capable of emitting the frequencies ν_i. For the case of the hydrogen atom the first terms have the numerical values 1.52, 0.28, 0.06 and the sum of the series gives a value for the refractive index which is larger than that found experimentally (Proc. Nat. Acad. **12,** 639 (1926)). But if we say that in the expression of $\psi\bar{\psi}$ for atoms originally in the state k acted on by a light wave, the terms of the form $C_{nk}u_nu_k$ can be taken quite literally as indicating the presence of charge distributions described as to extension by $u_n\ u_k$ and as to concentration by C_{nk}, and if we say that these just as other ordinary atoms, electrons or molecules are subject to collisions in the kinetic theory sense, then we find since the higher states u_nu_k occupy such large volumes that at the pressures of the experiments (about 1 mm) they collide so often that their contribution to the coherent scattering and therefore to the refractive index is greatly diminished. So far from being a difficulty, what was apparently a discrepancy between theory and experiment becomes on this point of view, evidence in favor of what some may regard as a rather extreme form of the theory.

92. A method for determining sound transmission. F. R. Watson, University of Illinois.—A sound generated in an electric loud speaker by means of an electron tube oscillating circuit is situated on one side of a test wall, or inside a "sound-proof" room. On the other side of the partition is an observer who listens to the transmitted sound. A comparison sound is set up by a microphone placed a fixed small distance in front of the loud speaker, which transmits an electric current through a transformer and variable resistance to a pair of head telephones worn by the observer. The resistance is varied until the telephone tone just masks the sound transmitted through the partition. This measurement is repeated when the observer stands near the loud speaker, which is reckoned as 100 percent. The ratio of the measurements of the transmitted sound to the direct (100 percent) sound gives the percentage of sound transmitted. Preliminary measurements of sound proof rooms gave satisfactory results.

93. Excitation of CuII spectrum by positive neon ions. O. S. Duffendack and J. G. Black, University of Michigan.—The method of Duffendack and Smith of employing positive ions to excite the spectrum of a once-ionized molecule with the exclusion of higher spark spectra was applied to copper. Low-voltage arcs of 20 milliamperes at 25 volts were maintained in mixtures of argon and copper and neon and copper in a tungsten furnace apparatus and their spectra photographed with a Hilger E2 quartz spectrograph. The pressure of the copper vapor was regulated by controlling the temperature of the furnace so that the green arc lines were faintly visible in a direct vision spectroscope. Under these conditions, the argon mixture failed to produce any spark lines. In neon the lines from the levels corresponding to the $(3d)^9$ $(4p)$ and $(3d)^9$ $(5s)$ configurations were strongly developed. These results are in accord with Shenstone's (Phys. Rev. **29,** 380, (1927)) analysis of the spark spectrum as the $(3d)^9$ $(4p)$ levels lie at 15.9 to 16.8 volts and the $(3d)^9$ $(5s)$ at 21.0 to 21.4 volts above the normal state of the coppper atom. Thus argon ions (15.4 volts) just fail to produce the lower state and neon ions (21.5 volts) can just produce both. In the neon mixture the lines from the higher level were considerably more intense relative to those from the lower level than they are in the ordinary spark.

94. The Stark effect in neon. J. S. Foster and W. Rowles, McGill University.—By employing a rather strong Lo Surdo source in which a maximum field of 130,000 v/cm was developed, the earlier observations by Nyquist have been somewhat extended. The observed symmetrical Stark patterns for the line groups of higher order (notably $2p_j-6q$ and $2p_j-7g$) are *remarkably hydrogen-like* in character. In these groups the complex nature of the initial states is not detected by the Hilger E1 spectrograph. On the other hand, each of the lines $2p_j-4f$ and $2p_j-5f$ appears as a doublet and the two members of the doublet present Stark-effects which are nearly identical. This effect is similar to that noted in orthohelium, where the multiplicity is in the final state. The initial terms involved in the production of the group of new lines which commonly appear in the electric field are more hydrogen-like than the diffuse terms, and consequently the majority of these lines have exceptionally large displacements. On the present plates some are displaced more than 50A. Another large group of new lines appear, however, without appreciable displacements, but with intensities which increase rapidly with the field. These ionized neon lines simply indicate the proportion of Ne$^+$ atoms in the various fields.