PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE WASHINGTON MEETING, APRIL 18–20, 1929

The 157th regular meeting of the American Physical Society was held in Washington, D. C., on Thursday, Friday and Saturday, April 18–20, 1929. The Thursday and Friday sessions were held at the Bureau of Standards in the East Building and the Industrial Building. The Saturday sessions were held at the National Academy of Sciences. The presiding officers were Professor H. G. Gale, President of the Society, and Dr. W. F. G. Swann, Vice-President of the Society. Friday morning was devoted to a Symposium on Dielectrics. The papers for the Symposium were invited and the titles appear with the following abstracts, numbers 47 to 54, inclusive.

On Friday evening there was a dinner for the members of the Society and their friends at the Cosmos Club. President Gale presided and the speakers were the guests of honor, Professors F. Hund, W. Heisenberg, L. S. Ornstein and A. Sommerfeld. Music was furnished by Professor Sommerfeld, Professor Heisenberg and Dr. Swann.

At the regular meeting of the Council held on Friday, April 19, 1929, one was elected to fellowship, two were transferred from membership to fellowship and twenty-eight were elected to membership. *Elected to Fellowship:* Addams S. McAllister. *Transferred from Membership to Fellowship:* Carleton C. Murdock and J. R. Oppenheimer. *Elected to Membership:* Walter E. Albertson, Thomas Alty, Arthur H. Barnes, Ralph W. Barnes, Julius V. C. Bucher, J. D. Cockcroft, Mabelle C. Dame, N. A. de Bruyne, J. B. Derieux, A. A. Dixon, J. B. Edwards, Lawrence Y. Faust, F. E. Fowle, Bernhard Frey, Robert C. Garth, Samuel D. Gehman, Walter A. Greig, Harvey Hall, Albert G. Ingalls, Montgomery H. Johnson, Jr., Ben Kievit, Jr., Gerald Kruger, S. E. Rodgers, Albert E. Shaw, A. Melvin Skellett, Szczepan E. Szczeniowski, J. Chester Swanson, Morgan Williams.

The regular program of the American Physical Society consisted of 135 papers, numbers 6, 10, 17, 18, 33, 38, 39, 40, 44, 45, 46, 68, 85, 89, 90, 98, 99, 105, 107, 108, 112, 114, 117, 126, 129, 130, 131, 132 133 and 135 being read by title. The abstracts of the papers are given in the following pages. An **Author Index** will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. Electron scattering in hydrogen. G. P. HARNWELL, *Princeton University.*—With an apparatus which has been previously described (Phys. Rev. **31,** 634 (1928)) an analysis has been made of the scattering of electrons in hydrogen. The electrons used had energies of from

40 to 200 equivalent volts. The angular distribution of the scattered electrons varied but little throughout this range. The only tendency noticeable was that the curves in which the number of elastically scattered electrons was plotted against the scattering angle dropped more sharply for the electrons with higher velocities. An attempt has been made to compare the observed distribution curves with those which would be expected on the assumption of different laws of force for the scattering centers. The results show that the scattering is very much greater than can be accounted for by an inverse square law or a law based on either Hartree's or Thomas' atomic field theories. No direct wave-mechanical calculations have been made for the scattering of electrons by molecular hydrogen, but the calculations have been carried through in detail for the scattering by atomic hydrogen. These calculations are the only ones which approach the experimental results in order of magnitude. The experimental points obtained in molecular hydrogen lie quite well on the calculated curve for atomic hydrogen.

2. On the theory of electron scattering in gases. Allan C. G. Mitchell, *Bartol Research Foundation of the Franklin Institute.*—The scattering of electrons in gases is here treated by the Born wave-mechanical method, using however for the potential energy of the electron in the field of the atom, an energy calculated on the basis of the Fermi statistical theory of atomic fields the first approximation wave equation, in spherical coordinates r, θ, ϕ, is

$$\nabla^2\psi_1+k^2\psi_1=k^2(V/E)\psi_0; \qquad k=8\pi^2mE/h^2$$

where $\psi_0=e^{ikx}$ and $x=r\cos\theta$, the equation for the oncoming electron wave, and ψ_1 is the wave function for the scattered wave. From the statistical potential theory we take $V(r)=-(Ze^2/r)\Phi(r/\mu)$. The solution of the wave equation is

$$\psi_1=\frac{k}{2E}\,\frac{Ze^2}{\sin(\Theta/2)}\,\frac{e^{ikr}}{v}\int_0^\infty\Phi\left(\frac{\rho}{\mu}\right)\sin\left(2k\rho\sin\frac{\Theta}{2}\right)d\rho.$$

The ratio of the number of particles scattered through an angle Θ to the number falling on the atom is

$$P=\left|\frac{\psi_1}{\psi_0}\right|^2=\left[\frac{k}{2E}\,\frac{Ze^2}{r}\right]\frac{1}{\sin^2(\Theta/2)}\left[\int_0^\infty\Phi\left(\frac{\rho}{\mu}\right)\sin\left(2k\rho\sin\frac{\Theta}{2}\right)d\rho\right]^2.$$

For $\Theta=0$ the number, of particles scattered is finite. The number of particles scattered is a maximum for $\Theta=0$ and a minimum for $\Theta=\pi$. The results are in qualitative agreement with a modification of Born's method proposed by Sommerfeld and with experiment.

3. A new method of recording electrons. Percy H. Carr, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—When electrons even at relatively low velocities impinge upon the surface of some metals, the properties of the metal surface are changed so that some vapors react toward the bombarded portion in a different manner than toward the unbombarded portion. Use is made of this fact to record the electron "lines" in a magnetic spectrograph. For instance, a gold plate after exposure in the spectrograph is held over hot mercury. Generally, the mercury vapor amalgamates the gold more readily on the unbombarded portions, and the exposed "lines" appear dark against a gray background. Metal plates when "developed" in the proper vapor are the equal of photographic plates for this purpose when the speed of the electrons is about 30 equivalent volts. For slower speeds the metals are much superior, and definite traces have been recorded below 15 volts. The metals used are gold, silver, copper, and zinc.

4. The diffraction of electrons by a copper crystal. H. E. Farnsworth, *Brown University.*—A sharply defined beam of electrons is directed normally against the {100} face of a copper crystal. The apparatus is so arranged that the total secondary electron current may be measured under the same conditions as the angular distribution, for bombarding potentials as low as 1 volt. Electron beams are found to issue from the crystal in the low voltage region at the bombarding potentials for which maxima occur in the total secondary electron curve. Electron beams which are the x-ray analogues, and which require a refractive index greater than unity, have been found in the region below 150 volts. In addition, other sets of beams are found which may be accounted for by assuming a wave-length for the electron which is one-half that given by the formula $\lambda = h/mv$. These beams also require a refractive index greater than unity. The sets of low voltage beams, with one exception, are of this latter type. This exceptional set, which occurs at about 3 volts, is not accurately reproducible.

5. The absorption coefficient of slow electrons in alkali vapors. ROBERT B. BRODE, *University of California.*—The absorption coefficient (α) or the reciprocal of the mean free path of electrons has been measured in the vapors of Na, K, Rb, and Cs. The apparatus used was a modified form of the type originally described by Ramsauer. The velocity of the electrons was varied between 0.5 volts and 400 volts. The shapes of the absorption curves for the 4 vapors were nearly the same except in magnitude. From 400 volts down to about 4 volts the curves were approximately hyperbolic, fitting the equation $\alpha = K/(\text{volts})^{1/2}$ where K has the values 1350, 1850, 2060, 2600 for Na, K, Rb and Cs respectively. α is expressed in cm^2/cm^3 for a pressure of 1 mm of Hg at 0°C. Below 4 volts the curves rise to maximums between 2 and 3 volts and then decrease to minimums at less than a volt. A further increase is then observed for lower velocities although the measurements are there not in close agreement. The size of the atoms as compared with the electron probability distribution is in good agreement. Except for the maximums at low velocities the shape of the curves is in agreement with the shape predicted by the wave mechanics for hydrogen atoms.

6. Refocussing of electron paths in a radial electrostatic field. A. L. HUGHES, V. ROJANSKY, AND J. H. MCMILLEN, *Washington University, St. Louis.*—If a beam of electrons of identical velocities enters a uniform magnetic field through a narrow slit in a partition bounding the field, the electrons describe circular paths. It is well known that if the entering electrons make but small angles with the normal to the partition a refocussing of the paths occurs after the path of the normally entering electrons has turned through 180°. The behaviour of electron paths in an inverse first power, radial, electrostatic field has been investigated, and it has been found that refocussing should occur when the path of the normally entering electrons has been turned through 127° 17′. This position should play the same part for the electrostatic case as does the 180° position for the magnetic case. The departure from perfect refocussing, and the resolution between different velocities, should be of the same respective orders as the corresponding quantities in the magnetic case. An apparatus was constructed to test the theory. The radial field was produced by a difference of potential between two pieces of metal machined to co-axial cylindrical surfaces. Satisfactory refocussing of electron paths entering the field at ±5° with the direction of perpendicular entrance was found.

7. Wave-length measurements of γ rays from radium and its products. LUVILLE T. STEADMAN, *Yale University.*—These measurements as reported in the Physical Review **33**, 120 (1929) have been continued with greater accuracy. Also, counting has been done with the crystal turned through an angle of 10°, thereby causing the diffracted rays of all wave-lengths to be changed in direction so that they cannot enter the chamber, but all other conditions remain the same. This method gives the background of the spectrum directly and from it a simple means of obtaining the relative intensities of the lines. Counts taken when the chamber slits are at a position which gives a line but taken now with the crystal turned, counts obtained both for the crystal set and when turned with the slits not on the line but nearby where a continuous spectrum would show up, are all of the same value which points to the absence of a continuous spectrum of γ rays. The twelve lines of shortest wave-length measured are as follows in X.U.: 8.72, 7.45, 6.78, 5.55, 4.97, 4.12, 3.38, 2.86, 2.38, 1.59, 0.95, 0.42. A diamond crystal will be used to check these short wave-lengths.

8. Basis for computing the age of a mineral. ALOIS F. KOVARIK, *Yale University.*—Calculation of the age of a mineral is based on the analysis data giving the uranium, thorium and lead contents and the atomic weight of the lead. Presence of common lead, various disintegration constants and atomic weights, and no alteration of contents except by radioactive changes are assumed. Formulae for the age and for the amount of common lead are deduced. Also, a formula giving the amount of common lead in a mineral to a fair degree of approximation is developed in terms of the same data which when applied as a correction to the lead found by analysis makes it possible to obtain the amount and the atomic weight of the lead formed by the radioactive disintegration, thus enabling the use of the formulae ordinarily used when the presence of common lead is ignored as is the usual but erroneous practice.

9. An apparatus for the determination of ionic mobilities. OSWALD BLACKWOOD, *University of Pittsburgh.*—A device for determining ionic mobilities has been made which is analogous to Fizeau's apparatus for determing the velocity of light. An electrometer plate and two pairs of grids are mounted at distances 5.6 cm, 5.4 cm, and 3.5 cm above a 20 cm brass disk. Ions produced by a polonium plaque near the disk tend to be driven upward by electric fields in the lower and upper compartments. Opposing fields in each of the grid pairs prevent the passage of ions except for brief intervals, periodically, when two commutators simultaneously reverse the fields. Passage of a thin sheet of ions through both grid pairs will occur when the period of the commutator equals the time for the ions to pass from the lower to the upper grid. From this period, the voltage between the grid pairs, and their distance of separation, the mobility of the ions may be computed. Using this arrangement, the time required for the elimination of fifty percent of the initial, positive, monomolecular (?), ions in undried air has been found to be 0.011 seconds, which is in accordance with Erikson's value. This method is superior to the "blast" method in that turbulence is eliminated and that the purity of the gases may be controlled by enclosure of the apparatus.

10. Factors affecting the nature of the ions in the air. HENRY A. ERIKSON, *University of Minnesota.*—It has been previously found that the rate of transition of the initial positive ion in air depends upon how the air used has been treated. In this paper results are given showing that in the case of air dried by passing through drying agents like P_2O_5 and $CaCl_2$ the transition is very rapid, but that when the air is dried by passing through coils immersed in liquid air the initial positive ion transforms very slowly. It is also shown that products due to the ionizing process cause a rapid transition of the initial ion.

11. Motion of positive ions in a plasma. L. TONKS AND I. LANGMUIR, *General Electric Co.*—Heretofore it has been assumed that positive ions in a plasma have a "temperature" approximating one-half the electron temperature to account for the positive ion currents which flow to electrodes and the walls. This assumption causes theoretical difficulties which are overcome by supposing that each new positive ion has the small temperature of a gas atom and accelerates only under the influence of fields arising from the tendency of the high temperature electrons to flow away. Thus a collector does not measure a positive ion current which exists independently of its presence but rather causes fields which impel positive ions toward it. The calculated potential distribution across the positive column of an arc checks the observed quantitatively, and other experimental results can be explained. The theory gives a new relation $a\lambda = s_0(2kT_e/m_p)^{1/2}$, a = discharge tube radius, λ = ions per electron per second, s_0 = known constant. This equation, an ion current equation, an ion generation equation, an electron mobility equation, and the energy balance equation are available now and are sufficient to fix λ, T_e, ion current density, ionization intensity, and longitudinal field in terms of arc current.

12. The influence of shape on the efficiency and stability of permanent magnets. D. P. RANDALL, *Syracuse University.*—The magnetic energy delivered to an air gap by a given weight of steel depends on the following factors: inherent magnetomotive force of the steel, degree of stabilization required, leakage and fringing flux between the limbs and pole pieces of the magnet. Each of these factors is greatly modified by the shape and proportions of the magnet and its pole pieces. A method is developed for correlating these various factors with the magnetic characteristics of the steel: residual induction, coercive force or potency, and incremental permeability. Curves are given showing efficiencies attainable with various gap energy densities and degrees of stabilization. Efficiency is defined as the ratio of magnetic energy in the air gap to maximum magnetic energy inherent in the steel; degree of stabilization, as the ratio of the maximum stray field not permanently affecting the magnetization to the field intensity maintained in the air gap. Comparison is made on this basis between tungsten, chromium, and some of the high coercive cobalt steels. Advantages of cast magnets in relation to stability are also considered. As applied to a meter magnet of tungsten steel, charts are given showing proper proportions for maximum efficiency over a considerable range of gap lengths and degrees of stabilization. By application of the principle of similitude these charts may be made to give specific dimensions for a magnet of any desired size.

13. Determination of the average size of the discontinuities in magnetization. RICHARD M. BOZORTH, *Bell Telephone Laboratories.*—The theory of the determination is analogous to that of the small shot effect. Instead of determing $n\epsilon$, the charge that moves as a unit in a conductor, nm_a is determined, where m_a is the change in magnetic moment corresponding to the reversal of one atom and n is the number of atoms which act together to produce one of the impulses of the Barkhausen effect. Since the moment corresponding to one atom reversal is known, the mean value of n can be determined from the equation which is derived for a cylindrical sample of magnetic material: $\overline{i^2} = A\bar{n}m_a(dB/dt)/\mu_r$, where $\overline{i^2}$ is the mean square current measured, A is a known constant depending on the amplifier and other apparatus, dB/dt is the mean time rate of change of induction, and μ_r is the reversible permeability. The fundamental relation used in deriving this formula is that deduced by T. C. Fry in his theory of the small shot effect [Jour. Frank. Inst. **199,** 203–20 (1925)]. The value of $\bar{n}$ (about 10^{15}) is found to be greatest near the steepest part of the hysteresis loop and to diminish rapidly as the end of the loop is approached.

14. Magnetic properties of iron crystals. DONALD FOSTER, *Bell Telephone Laboratories.*—Large crystals were grown by annealing hard drawn wires of electrolytic iron in vacuum. The method of growing differs from the well-known means developed by Edwards and Pfeil in several essential respects. The crystals are 0.1 cm in diameter and from a few millimeters to 15 cm in length. Measurements by an x-ray rotation method show that the wire axis always lies at a considerable angle to the nearest (111) direction, but is otherwise unrestricted. The magnetic data were obtained by means of a new method whereby the demagnetizing field is experimentally determined for each crystal. The hysteresis loop is characterized by extremely steep sides with sharp corners and high remanence. The coercive force for $H_{\max} = 30$ gauss is 0.4 gauss and in respect to the effect of orientation there is qualitative agreement with earlier work. Contrary to reports by previous investigators we find no "breaks" at the knee of the magnetization curve. The initial permeability is about 175. The maximum permeability occurs at a field intensity of about 0.8 gauss. The effect of tension is being investigated.

15. A theory of light. GLEN H. DRAPER, *U. S. Naval Observatory, Washington, D. C.*—Accepting the law of cause and effect as an absolute law and accepting the mathematics perdicated on this law, the theory propounds: (a) That space is a three-dimensional void, except as occupied by matter and light. (b) That the nature of matter is determined by its normal light content or the normal energy relations existing between electrons and their nuclei. (c) That the velocity of light through any substance tends toward a constant velocity by a measurable value. (d) That the velocity of light indicates the center of force, as gravitation indicates the center of mass. The theory may be applied to the Michelson-Morley experiment and offers an explanation of why Dr. Roy Kennedy obtained a zero result from his recent experiments, while Dr. Dayton C. Miller obtained a small positive result.

16. The electronic theory of light and other forms of electromagnetism. HERBERT J. BRENNEN, *Department of Chemistry, Northwestern University.*—My hypothesis, (Journal of the Franklin Institute, **202,** 828–831 (1926)) that light is corpuscular and that the corpuscles are electrons, is further developed on the basis of Newtonian dynamics. It is found that (1) the electric charge e of a moving electron is given by: $e = e_0(1-\beta^2)^{1/2}$ where e_0 is the electric charge in E. S. U. of a stationary electron, whence follows (2) the Lorentz-Einstein formula and (3) Sommerfeld's Theory of the fine spectral structure. From (1) when $\beta = 1$, we have: (4) the electric charge of an electron moving with the speed of light is zero and hence will not be deflected by an electric or a magnetic field. It is further shown that (5) the velocity of light is given by: $c = e_0/(Kmr)^{1/2}$ where m and r are the mass and radius of the electron and K is the specific inductive capacity of the medium. Since K is known by experiment to be proportional to the square of the refractive index of the medium, we have (6) the velocity of light is inversely proportional to the refractive index of the medium. For a vacuum, $K=1$, and hence (7) the number of natural constants is reduced by one.

17. Group velocity. D. G. Bourgin, *University of Illinois.*—In the Phys. Rev. **33,** 239 (1929) Tonks suggests the interesting empirical theorem; $\mu E=vE_i$ where μ and v are the group and phase velocities and E and E_i are the total and doubled reactive energies/unit length respectively. The conditions for the validity of this and similar theorems have been developed. In particular, it turns out that the theorem does not hold in general if the characteristic linear differential equation involves higher space derivatives than the second—the physical interpretation is immediate.

18. The optical constants of solid mercury. Rollin Smith Baldwin, *Yale University.*—The optical method and apparatus used was essentially the same as that of O'Brien (Phys. Rev. **27,** 93 (1926)). A vacuum of the order of 10^{-5}mm of Hg and suitably placed liquid air traps reduced any error due to adsorbed gases or vapors condensing on the free surface of the Hg below an amount detectable by the method of measurement. Distillation of the Hg both in vacuo and a continuous current of air (2–3 cm press.) was found necessary to obtain Hg of the required degree of purity. The values for the absorption coefficient showed no appreciable change, but the values of the index of refraction for the solid state were greater by approximately 10 percent or more than those of the liquid state for the wave-lengths of light used (λ5790–69, λ5460, λ4358). Although this is contrary to results of Haak and Sissingh (Proc. Royal Acad. Amsterdam **21,** 691 (1919)), it is believed that the change is due to a change in the optical constants with the change of state of the Hg itself, and not to spurious effects.

19. On the continuous spectrum of mercury. Lieut. W. N. Thornton and W. H. Crew, *Postgraduate School, U. S. Naval Academy.*—The continuous spectrum of mercury has been photographed with a small quartz spectrograph and evidence supports the view that it is due to the recombination of electrons with molecules, or, what amounts to the same thing, with atoms held in molecular bond. The source of radiation was a mercury arc [J.O.S.A. **17,** 261 (1928)] operating at atmospheric pressure and at about 500°C. A low current, low voltage, high frequency, condensed discharge in the vapor between two liquid mercury surfaces gave a spectrum consisting of two very strong bands (maximum intensities at about λ4500 and λ3300) and four extremely weak lines: (λ5461; λ4358; λ4047; λ2536).

20. The refractive index of sodium vapor. S. A. Korff, *Princeton University.*—Continuing the study of the refractive index of sodium vapor in relation to the widths of the D lines in absorption, (Phys. Rev. **32,** 584 (1929)) more accurate values are obtained. Plates showing the fringes formed by the rapidly varying refractive index were obtained, and measured on a microscope, showing classically predicted values to hold to better than 1 percent an increase in accuracy over the previously reported value (8 percent). The plates were also examined on a densitometer.

21. Energy distribution in the solar ultra-violet spectrum. Brian O'Brien, *Buffalo Tuberculosis Association, Perrysburg, N. Y.*—Energy distribution in the solar spectrum was measured by a method previously described (Phys. Rev. **33,** 640 (1929)) from Dec. 24 to Mar. 21 from λ3300A to λ3007A on Dec. 24, and to λ2939A on Mar. 21 at a station 42° 27′ N. lat. and 1480 ft. elevation. Where necessary scattered light of longer wave-length was eliminated by preliminary dispersion with a 30° quartz prism. Atmospheric transmission was measured to λ2953A on several days near the equinox of uniform sky conditions as determined by a recording radiometer. A curve of atmospheric opacities reduced to zenith sun lies parallel to but slightly below that of Fabry & Buisson (Astrophys. J. **54,** (1921)). Error of a single log intensity determination is less than 0.05 and systematic errors are an order of magnitude less than this as has already been shown. Error in λ is less than 1A. Intensities were reduced to absolute units by a calibrated thermopile and silver film on quartz filter.

22. The attenuation of ultra-violet light by the lower atmosphere. L. H. Dawson, L. P. Granath and E. O. Hulburt, *Naval Research Laboratory.*—Measurements were made with a quartz mercury lamp, a quartz spectrograph and a recording densitometer of the attenuation of ultra-violet light from 3000A to 2050A by the atmosphere at sea level. For wave-lengths longer than 3000A no absorption could be observed at distances up to 400 meters; for wave-lengths below 2800A there was pronounced absorption above that attributable to molecular scattering. The absorption was the same day and night, was unaffected by changes in the humidity, but increased with haze. The thicknesses of clear air necessary to reduce the light to 10^{-2} were about 22, 5, 0.57 and 0.20 km for 2800, 2500, 2200 and 2050A, respectively. The absorption in the lower atmosphere around 2800 to 2900A was not sufficient to account for the sharp cessation of the solar spectrum in this region. This result is in keeping with the fact that the ultra-violet limit of the solar spectrum is due to ozone in the high atmosphere. The absorption in the lower atmosphere at 2200 to 2050A, a spectrum region where ozone is relatively transparent, is great enough to prevent sunlight of these wave-lengths from penetrating to sea level.

23. The absorption of light by fog. L. P. Granath and E. O. Hulburt, *Naval Research Laboratory, Washington, D. C.*—Measurements between two stations 0.4 km apart with a thermocouple and galvanometer and with spectrograms, properly calibrated, of the absorption of light by fog for wave-lengths from 0.4 to 3μ showed that the absorption increased slightly with decrease in wave-length, but hardly enough to indicate that red light is appreciably better than blue light for the purpose of penetrating fog. For a fairly dense fog, such that in daylight dark colored objects at about 0.6 km could barely be seen, the distances necessary to reduce the light to 10^{-2} of its original value were about 710, 843, 910, 970, 980 and 980 meters for wave-lengths 0.4, 0.5, 0.6, 1.0, 2.0 and 3.0μ, respectively.

24. Absorption of ultra-violet light by oxygen, water vapor and quartz. L. P. Granath, *Naval Research Laboratory.*—Quantitative measurements were made of the absorption of light by oxygen, water vapor and crystalline quartz in the spectral region 1900 to 2100A, by means of a quartz spectrograph and a recording densitometer. Defining the absorption coefficient α by $I=I_0 10^{-\alpha d}$ where d is the distance in cm, values of α were obtained for oxygen at atmospheric pressure in tubes up to 5 meters in length which showed the peaks of absorption due to the Schumann-Runge band system below 1970A. From 2000 to 2100A the absorption appeared continuous with no marked peaks, α being 0.00025, 0.00032, and 0.00050 cm^{-1} at 2100, 2050 and 2000A, respectively. The values of α for saturated water vapor at 25°C were 0.0005, 0.0013 and 0.003 cm^{-1} for wave-lengths 2050, 1950 and 1900A. For a specimen of crystalline quartz 2.5 cm thick α was found to be 0.086, 0.11, 0.13 and 0.17 cm^{-1} for wave-lengths 2040, 2000, 1940, and 1870A.

25. The development of "thermodynamic symbolism"—second paper. John Q. Stewart, *Princeton University.*—At the February meeting the proposition was advanced that the formulae and concepts of thermodynamics, when interpreted symbolically, form a structure of mathematical relations which is applicable for the coordination (and discovery) of principles in each of numerous special fields in physics. The present paper treats in this manner a problem in mechanics and electrostatics—that of particles acting on one another with forces which vary as some function of the distances. To such a system energy can be communicated in two ways. When a given particle is moved under the influence of an arbitrary force, work is supplied. On the other hand energy must be supplied when the mass present in any volume-element in the field of potential is varied. Such increments of energy may be taken as the analogue of heat in thermodynamics. Potential is the analogue here of temperature. Accordingly the discussion of the mechanical problem proceeds along thermodynamical lines.

26. Classification of physical laws: periodicity of physical concepts. Victor Cofman, *E. I. du Pont de Nemours and Co.*—A tabular arrangement of the *extensive* factors: mass (M) volume (V), entrophy (S), time (t), and their corresponding *intensive* factors: molar free energy (dE/dM), pressure (dE/dV), temperature (dE/dS) and power (dE/dt), gives a set of 28 laws.

Some of these are well-known laws; other have not been clearly stated as such. They can all be deduced from an extension of a well-known thermodynamic equation, namely $(FdM-PdV)+(TdS-Xdt)=0$. The symmetry of this equation suggests that entropy extends in time, just as mass extends in space. This is a fruitful concept because entropy can be taken as a measure for change or happening, and time becomes a thermodynamic variable. Planck's constant h, as shown by J. Q. Stewart also, is the entropy analogue in the radiation system; a quantum wave has constant value at different *places* for the same reason that a gram weight has the same mass at different *times*. Laws of electronic or gravitational systems can also be tabulated, by the substitution of suitable variables: i.e., gravitational force, or e.m.f., in place of gas pressure, (velocity)^2 instead of temperature, etc. Equations like

$$dP/dp=v/V; \qquad dP/(pdh)=-g/(RT);$$
$$E=E_0+RT/(nF)\ \ln c;$$
$$-P_0=(RT/V)\ \ln p+\text{const}; \ \Gamma=-(cd\sigma)/(RTdc)$$

should be identical in form.

27. The curvature radius of space-time derived from 24 Cepheid variables and 35 O-stars. LUDWIK SILBERSTEIN, *Research Laboratory, Eastman Kodak Co.*—The combination of the expressions for the spectroscopic radial velocity and the transversal velocity (proper motion) of a star in isotropic (deSitterian) space-time gives for the curvature radius R the statistical formula

$$R^2/c^2=[(\overline{r_1^2 v_{r2}^2/v_1^2})-(\overline{r_2^2 v_{r2}^2/v_2^2})]/(\overline{v_1^2}-\overline{v_2^2})$$

where r is the distance, v the resultant, v_r the radial velocity of a star belonging to one of two groups of stars, marked by the suffixes 1 and 2, and the bars indicate averages taken over each of these groups. This formula applied to two groups of Cepheid variables, each consisting of 12 objects, gives $R=3.01\times10^{11}$ astron. units, and applied to thirty-five 0-stars, split into groups of 17 and 18, yields $R=3.25\times10^{11}$ astron. units. Since scarcely more that two figures are dependable, these two estimates of the world radius are to all purposes identical. Both are about 20 times smaller than that derived (1924) from 18 globular clusters and the Magellanic clouds. But there are weighty reasons for relying more upon this new value. This is most impressively corroborated by the results just obtained (April 7) from 246 stars from Young and Harper's list, viz. 3.39×10^{11}.

28. A new electromagnetic effect and its application to a theory of the permanent magnetic field of the sun and earth. ROSS GUNN, *Naval Research Laboratory.*—A study of the motions of ions as they spiral about an impressed magnetic field shows that a two-fold effect is produced (1) a diamagnetic effect, dependent on the field strength (2) a systematic ion drift, dependent on the gradient of the field. The ion drift is considered and expressions obtained for the current density. Under the conditions of radial symmetry and a closed circuit a current flows, in such a direction as to reduce the inhomogeneity of the impressed field and *increase* the total flux enclosed by the current circuit. This increase in flux suggests that the phenomenon is regenerative. Application to the sun shows that westward currents flow in the solar atmosphere accounting for the observed magnetic moment. Diamagnetic data indicate, however, that the observed vaule is 1/230 of the actual value. The seat of the largest currents appears to be in regions of short free paths well within the sun. Similar arguments apply to the earth and the correct magnetic moments are found in each case if the mean gradient is taken equal to that observed at the surface and if the mean free paths of the ion approach 10^{-6} cm. On the present view the magnetic field arises from the thermal energy of the sun and earth and has no direct connection with its rotation.

29. Resonance in circuits with parallel resistances. ALLEN ASTIN, *National Research Fellow, Johns Hopkins University.*—Jezewski (Zeits. f. Physik, **48**, 123 (1928)) and Doborzynski (Zeits. f. Hochfrequenz., **31**, 15 (1928)) have shown theoretically that in a resonance circuit of inductance, capacity and parallel non-inductive resistance the value of the capacity for maximum p.d. across it is independent of the value of the parallel resistance. The author (Dissertation, New York, 1928) has shown that the same condition holds when a non-conducting condenser is placed in series with the shunted condenser. This type of resonance may be detected with either a vacuum tube voltmeter or a thermocouple connected as the parallel resistance. By using the former method of detection the relation is verified at a frequency of 2×10^6 with resistances as low as 100 ohms (d.c. value) for the first circuit and down to 30 ohms for the series circuit. The resistances used for the test are capillaries filled with carbon particles. In comparing the two circuits it is shown for small values of the parallel resistance (less than 1000 ohms) the voltages across the shunted condenser at resonance are much greater in the series circuit than in the simple one. The circuits are considered because of their value in measuring the dielectric constants of conducting liquids.

30. Rectification by oscillation of positive ions about the potential minimum of a thermionic triode. K. H. KINGDON, *General Electric Co.*—Positive ions are trapped in the potential minimum surrounding the cathode and have a natural frequency of oscillation about it. An alternating voltage of the same frequency (10^5 to 10^6 cycles) applied between grid and cathode sets the ions in motion, and leads to a decrease in the electron current to the anode. This rectification effect has been reported previously [Science, **68,** 599 (1928)] for caesium ions generated at the cathode. It has now been studied for ions of other gases made by electron collision between grid and anode. By using a low voltage caesiated filament as cathode, separate rectification peaks may be obtained for the ions of each of the argon and neon isotopes. Helium shows two peaks whose separation is that of ions having masses 4 and 5. It is uncertain whether the 5 peak can be attributed to He H (Aston). Oxide coated equipotential cathodes apparently usually do not have sufficiently uniform surfaces to separate the isotopic peaks. Detection in the old argon filled detector tubes is due to this ionic rectification.

31. Forced electric oscillations in three circuits with electromagnetic coupling. W. J. SETTE AND R. E. MARTIN, *Lehigh University.*—Three circuits containing inductance, capacitance, and resistance, each of the circuits being coupled by a mutual inductance to the others, were considered. From the differential equations showing the potential drops in the networks with a sinusoidal electromotive force in the circuit designated 1, the values of the currents flowing in the circuits were obtained. The expressions for the current amplitudes in the networks 2 and 3, I_2 and I_3, are symmetrical, but the expression for I_1 is different. The resonance relations were calculated. To check the theory apparatus in accord with the hypotheses was set up. Taking each current as a function of the reactance in its own network the curve I_k against X_k exhibits the ordinary resonance peak and zero asymptote. Considering I_2 with X_3 variable, it has a maximum, minimum, and a horizontal asymptote not zero. Supposing I_1 a function of X_3 there are again a maximum, a minimum, and a determined asymptote. The experimental curves agree with those indicated by the theory. Some equations have been checked to within a few percent though accurate check is difficult.

32. Some characteristics of electric sparks excited by an ignition coil. R. A. WOLFE AND O. S. DUFFENDACK, *University of Michigan* AND D. W. RANDOLPH, *The A C Spark Plug Co.*—Investigations have been made with a high vacuum cathode-ray oscillograph on various characteristics of an electric spark excited by an ignition coil. The peak voltage depends on the material of the electrodes and is less for materials of low work of extraction of electrons. Th. peak voltage of a spark gap has been correlated with the thermionic emission of the electrodese The voltage across the gap rises from zero to its maximum in from one to two microseconds, the time being affected to some extent by the capacitance of the circuit. The spark current has small superposed oscillations at its beginning. Increasing the capacitance in parallel with the gap increases the duration of the superposed oscillations, increases the maximum value of the current, and also increases the time required for the current to reach its maximum. Added capacitance completely changes the amount of energy dissipated in the several phases of the spark. The maximum power of a spark with a capacitance of $750\mu\mu f$ in parallel with the gap has been observed to reach 66 kilowatts.

33. Resistance of air condensers. R. R. Ramsey and B. D. Morris, *Indiana University.*—The method of measurement is the differential thermometer method as used by Ramsey (Phys. Rev., **27,** 815 (1926)) except that iron-advance thermocouples were used to determine thermal equilibrium. Measurements were made at wave-lengths of 125 to 410 meters with capacities varying from 0.00001 to 0.00054μf. The resistances obtained ranged from 0.076 to 11 ohms. When these results are reduced to "standard conditions" by the empirical formula, ($R_s = R(300/\lambda)(C/.001)^{3/2}$) the value of R_s ranged from 0.0078 to 0.0132 ohms. The values obtained by applying the formula to Ramsey's data are practically the same as the above. Applying the formula to Dye's (Proc. Phys. Soc. Lon., **40,** 285 (1928)) data, which were obtained by a substitution method, R_s ranged from 0.0021 to 0.006 ohms. Dye's measurements were made at 200 to 15000 meters. Applying the formula to measurements made by the resistance variation method higher results are obtained. The measurements by Weyl and Harris (Proc. Inst. Rad. Eng., **13,** 109 (1925)) made at wave-lengths 96 to 260 meters with resistances from 0.71 to 18.5 ohms give values of R_s ranging from 0.41 to 1.33 ohms. Callis' (Phil. Mag., **1,** 428 (1926)) data give a mean value of 0.98 ohms for R_s. Brown, Wiebusch and Colby's (Phys. Rev., **29,** 887 (1927)) data give values for R_s ranging from 0.26 to 0.56 ohms.

34. Properties of Rochelle salt as a dielectric with Braun tube oscillograms. C. B. Sawyer and C. H. Tower. *The Brush Laboratories Co., Cleveland, O.*—Both saturation and hysteresis appear in Braun tube oscillograms made at various temperatures with a condenser whose dielectric consists of Rochelle salt slabs cut perpendicular to the *a*-axis. Some polarization effects are observable. Curves are also given, showing the variation in mechanical and electrical saturation with temperature. These correspond in only a general way to the piezoelectric constant's variation with temperature. Certain marked peculiarities are noted in the resulting mechanical deformation when Rochelle salt is excited with alternating potentials. Clear Rochelle salt half-crystals have been produced up to forty-five centimeters in length.

35. Mechanism of dielectric breakdown in thin layers. F. E. Null and J. B. Edwards, *Georgia School of Technology.*—Whitehead has shown that it is practically impossible to remove the last traces of moisture from paper insulation. To determine whether moisture was responsible for pyroelectric breakdown in impregnated papers on d.c. potential, we made a study of the electrical characteristics of 0.0005 inch, unimpregnated, linen condenser paper for different moisture contents. We were able to separate the effects of hot spots and ionization by collision, upon the breakdown potential, by the variation with the number of layers tested, of the current-voltage characteristics, the conduction current, and the breakdown potential. For atmospheric pressure and a relative humidity of 22.5 percent breakdown was due to hot spots, the breakdown potential per layer being approximately constant from 1 to 16 layers, thus indicating lateral, thermal conduction from the hot filaments. Breaks in the characteristics present strong evidence of some ionic discharge wich does not affect the breakdown potential. Tests for paper dried in vacuum are complete; others for paper dried by heat and vacuum, and impregnated with dry air under pressure are in progress.

36. Dielectric polarization potential and the law of superposition for hard rubber. H. H. Race and J. R. Campbell, Jr., *Cornell University.*—If a constant potential E_1 is applied to an imperfect dielectric like hard rubber, there is evidence that an electric potential E_p is built up in the dielectric. If, after a long time charge at E_1, the applied potential is suddenly reduced to a lower value E_2, current will flow in a negative direction if E_p is greater than E_2. Therefore a sample of hard rubber was subjected to several exactly similar conditions of charge at $E_1 = 750$ volts ($G = 884$ v/cm), but different conditions of discharge in that E_2 was varied from 703 to 748.5 volts. The results indicate that for hard rubber the polarization potential built up during a long time charge is approximately equal and opposite to the charging potential. Under the assumption that Curie's law of superposition held true for the existing conditions, the curve of current against time, was predicted from data obtained for the same test piece over two years ago. (Fig. 8, "Electric Conduction in Hard Rubber, Pyrex, Fused and Crystalline Quartz," by Hubert H. Race, A.I.E.E., Quarterly Trans. **47,** 4 (1928)). The time when this current changed direction (measured from the instant the lower voltage was applied) was also predicted. The close correspondence between the predicted and actual curves bore out the truth of the law of superposition for the gradients used.

37. On the red shift of spectral lines through interstellar space. F. Zwicky, *California Institute of Technology.*—Distant objects in the skies show an average receding velocity which is approximately proportional to the distance. Assuming that a light quantum $h\nu$ has a gravitational mass $h\nu/c^2$, an exchange of momentum and energy might be expected between the quantum and the masses around its path (essentially the masses in a 90° cone behind the quantum, because of the finite velocity of the gravitational waves). This gravitational analogy to the Compton effect would lead to a red shift roughly given by $\Delta\nu/\nu=\alpha f\rho l^2/c^2$, where f is the gravitational constant. The density ρ of matter in space is taken to be uniform. l is the distance travelled by the quantum, c the velocity of light and α a constant of the order one. For very great distances l^2 has to be replaced by ll_1, where l_1 is a constant. For the clusters outside of the galactic system ($l\sim15000$ parsecs, $\rho\sim10^{-20}$ to 10^{-24} gr/cm^3) we should expect $1.5\times\alpha\times10^{-3}>\Delta\nu/\nu>1.5\times\alpha\times10^{-7}$, whereas the observed values given in the following paper are about 3×10^{-4}. The above formulae will be changed (*a*) if the density ρ is not uniform, (*b*) if there are systematic motions of matter in space which might cause violet shifts also, (*c*) by the irregular motions of matter in space.

38. On the radial velocities of globular clusters. P. ten Bruggencate, *p. t. Mt. Wilson Observatory.* (*Introduced by F. Zwicky.*)—Radial velocities of spirals, corrected for solar motion, show a linear correlation with distances. Zwicky's explanantion (the foregoing note) predicts a similar correlation for globular clusters, since the larger densities inside the galactic system compensate the smaller distances. Preliminary examination of the data for clusters indicated a correlation between velocities and galactic latitude, the red shift increasing with decreasing latitude. Since the star counts of Seares offer a means of estimating densities between us and the clusters, correlations were sought between velocities and total numbers of stars inside cones, whose axes were lines joining the sun and the clusters. No correlations were found for cones whose solid angles are 1° and 30°, but for a solid angle of 60°, a definite linear correlation appeared, giving a red shift of 100 ± 60 km/sec ($(\Delta\nu/\nu)\approx3\times10^{-4}$) for 15000 parsecs and a density of matter of about 10^{-23} gr/cm^3. The large solid angle of the cones makes an explanation based on the ordinary Compton effect improbable; the correlation between star numbers inside such cones and velocities rules out a deSitter effect. Thus the results, obtained from globular clusters, suggest the real existence of the new effect proposed by Zwicky.

39. On the spherically symmetrical statical field in Einstein's unified theory of electricity and gravitation. Norbert Wiener and M. S. Vallarta, *Massachusetts Institute of Technology.*—In Einstein's new unified theory of electricity and gravitation (Berliner Sitzungsber. 1928, p. 217 and p. 224; 1929, Feb. 1) the electromagnetic and the gravitational fields are described in terms of an antisymmetrical tensor ${}^{a}h_{\lambda}$ which associates with each point of a continuum X_4 a quadruple of axes and consequently determines a parallelism of directions valid for the whole of space. In this paper the components ${}^{a}h_{\lambda}$ are determined under the same assumptions made in the previous (1916) Einstein theory to obtain Schwarzschild's solution. It is shown that an electromagnetic field is incompatible in the new Einstein theory with the assumptions of static spherical symmetry and of symmetry of past and future. Further, with the same assumptions, it follows from the new Einstein field equations that the gravitational field also vanishes. Since all experimental confirmations of general relativity are essentially tests of the Schwarzschild solution, the new Einstein theory lacks at present all experimental confirmation.

40. Note on the statistical interpretation of Maxwell's equations. M. S. Vallarta, *Massachusetts Institute of Technology.*—Following a method given by Dirac it is shown that the energy density and the Poynting vector of Maxwell's theory, respectively, can be interpreted as the probability that n photons be wholly within a given region at a given time, and the probability that n photons cross a given boundary in a given direction. Further, the change in probability of n photons being within a given closed region is equal to the probability of their having crossed the boundary of that region. These considerations lead to a discussion of the relations between Maxwell's equations and Dirac's equations of the spinning electron (Proc. Roy. Soc. **117,** 610 (1928)).

41. Indetermination principles. ARTHUR E. RUARK, *Mellon Institute, Gulf Oil Companies and University of Pittsburgh.*—The writer has shown (Proc. Nat. Acad. **14,** 322) that in experiments on a single electron we encounter limits to the accuracy with which its position can be measured. It will be shown that this circumstance is connected with Heisenberg's indetermination principle. It is a consequence of Heisenberg's principle, together with the fact that there is an upper limit to the uncertainty of a measured velocity, since a particle cannot move with velocity greater than that of light. Conversely, the existence of a limit of accuracy in length measurements, together with the upper limit for velocity, enables us to prove a theorem which resembles and is related to Heisenberg's indetermination principle. We do not encounter a limit to the accuracy of length measurements when Newtonian dynamics is used, which shows clearly that the existence of this limit is connected with the validity of relativistic mechanics.

42. Interpretation of deviations from Ohm's law on Fermi statistics. HENRY MARGENAU, *Yale University.*—K. T. Compton (Proc. Nat. Ac. Sci., 12, 1926) has shown that the classical free electron theory, applied to Bridgman's observations on deviations from Ohm's law, leads to a value of the mean free path $l=3.13\times10^{-6}$cm. Compton's method has been used, with certain modifications required by the new statistics, to recalculate l assuming a Fermi distribution of electrons. The only points of departure from his procedure lie in the circumvention of the use of Langevin's formula for mobilities—Sommerfeld's expression for conductivity being employed instead—and the substitution of different relations between arithmetic mean speed and root mean square speed. The resultant formula for l becomes

$$l=[(kT)/(Ee)][(22.5m/M)(\sigma_0-\sigma)/\sigma_0)]^{1/2}$$

it differs from Compton's formula only by a numerical constant slightly greater than one. The value of l if computed on the basis of Compton's figures (taken from Bridgman's work) is 3.29×10^{-6} cm. Calculated from the classical conductivity formula, with the number of free electrons equal to that of atoms, (assuming $T=500$°K, corresponding to Compton's figures) it would be 3.6×10^{-7} cm. Sommerfeld's theory, on the other hand, (gives $l=3.1\times10^{-6}$ cm). It is seen that the mean free path here computed agrees better with Sommerfeld's value. The evidence from Bridgman's work appears to favor distinctly the Pauli-Sommerfeld point of view.

43. Solution of problems in quantum mechanics by operator analysis. R. B. LINDSAY AND R. J. SEEGER, *Yale University.*—The operator method of Hilbert, Neumann and Nordheim (Math. Ann. **98,** 1 (1928)) is based upon a set of physical axioms interpreting quantum laws statistically. With the introduction of Dirac's function $\delta(x-y)$ and the fundamental operators $p\equiv\epsilon\partial/\partial x$, $q\equiv x\cdot$, satisfying $pq-qp=\epsilon I$ (where $\epsilon=h/2\pi i$ and I is the unit operator), they derive the equations

$$(1)\qquad (F-y)\phi(x, y)=0 \qquad \text{and} \qquad (2)\quad \left(G+\epsilon\frac{\partial}{\partial y}\right)\phi(x, y)=0,$$

where F and G are any two canonically conjugate hermitian operator functions of p and q and x and y any two dynamical quantities. If $F\equiv H$, the Hamiltonian, $y\equiv W$, the energy, and x is the position coordinate, (1) becomes the usual Schrödinger equation, where $\phi_n\bar{\phi}_n dx$ measures the probability that for $W=W_n$, the coordinate lies between x and $x+dx$. The present paper investigates the special cases: (I) free particle, $H=p^2/2m$ and G found to be $-m/2(qp^{-1}+p^{-1}q)$; (II) uniform field, $H=p^2/2m+kq$, $G=p/k$; (III) harmonic oscillator, $H=p^2/2m+k^2q^2$, $G=(i/4)\{\log[(p/(2m)^{1/2}+ikq)2^{-1/2}]-\log[(p/(2m)^{1/2}-ikq)2^{-1/2}]\}$. A partial differential equation method for finding G is introduced, and the problem of uniqueness and the introduction of transcendental functions are discussed. The associated equation (2) is not unique, and more general equations are constructed whose properties are investigated. In (I) (2) determines the dependence of ϕ on W; in (II), (2) appears to add nothing new. The normalized solutions for ϕ are obtained.

44. On the principle of microscopic reversibility. G. E. Uhlenbeck and H. C. Wolfe, *University of Michigan.*—It is shown that for collisions in which energy, momentum, and number of particles are conserved—e.g. elastic collisions between particles with spherical symmetry, scattering of light quanta by electrons, the probability coefficients for direct, inverse, and reverse collisions are equal. Following Pauli (Zeits. f. Physik **18,** (1923)) the particles are represented by their "four-vectors" of energy and momentum. A collision means a rotation of the two vectors about their resultant. The fundamental geometric constants of the collision are obtained as functions of the energies and momenta. These functions are invariant to Lorentz transformations and are also invariant if we make the substitutions which correspond to the inverse and reverse collisions. Hence, all functions of the collision variables (energies and momenta, before and after collision), which are invariant to Lorentz transformations, are invariant to the inverse and reverse substitutions. From invariance to Lorentz transformations of the six dimensional phase volume (where the space range is a volume element moving with the particle), there follows the Liouville theorem of the conservation of extension in phase in a collision. Using, in addition, the invariance to Lorentz transformations of the number of collisions of a specified type in a specified time, the equality of the probability coefficients for the direct, inverse, and reverse collisions is proved.

45. Some critical points in a study of recent quantum theories. R. J. Seeger, *Yale University.*—A critical survey is made of several recent quantum theories: matrix; q-number; operator of Born and Wiener; operator of Hilbert, Neumann, and Nordheim. A presentation is given in the symbolical manner of Dirac upon a new algebraical postulate for non-permutable variables q, p. Suppose $u(q)$ and $v(p)$ or $u(q^m p^m)$ and $v(q^n p^n)$ are homogeneous. Let $uv^2u = vu^2v$. Hence, it can be shown that $uv - vu$ is equivalent to a parameter. Identify one such parameter with the symbolical idemfactor. From this, old formulae are extended in meaning and in use. Several new ones are developed for convenience. The inverse of a polynomial is proved to be a non-permutable binomial expansion. Throughout, equivalence and identity are kept distinct. The symbols are interpreted as matrices, and then as operators. The Hermitian conditions of both suffice to prove canonical conjugates unique. Differences arise in the kinds of functions allowable and in the use of the inverse function. Schrödinger's equation and the diagonal matrix H are found to be different possible interpretations of an equation mathematically incidental to the problem of finding canonical conjugates. The matrix $q \equiv \left| q(nm) \epsilon^{2\pi i \nu(nm)t} \right|$ is extended to allow $q(nm)$ dependent on t. The damped linear oscillator is then solved by the matrix theory, as well as by the methods of Schrödinger and of Born and Wiener. The matrix theory is applied to the physical pendulum with an approximate solution.

46. Saturation of electric and magnetic polarization of gases on the basis of quantum mechanics. K. F. Niessen, *International Education Board Fellow, University of Wisconsin.* (*Introduced by J. H. Van Vleck.*)—Van Vleck's previous calculations are extended to include higher powers of the field F. The electric polarization is calculated (1) to all powers of F for rigid molecules, (2) to terms in F and F^3 for deformable ones. In (1) we obtain the ordinary Langevin formula, if the rotational frequencies are small compared to kT/h. In (2) only the chief terms agree with Debye's classical formula. Analogous calculations for the magnetic case yield the following results

$$(3a)B(l, \beta, H, T)+B(s, 2\beta, H, T), \qquad (3b)B(j, g\beta, H, T),$$
$$(4a)L(\sigma_l, \beta, H, T)+B(s, 2\beta, H, T), \qquad (4b)L(\sigma_l+2\sigma_s, \beta, H, T)$$

where $L(l, \beta, H, T)$ is the result of putting $\mu = l\beta$ in the Langevin function and $B(l, \beta, H, T)$ is the same for Brillouin's function. Cases 3 and 4 apply to atoms and diatomic molecules respectively, and a and b to narrow and wide multiplets respectively. Here s, j, l, g have their usual spectroscopic meaning, β is the Bohr magneton and σ_l, σ_s are the components of l and s along the molecular axis. The relation $B(l, \beta, H, T) = L(l+\frac{1}{2}, \beta, H, T) - L(\frac{1}{2}, \beta, H, T)$ brings B in accordance with Nernst's theorem. The influence of the electric (magnetic) polarization by magnetic (electric) field is calculated for rigid molecules and is a small second order effect.

47. "Dielectrics and insulation" (10 minutes) by J. B. WHITEHEAD, *Chairman of the Committee on Insulation of the National Research Council and Dean of Engineering, Johns Hopkins University.*—Present knowledge and theory as to the fundamental properties of dielectric materials, as revealed in the literature of physics, is not sufficient to explain the behavior of dielectrics as employed in the insulation of electric circuits. This discrepancy has been the chief concern of the Committee on Electrical Insulation, of the Division of Engineering and Industrial Research of the National Research Council. A brief description will be given of those properties of electrical insulation which seem to limit its performance and life, and of the gap which exists between knowledge of these properties and the products of fundamental physical research and of classical theory. The picture presented emphasizes the importance of a closer knowledge of dielectric absorption and other anomalous properties of dielectrics.

48. "On the mechanical and electrical strength of dielectric crystals" (30 minutes) by F. ZWICKY, *California Institute of Technology.*

49. "Electrical convection phenomena in oil" (10 minutes) by LEWI TONKS, *Research Laboratory, General Electric Company.*

50. "The effect of temperature, pressure and frequency on the electrical properties of rubber" (10 minutes) by H. L. CURTIS, A. T. MAC PHERSON AND A. H. SCOTT, *Bureau of Standards.*—The dielectric constant, power factor, and resistivity of rubber are dependent on the percentage of sulphur with which it is vulcanized, on the temperature and pressure, and, for the first two properties, on the frequency at which the measurements are made. At normal temperatures, pressures, and frequencies, the curve showing the relation between dielectric constant, or power factor, and the percent of sulphur has a maximum in the neighborhood of 12 percent sulphur and a minimum near 19 percent. For 60 cycles both the maximum and minimum occur at higher percents of sulphur than for 1000 cycles or for 3000 cycles. At lower temperatures the maxima and minima are shifted in the direction of lower percentages of sulphur and become less pronounced until at $-76°C$ they entirely disappear. Increasing the pressure in the range from 1 to 700 atmospheres has the same effect as slightly reducing the temperature. This behavior of rubber can probably be interpreted from a consideration of the electric moments of molecules or molecular groups, and their rotational mobility. Electric moment is a function of chemical composition; rotational mobility is conditioned by temperature and pressure.

51. "Influence of surfaces and space charges on the apparent conductivity of dielectrics" (30 minutes) by KARL F. HERZFELD, *Johns Hopkins University.*

52. "Electron bombardment of hydrocarbons" (10 minutes) by V. KARAPETOFF, H. A. TREBLER AND E. G. LINDER, *Cornell University.*—As a part of a study of the mechanism of the deterioration of dielectrics in underground cables, hydro-carbon vapors have been subjected to electron bombardment and the resulting chemical changes observed. The bombardment results in the condensation and polymerization of the hydrocarbons, and in the evolution of gases, chiefly hydrogen. An attempt has been made to find the relationship between the amount of gas evolved and the molecular structure of the hydrocarbons.

53. "Electrical insulation from the engineering viewpoint" (30 minutes) by G. M. J. MACKAY, *Research Laboratory, General Electric Company.*

54. "The dependence of dielectric polarization upon molecular condition" (10 minutes) by C. P. SMYTH, *Princeton University.*—The equation of Debye for the variation of dielectric polarization with temperature, which has been found accurate for gases, gives misleading results when applied to pure dipole liquids because of the mutual action of the dipoles. When the dipoles are sufficiently separated from one another by the molecules of a non-polar solvent, the equation is found to apply satisfactorily and the value obtained for the electric moment is the same as in the gas. When the distance of separation of the dipoles decreases with increasing concentration, the polarization commonly decreases, but, in the case of strongly associated liquids like the alcohols, may increase. Because of the conflicting effects of thermal agitation and intermolecular attraction, solutions may be obtained in which the polarization is almost independent of temperature. Many liquids show an increase in polarization with temperature instead of the decrease required by the Debye equation, and acetic acid and some of the octyl alcohols even show an increase in dielectric constant with rising temperature. The polarizations and dielectric constants of the isomers of octyl alcohol, the molecules of which presumably differ little in electric moment, differ greatly because of the different molecular force fields resulting from the different locations of the doublet in the molecule.

55. Location of the electromotive force in a photovoltaic cell. W. NORWOOD LOWRY, *Cornell University*.—A method was used patterned after that of Murdock (Nat. Acad. Sci. 12, 1926). In a Pt-Rhodamine B-Pt cell, curves plotted with e.m.f. and position of electrode in respect to the window, showed no sudden break in the slope of the curve when passing from a dark to an illuminated region, as had been previously observed in the case of current measurements. In another investigation it was found that the voltage sensitivity of the above type of cell increased with the concentration of the electrolyte. A voltage amplifier system was developed utilizing a 4-element vacuum tube, with which a sensitivity greater than 5,000 mm. per volt was obtained, with a current drain of an order of magnitude comparable to that of an electrometer, and with a period shorter than the latter. Some of the data were taken with this device, and the rest of the measurements were made with a Compton type electrometer.

56. Departure from Einstein's photoelectric equation with certain alkali metal films. W. B. NOTTINGHAM, *Bartol Research Foundation*.—Photoelectric current measurements with light near the long wave-length limits for sodium and potassium films on platinum gave 3.0×10^{-14} amp. at 8200A and 1.3×10^{-13} amp. at 9400A respectively. Light from the anode of a 15 amp. carbon arc was used. The long wave-length limit is probably greater than 8400A for sodium and 9600A for potassium. Miss J. Butterworth (Phil. Mag. **6**, 1 (1928)) reports 9700A for potassium from measurements of the "complete" photoelectric effect. Departures from Einstein's photoelectric equation have been found for both metals near their long wave-length limits with very thin films. The cell potential for zero current plotted versus the quantum energy for the different wave-lengths, expressed in their voltage equivalent, showed that the equation $Ve=\alpha h(\nu-\nu_\alpha)$ held with $\alpha=1$ for wave-lengths shorter than 5200A; $\alpha=2$ between 5200A and 5400A; $\alpha=3$ between 5400A and 6200A; and $\alpha>3$ for wave-lengths greater than 6200A. The range over which α has a constant value depends on the film thickness. When the film has the thickness which makes the photoelectric response and the long wave-length limit the maximum, α is unity over almost the entire range of wave-lengths.

57. Use of dielectrics to sensitize alkali metal photoelectric cells to red and infra-red light. A. R. OLPIN, *Bell Telephone Laboratories, Inc.*—A technique is described for greatly enhancing the photoelectric response of sodium and potassium surfaces in vacuum by the introduction of very small amounts of such dielectrics as sulphur vapor, water vapor, benzene, and organic dyes. Cells thus produced are far more sensitive to light of color temperature 2848°K than the best vacuum cells heretofore studied; the increase being due mainly to a striking red sensitivity, especially in the case of the sodium cells. Spectral distribution curves show the presence of new maxima, lying between $\lambda5000$ and $\lambda5500$A for sodium and between $\lambda6000$ and $\lambda6500$A for potassium, the former being much more pronounced. In each case $\lambda_0=$approximately 1μ. The frequency difference between the regular and new maxima for each surface corresponds to a wave-length of about 1μ. This is the wave-length region at which the dielectrics used exhibit strong absorption bands. A theory is proposed which suggests a modulation of the exciting light at the cathode surface, the incident frequency combining with the characteristic vibration frequency of the dielectric. Extension of the theory to explain similar phenomena in the sensitization of photographic plates and in the field of fluorescence is suggested.

58. The preparation of photoelectric cells with thin films of lithium as the photoactive material. HERBERT E. IVES, *Bell Telephone Laboratories, Inc.*—Lithium is a difficult material to handle in a vacuum tube for the following reasons: (1) the shell of oxide which forms on a slug cut in air is too stiff for molten lithium, which is very light, to break through; (2) the oxide distills at a lower temperature than the pure metal; (3) lithium rapidly attacks glass and platinum. It has been found possible to prepare thin films of lithium by the following process: A thin walled steel tube is driven through a slug of lithium so that on withdrawal of the tube a cylindrical rod of lithium is obtained which is protected from the air except on its two ends. A heavy steel rod is then inserted in the steel tube, above the lithium, and this, when the whole system is heated in vacuo by a high frequency field, forces the lithium out in a globule from which a thin film may then be distilled on to a plate of tungsten. This film at one stage in its formation is sensitive to red light as far out as λ6708.

59. On the emission of positive ions from hot tungsten. LLOYD P. SMITH, *Cornell University, Ithaca, N. Y.*—A decay in the positive ion emission over a long period of time has been noted at temperatures above 2600°K which were not previously found for a temperature of 2500° following a flash treatment. For a given temperature the ion current seems to approach a steady value. When the temperature is increased there is a decay from the new value down to a steady value which is higher than the previous steady value. Before the ion current is allowed to decay appreciably the heat of evaporation of the ions, determined by plotting the data according to the Langmuir evaporation equation for tungsten, may be as high as 8.3 volts. After heat treatment and partial decay of the ion current, it gradually decreases to 6.5 volts. After this value has been reached there is no further change regardless of further decay or heat treatment. Theoretical considerations have thus far failed to establish the nature of the ions but experiments are now under way to determine the ratio of their charge to mass.

60. Thermionic emission as a function of the amount of adsorbed material. J. A. BECKER, *Bell Telephone Laboratories, Inc.*—It is commonly assumed that the logarithm of i, the thermionic current from a cm^2 of tungsten at a fixed temperature, increases linearly with θ, the fraction of the surface covered with an electropositive element. Experiments with barium-on-tungsten show, however, that this assumption is untenable and that for $0 < \theta < 0.85$

$$\log i/i_0 = 1.1(\log i_1/i_0)(1-\epsilon^{-2.0\theta}) \tag{1}$$

Subscripts indicate values of θ. θ is determined from the deposition time and is unity at the optimum activity. Log i increases principally because the work function ϕ decreases. Probably $\Delta\phi$ is caused by the existence of adsorbed Ba$^+$ ions. If N_p = number of ions/cm^2 and l = diameter of Ba$^+$,

$$\Delta\phi = -300\cdot 4\pi N_p 4.77\times 10^{-10} l \text{ volts} \tag{2}$$

From Richardson's equation and (1) and (2) we conclude: for small θ, about 1 in 5 Ba particles are adsorbed as ions, the remainder being adsorbed as atoms; as θ increases the ratio of ions to atoms decreases; the tendency to form adsorbed ions is approximately proportional to the amount by which ϕ exceeds the resonance potential of Ba; when $\theta = 1$, about 1 in 10 adsorbed particles are ions.

61. Thermionic and photoelectric emission from caesium at low temperatures. L. R. KOLLER, *General Electric Co.*—Cathodes consisting of very thin films of caesium on caesium oxide on silver have been found to give high values of thermionic emission at very low temperatures. Measurements of emission have been made at different temperatures and the emission was found to follow the equation $I = AT^2 e^{-b/T}$ over a range of from 373 to 443°K. Above this temperature the cathode surface deteriorates. The constants determined from a plot of this equation were $A = 9.8\times 10^{-2}$; $b = 8{,}700$. The cathodes used had an area of 10 cm^2 and were formed directly on the bulb wall so that it was possible to heat them by immersing them in a temperature bath. This large surface makes it possible to measure thermionic emission at temperatures below 473°K. These cathodes are also highly photo-sensitive, giving about 5 microamperes per lumen of incident light from a tungsten filament at 2465°K. The photoelectric current was measured over the same range of temperature as the thermionic current. Under these conditions it was possible to measure at the same time photoelectric and thermionic currents of the same magnitude. The photo-current was found to show a slight positive temperature coefficient.

62. Thermionic emission from tungsten and the Schottky equation. H. L. VAN VELZER AND W. R. HAM, *Pennsylvania State College.*—Values of the thermionic currents from tungsten filaments show that the Schottky relation

$$\log i = \log i_0 + e^{3/2}(dV/dx)^{1/2}/(kT)$$

can be verified with sufficient accuracy to furnish a satisfactory method of determining the electronic charge, e. The behavior of the current from small wires during the process of "clean up" is similar to that found by Millikan and others and there is a temporary clean up by intense electrical fields above that that may be obtained by ordinary methods. Using extended high voltage clean up, Shottky's equation appears valid for tungsten up to 10^6 volts/cm. No upper limit is indicated.

63. Schottky effect and contact potentials of thoriated tungsten filaments. N. B. REYNOLDS, *Princeton University.*—Becker and Mueller's experiments on the lack of saturation of thermionic currents from thoriated filaments have been repeated under a variety of conditions. The point of departure of the curves from the theoretical Schottky line seems independent of the amount of thorium present on the surface, and to depend only on the field. At gradients of 10000 volts/cm and higher, Schottky's equation applies accurately. Subjecting the filament to positive ion bombardment with ions of above 500 volts velocity causes a subsequent greater deviation from this line, making it difficult to attain saturation with gradients of 30000 volts/cm. The emission at high fields may be actually increased by this process, suggesting a possible roughening of the surface. The variation in contact potential of a thoriated filament with θ, the fraction of the surface covered with thorium, has been investigated by a method of retarding fields. There is a positive temperature coefficient, and taking this into account, the change in contact potential with θ agrees quantitatively with the resultant change in b_0 of the thermionic emission equation. The emitted electrons are found to have a Maxwell's velocity distribution, except near the zero of potential, which is now being investigated.

64. The use of the Schottky relation in the determination of the thermionic work function of tungsten. W. R. HAM, *Pennsylvania State College.*—Thermionic emission data for tungsten suggest a method, independent of T, of measuring and examining ϕ, the work function, as follows. The thermionic equation assumed is $i_0 = A\,\epsilon^{-(\phi e/kT)}$. Substituting in Schottky's equation $i = i_0\,\epsilon^{e^{3/2}(dV/dx)^{1/2}kT}$ we have $i = A\,\epsilon^{\phi e/kT + e^{3/2}(dV/dx)^{1/2}/kT}$ and taking logarithms

$$\log i = \log A - [\phi e + e^{3/2}(dV/dx)^{1/2}]/kT.$$

If data of log i and $(dV/dx)^{1/2}$ are plotted for a particular T

$$\log A - \phi e/kT = I \qquad \text{(the intercept)} \qquad (1)$$

$$e^{3/2}/kT = S \qquad \text{(the slope)} \qquad (2)$$

or

$$\log A = I + \phi S/e^{1/2}.$$

And for a family of such curves taken at different temperatures and ϕ considered constant

$$\phi = e^{1/2}(-\delta I/\delta S)$$

Hence, if plotting I against S for such data, we obtain a straight line we may conclude that ϕ is constant for the thermionic equation with which we started; i.e., the T^0 equation. If, on the other hand, a linear relation is not found, we can determine by the deviation from a straight line just how ϕ varies with temperature and hence experimentally arrive at the correct form of thermionic equation for ϕ constant. An advantage of this method is that precise measurements of temperature are not necessary and the values of dV/dx, the potential gradient, need be only relatively accurate.

65. Molecular rays of hydrogen chloride in an electric field. M. J. COPLEY AND W. H. RODEBUSH, *University of Illinois.*—In this work a beam of hydrogen chloride molecules of initial temperature −80°C is passed through the inhomogeneous electrostatic field between a wire and a cylinder which are at a difference of potential of about 10,000 volts. The beam is 0.04 mm in width and the value of $\partial E/\partial r$ is 10^6 volts/cm^2. The field is produced by a transformer and condenser with a kenetron. The hydrogen chloride molecules are condensed on a liquid air-cooled target upon which a layer of ammonia has first been condensed and an image of ammonium chloride is formed which is easily seen, although difficult to photograph. Preliminary results indicate that a large fraction of the molecules are deflected in the field since the central portion of the image is almost obliterated but it has not yet been possible to obtain a clear image of the deflected beam.

66. Effect of crossed electric and magnetic fields on the helium spectrum. J. S. FOSTER, *McGill University.* (*Assisted by National Research Council of Canada.*)—New lines appear in the helium spectrum when the source is subjected to crossed electric and magnetic fields. Some of these are found near the diffuse series lines (λλ4472, 4388, 4026) with nearly twice the separations observed for the fundamental combination lines in the Stark-effect.

67. Zeeman effect in MgH. F. H. CRAWFORD AND G. M. ALMY, *Harvard University.*—The MgH band at λ5211 ($^2P\rightarrow{}^2S$) consists of three branches of narrow doublets. In a magnetic field the behavior of each branch is qualitatively the same. For high j it is about as follows: At 8300 gauss the doublets are unsymmetrically widened to around 5/4 of their no-field separation and fairly sharp, with a faint continuous band between. As the field is increased, this faint band increases in intensity, its width remaining slightly less than the no-field separation. The outside components move out and become fainter. Their separation at 16000 gauss is about twice that of no-field, at 28400 about three times (observed only in P branch). For lower j (4 1/2 to 9 1/2) the above behavior is modified. At 8300 gauss each member of the doublet is diffusely broadened to approximately $2\Delta v_n$ the intensity distributions being complementary. Thus the low frequency member is most intense in the center, while the high frequency one appears as a doublet. As the field is increased, a single pattern is obtained for the doublet, most intense at the edges, of width somewhat less than the no-field separation. For lowest j (1/2 to 3 1/2) the patterns of the observable lines are resolved, increasing in width and complexity with the field.

68. Interaction of the Stark effect and electronic spin in alkalis. V. ROJANSKY, *Washington University.*—As pointed out to the writer by Professor J. H. Van Vleck, the matrix approximation formulas for the energy levels of a non-degenerate system, when applied to the evaluation of the Stark levels of non-hydrogenic atoms in a weak electric field, cannot be expected to give accurate results throughout the range of the (weak) field. In fact, in the case of alkalis, after the original Hamiltonian H_0+H_1 is transformed by the proper first order canonical transformation, terms of the type $(n, l, j; n, l, j\pm1)$ appear in the new (second order) Hamiltonian. The frequencies associated with these terms are relatively very small, and thus the system should be treated by methods appropriate to degenerate systems, especially when the Stark separation (which is a second order effect in non-hydrogenic atoms) is comparable to that of the fine structure. Physically, in fields which produce such separations the multiplet structure should be distorted, and intensity redistributed. For small fields the effect should be negligible. The corrected expressions for the energy levels and the transformation functions necessary for the calculation of relative intensities were thus found. Comparison with experiment has not yet been carried out.

69. Relative intensities of Stark components in helium. G. O. LANGSTROTH (*Canadian National Research Bursary*), *McGill University.* (*Introduced by J. S. Foster.*)—Quantitative measurements of the relative intensities of individual Stark components in two typical helium line groups (λλ4388, 4026) have been made. The agreement with the theory based on quantum mechanics is somewhat better that that noted by Dewey, (Phys. Rev. **30**, **770** (1927)), there being no really serious departure from the predicted values. The method of measurement employed is a variation of Koch's procedure and depends on the use of a neutral wedge for the production of the intensity marks. A useful feature in this research is the development of a Lo Surdo tube in which the electric field is uniform through an appreciable portion of the Crookes' dark space. This permits the Moll photometer to operate at its maximum efficiency.

70. Extreme ultra-violet spectra of Ne and A excited by electrodeless ring discharge. K. T. Compton, J. C. Boyce and J. L. Nickerson, *Princeton University.*—High frequency currents from an oscillator giving between 0.25 and 3.5 K. W. traversed ten turns of wire surrounding a discharge tube located at the slit of the vacuum spectrograph. Whereas spectra excited by controlled electron impacts show only arc and first spark lines, the electrodeless ring discharge brings out higher stages of excitation. Some differentiation between these is possible, since increased gas pressure and decreased energy input relatively intensify lower stages of ionization, and vice versa. Gas is driven in large quantities into the glass of the discharge tube, whence it gradually comes out again to contaminate later spectra unless special precautions are taken. We find for Ne III, ionization potential 63.2 volts or 511,700ν, and higher limits at 545,350 and 566,517 approximately. Metastable singlet states are at about 22,300 and 52,250 above the low triplet state. Two triplet series of three members each and one singlet series of two are found, as well as the low quintet state, and the low states associated with the higher limits. All predicted *a–b* lines are found. Similar though less complete analysis of A III gives its ionization limit as 329,476. *a–b* lines of Ne IV and A IV are strong, but those of Ne V and A V are, if present, too weak for identification.

71. Low voltage electron impacts in hydrogen. F. G. Slack, *Vanderbilt University.*—Observations were made on the effect of electron impacts with hydrogen in a three electrode tube with unipotential, oxide coated, hot filament. The gas was streamed through the tube at pressures from 0.05 to 0.50 mm of Hg. Curves showing the variation of current from filament to grid-plate with varying accelerating potentials agree in general with those reported by Duffendack (Phys. Rev., **20,** (1922)), Olmstead (Phys. Rev., **20,** (1922)), and by Richardson and Tanaka (Proc. Roy. Soc., **106A,** (1924)). The breaks below 10.2 volts in the curves of Richardson and Tanaka, attributed by them to the presence of Hg vapor, are entirely missing thus confirming their suspicions. Spectroscopic observations were made in the field free region between the grid and plate. Photographs show no Balmer lines but some of the secondary spectrum at 13 volts in pure hydrogen. No means other than the electron impacts were used to increase or produce radiation.

72. Simultaneous ionization and excitation by positive ions and excited atoms. O. S. Duffendack and H. L. Smith, *University of Michigan.*—An extension of an investigation of the simultaneous ionization and excitation of diatomic gases admixed with a rare gas (Phys. Rev. **29,** 914 (1927)) reveals that both ions and excited atoms are effective. By adding hydrogen to He-CO and Ne-CO mixtures a comparison of the effectiveness of the two types of impacts in producing certain excited states of CO^+ could be made. Hydrogen has a marked quenching action on the production of the A′ state of CO^+, the initial level on the comet tail bands, particularly when excited Ne atoms were used for its excitation. This action is probably due to the nearness of the values of the ionizing potential of H_2 and the minimum radiating potential of Ne.

73. The excitation of N lines by controlled electron impact. Louis A. Turner and E. W. Samson, *Princeton University.*—The $3s^4P-3p^4P$ lines of N at 8200A are produced by bombardment of N_2 at a pressure of 0.05 mm with electrons having 22.3 volts or more of energy. The behavior of the intensity of the lines with changes of exciting current and pressure indicates that they result from a primary process of dissociation of N_2 into a neutral atom and an excited atom, as suggested by Herzberg. Since the excited atom has 11.8 volts of energy an upper limit of 10.5 volts for the heat of dissociation of N_2 is obtained in agreement with the conclusion of Mulliken and Birge that its value is considerably less than 11.4 volts. The correction to the applied voltage was obtained by determining the ionizing potential of Hg vapor present, using the Hertz-Kingdon method. The value of 22.3 volts may be several tenths of a volt too high because of the difficulty of determining the exact voltage for disappearance of the lines and a slight uncertainty concerning the correction to the voltage to be deduced from the measurements of the ionizing potential of Hg.

74. The mean life for the spark spectrum of mercury. L. R. MAXWELL, *National Research Fellow. The Bartol Research Foundation.*—By using the method for determining the life of excited states recently described by the writer (Phys. Rev. **32,** 721 (1928)), the following results have been obtained for several lines of the mercury spark spectrum;

Wave-length (A)	Type of Spectrum	Mean Life (sec.)
3090 (E_2)	Hg III	6×10^{-7}
3312 (E_2)	Hg III	4×10^{-7}
3114 (E_3)	Hg IV	9×10^{-7}
2572 (E_3)	Hg IV	8×10^{-7}

These results indicate that the life of the excited states for the triply charged ion is slightly greater than for the doubly charged. The mean life for the lines of Hg II have not been measured but are estimated to be of the order of 10^{-8} seconds. From current-light intensity measurements it is found that at a single electron collision the atom is multiply ionized and excited. This experimental result substantiates the assumptions made in calculating the mean lives given in the above table.

75. Decay of the spectrum of the afterglow of nitrogen mixed with argon. A. G. WORTHING AND H. E. WAY, *University of Pittsburgh.* The afterglow chamber consisted of a glass bulb with tungsten terminals and was filled with a mixture of the order of 99 percent A and 1 percent N at a pressure of about 2 cm of Hg. Periodic discharges, followed in succession by exposures to different parts on a photographic plate in a spectrograph, yielded three spectrograms of the afterglow in succeeding stages. Using notation of the I. C. Tables, the early stage showed a maximum in the orange sequence for the 8→4 vibrational transition and in the red sequence for the 8→5 and the 4→1 transitions. The third stage showed maxima for 11→7, 9→5, and 9→6 transitions, and a tendency to a maximum at 11→8. The second stage showed an intermediate shift. At the same time decay tended to strengthen the orange sequence relative to the red sequence. With time the afterglow spectrum seemed to approach that in pure nitrogen. Metastable argon atoms interspersed with the neutral nitrogen molecules transferring energy by collisions of the second type to neutral nitrogen molecules and exciting them to B_8 and B_4 stages seems a possible explanation. It is necessary to suppose that this process decays faster than does the normal pure nitrogen afterglow.

76. Spectra in condensed discharges. J. W. BEAMS, *University of Virginia.*—Light emitted by an electric spark occurring between metallic electrodes in air together with that emerging from condensed discharges at low pressures has been studied by means of a mirror rotating 1600 revolutions per second. The rotation of the mirror was obtained by the method of Henriot and Hunguenard (Jour. d. Phys et Ra. **8,** 443 (1927)) as modified by Lawrence, Beams and Garman (Phys. Rev. **31,** 1112 (1928)). Photographs of single discharges were obtained, one millimeter on the plate corresponding to 5×10^{-8} sec. The velocities of propagation of the luminosity of various metallic vapors in the spark previously studied by Schuster and Hemsalech and others (Baly Spectroscopy, Longmans, 1912) have been measured. The time of appearance of the spectrum lines was found to be in accord with the values obtained by the Kerr cell method (Phys. Rev. **28,** 475 (1926)). The air lines appeared first followed by the spark lines and later the arc lines of the metal. The air lines die out first followed by the spark and finally the arc lines of the metallic vapor. The photographs indicate that the spark at first appears as a narrow thread then, during its initial stage, expands radially.

77. The photo-ionization of the vapors of caesium, rubidium and potassium. ERNEST O. LAWRENCE AND N. E. EDLEFSON, *University of California.*—A modification of the space charge method of Foote and Mohler has been devised which compensates out the effects of temperature changes, thereby allowing full use of the great inherent sensitivity of the space charge method. A water-cooled hydrogen discharge tube carrying 5 amperes at 3000 volts served as a source of continuous ultra-violet light of great intensity. The ionization efficiency of the light in caesium and rubidium falls off continuously from their respective series limits to shorter wave-lengths. Potassium shows a striking dissimilarity in qualitative confirmation of the previous observations of Williamson (Proceedings of the National Academy, **14,** 793 1928)) and Lawrence (Philosophical Magazine, **1,** 345 (1925)). The probability of ionization in potassium vapor is a maximum at the series limit and falls off rapidly to 2710A where the ionization increases to a second maximum at 2340A where it again rapidly decreases. The ionization efficiency at 2340A is about three times its value at the series limit. The separation of these two maxima is equivalent to 0.96 volt. Spectroscopic data give 0.8 to 1.0 volt for the heat of dissociation of K_2, indicating dissociation plus ionization as the origin of the second maximum.

78. Photo-ionization of alkali vapors. F. L. MOHLER AND C. BOECKNER, *Bureau of Standards.*—Relative measurements of photo-ionization of caesium, rubidium and potassium as a function of the wave-length have been made by the space charge method as well as absolute determinations by a direct method for the first two elements. The sensitivity drops rapidly from the limit to about a tenth of the maximum value at 600A beyond the limit in both caesium and rubidium. Ion current measurements give the atomic absorption coefficients at the limits as 2.3 and 1.1×10^{-19}, respectively. The sensitivity of potassium is low at the limit and increases rapidly from 2600A to 2200A in agreement with published results. Absorption measurements in caesium vapor at low pressure, as well as computations using the principle of detailed balance and the intensity of the recombination spectrum, give values agreeing in magnitude with the photo-ionization value of atomic absorption at 3184A.

79. Determination of the orientation of single crystal specimens of metals of the hexagonal system. THOMAS A. WILSON, *General Electric Co., Department of Chemistry, Union College.*—The x-ray method previously described (Bulletin of the Physical Society Vol. **4,** No. 1) for cubic metal single crystals has been extended to crystals of the hexagonal system. The equations for the interperpendicular angles have been derived. The necessity of using symmetrical photographs has been eliminated, so that one Laue photograph alone is needed to fix the orientation. The method has been applied to zinc crystals grown according to the method of Mathewson and Phillips (Am. Inst. Min. Met. Eng. Preprint 1623-E Feb. 1927). A twin has been shown present in a poorly formed crystal.

80. Experimental evidence for the filling of electron levels from the relative intensity of x-ray lines. SAMUEL K. ALLISON, *University of California.*—According to the accepted theory of the periodic system, electrons first enter the 5_3 orbits at 57 La; only one electron remaining in these orbits until 72 Hf from whence the orbits fill up to 10 electrons at 78 Pt or 79 Au. The $L\beta_5$ line is double, representing the transitions 5_{32}, $5_{33} \rightarrow 2_{22}$. In a previous paper (Phys. Rev. **32,** 1 (1928)) the author found that this line was about 32 times more intense (relative to lines involving more deeply buried orbits) in the uranium than in the tungsten L series. This paper reports intensity measurements involving this line in 76 Os, 77 Ir, 78 Pt, 79 Au, 81 Tl, 82 Pb, 83 Bi. The experiments were carried out at a voltage about 2.66 times the average of the critical excitation voltages for the L series in each case. A curve showing the ratio of the intensities $L\beta_5/L\beta_1$ as a function of the atomic number rises rapidly with increasing atomic number and takes a sharp upward jump between 78 Pt and 79 Au. This indicates that the first element in which 10 electrons occupy the 5_3 orbits in an approximately undisturbed condition in the solid state is 79 Au. The curve is similar to one obtained in the region about 46 Pd for the lines $L\beta_2$ and $L\gamma_1$ by Jönsson (Zeits. f. Physik **41,** 221 (1927)).

81. Diffraction of x-rays in liquids: isomers of n-octyl alcohol. G. W. STEWART, *University of Iowa.*—Through the kindness of Professor E. Emmet Reid of Johns Hopkins University, the following carefully prepared isomers of n-octyl alcohol were tested: four octanols and sixteen heptanols. The conclusions are: (1) That the polar group OH produces a molecular chain doubling only when it is attached to the carbon at the end or next to the end of the chain. (2) That the molecular space arrangement or cybotactic condition in the isomers is usually sufficiently marked to give two sets of intersecting planes containing diffracting centers. (3) That the arrangement of molecules in a second set of planes is most conspicuous when the OH is attached at the center of the molecule. (4) That the CH_3 in a branch causes an increase in the diameter of the chain of 0.25A and 0.50A, apparently depending upon the distance from the OH group. (5) That the chain remains a fairly rigid one, in contrast to the chain in the case of paraffins. The results as stated assume the validity of Bragg's Law and the correctness of the view of the author as to the cybotactic condition.

82. Wave-length measurements of L lines (Zn to Ca). CARL E. HOWE, *University of Chicago*.—Using the first inside order from a plane grating, (600 lines to the millimeter) L lines of Zn, Cu, Ni, Co, Fe, Mn, V and Ca have been measured. The wave-lengths extend from Zn $L\alpha_1$ (12.2A) to Ca L_l (39.7A). With few exceptions, for the elements from Zn to Mn inclusive, four lines ($L\alpha_1$, $L\beta_1$, $L\eta$, L_l) have been measured. The $L\alpha_1$ line of V (origin $M_{33}\rightarrow L_{22}$) appears to be present thus indicating at least one electron in the M_{33} level of V. Measurements of the lines of Cr, V and Ti now in progress will probably give definite information on this point. Neither the $L\alpha_1$ nor the $L\beta_1$ line of Ca was observed as is to be expected. Separation of the lines was attained by adjusting the grating so that the angle between the inside order and the plane of the grating is small. Under this condition the angular dispersion is given by $\Delta\alpha=\Delta\lambda/(D\beta)$ where D is the grating space and β the small angle between the plane of the grating and the first inside order. All measurements are absolute.

83. On the determination of the wave-length of x-ray satellites. F. K. RICHTMYER, *Cornell University*.—A densitometer record of an x-ray (diagram) line and its satellites shows the latter as a complex structure on the side of the former. Only if one knows the exact shape of the densitometer record through the diagram line alone (i.e., without satellites) can one, by substraction, determine the satellite structure, and thus the wave-lengths of the satelline components. For this purpose, advantage may be taken of the fact that the excitation potential of the satellites is some 25 percent higher than that of the parent line. If a spectrum plate of the parent line be obtained at, say, 20 percent above its excitation voltage, the satellites are either absent or relatively very weak. By comparing the densitometer record of such a plate with one obtained at higher voltages, a less ambiguous record of the satellite structure is obtainable

84. Absolute wave-length of the $K\alpha$ and $K\beta$ lines of Cu. J. A. BEARDEN, *University of Chicago*.—Using plane optical gratings ruled with 50 and 600 lines per mm, spectra of the K series of Cu have been obtained. The $K\alpha$ lines were not resolved but the mean wave-length was found to be $K\alpha=1.5439\pm0.0002$. This is about 0.36 percent higher than previously reported measurements by this method and also 0.36 percent higher than given by crystal measurements. The $K\beta=1.3940\pm0.0002$, which is about 0.34 percent higher than the crystal measurements give. The ± values given are the probable errors obtained in taking the average of 10 plates. All of these plates were taken under different conditions and many of the plates had 8 measurable orders. The angles were measured by using two plates, one 8 cm from the grating and the other 205 cm from the grating. The plates were parallel to within 5 sec. of arc and the distance between them was measured to one part in 50000. The gratings were centered over the axis of rotation of the spectrometer by the use of an interferometer. The interferometer was also used to make sure that the grating did not move during an exposure. The measurements of the distance between the plates and the separation of the lines on the plates have been carefully checked by independent observers in order to find if there was a consistent error which was being overlooked. These results give a value of the electronic charge $e=4.824\times10^{-10}$ and Avogadro's number $N=5.999\times10^{23}$.

85. Temperature and the Compton effect. G. E. M. JAUNCEY AND H. BAUER, *Washington University, St. Louis*.—The intensity of x-rays reflected from a crystal decreases with temperature. According to Debye (Ann. d Physik **43**, 49) this decrease in intensity should be accompanied by an increase in the intensity of the rays diffusely scattered by a crystal, but Jauncey (Phys. Rev. **20**, 405 and 421) has shown that this increase is either zero or very small. The effect of temperature on the ratio of modified to unmodified scattered x-rays has therefore been examined. Using DeFoe's method (Phys. Rev. **27**, 675) an aluminum absorbing sheet was transferred from the primary beam to the scattered beam and the ratio of the two ionization currents found at room temperature and also when the scattering substance was heated to 565°C. Wave-lengths ranging from 0.35A to 0.62A were scattered by carbon at angles of 60°, 75° and 90° and no definite effect of temperature was observed. In five cases the ratio was slightly less and in four cases slightly greater at the higher temperature. In each case the difference between the cold and hot ratios was not greater than the probable error of each ratio. Similar results were obtained for scattering from aluminum and copper.

86. Fine structure in the Compton effect. Bergen Davis and Harris Purks, *Columbia University.*—A continuation of two crystal analysis of fine structure of scattered radiation: A special x-ray tube was constructed with small piece of graphite near the target spot. Mean angle of scattering was $\theta = 155°$. The displaced radiation had fine structure as follows going toward long wave-lengths: A relatively strong line 0.0421A from Mo $K\alpha_1$ position, and then three weaker lines at 0.0012A, 0.002A and 0.0109A from this strong line. These agree with the fine structure previously found in the undisplaced scattered radiation. (Davis and Mitchell, Phys. Rev. **32,** 331 (1928)). The two pictures are alike but the displaced one is shifted 0.0421A from the undisplaced. The displacement is less than is to be expected from $d\lambda = 0.0243\ (1-\cos\theta)$. Our results give $d\lambda = 0.022\ (1-\cos\theta)$. This is about 9 percent smaller than required by theory. Our errors cannot be as great as this. Beryllium, investigated at $\theta = 163°$, gives a strong main line at $0.0446\text{A} = 0.0228\ (1-\cos\theta)$ from $K\alpha_1$ position and a line at 0.0051A from this main line. This agrees with the Be K energy level. A weak line 0.00087A toward short wave-length from main line. The last two were also observed in undisplaced radiation by Mitchell and described at the December meeting of this society.

87. On the polarization of x-radiation from mercury vapor. William Duane, *Harvard University.*—Experiments have been described on the x-radiation coming from the impacts of homogeneous electron rays against mercury vapor atoms. This paper deals with experiments on the polarization of this x-radiation. The x-ray tube employed was substantially the same as that previously described, except that the mercury vapor from the electric furnace passed down into a tube cooled with liquid air. The polarization was tested by means of the secondary radiation scattered from a block of carbon struck by the primary radiation. The secondary radiation was detected and its intensity measured in different directions by means of a point counter, similar to that which I described in the Comptes Rendus for July 18, 1910. (Since that date, these point counters have been greatly improved by Geiger and others.) Experiments on the radiation coming from the mercury vapor at right angles to the stream of electrons showed that this radiation was largely, but not completely, polarized. The secondary radiation coming from the block of carbon in a direction parallel to the stream of electrons was about 0.37 as intense as that coming from the block of carbon at right angles to the stream.

88. Reflection of electrons and its application to the design of molybdenum target water cooled Coolidge tubes. H. R. Kiehl, W. R. Ham, M. W. White and W. P. Davey, *Pennsylvania State College.*—Calorimetric measurements previously made on molybdenum target Coolidge tubes indicated that approximately twelve percent of the energy input to the tube was reflected to the walls at 14 kv and 3.00 ma. Later experiments on similar tubes showed an electron current along the walls to the anode during this reflection, which was probably due to the increased conductivity of the glass during electron bombardment. Failure of the tube due to cracked glass was attributed to local heating. Occasionally minute portions of the walls even become melted. The tube was accordingly redesigned by one of us in order to reduce the reflection to the walls by decreasing the cathode-anode distance to 0.3 centimeter. Using the new design, calorimetric measurements showed a reflection of roughly 1/3 that of the old type tubes. The average life of 26 old type tubes was 538.5 hours. On the same group of apparatus, one new type tube has already been run 5340 hours, one 3607 hrs. and one 1830 hours at 20–25 ma, 30 kv, and one tube 556 hours at 40–45 ma, 30 kv. All of these tubes are still in successful operation. These results clearly show the dependence of the length of life of such tubes upon the electron reflection to the walls.

89. Separation and relative intensity of the diagram-components of the $L\beta_2$ line by means of the double x-ray spectrometer. Samuel K. Allison, *University of California.*—According to the energy level diagram applicable to atoms which have lost one electron from an inner level the $L\beta_2$ line should be double, since it consists of electron transitions from the levels $N_{IV}, N_V \rightarrow L_{III}$. Crofutt (Phys. Rev. **24,** 9 (1924)) claims to have measured the weaker component of β_2 in tungsten (74) calling it β_{15}. The present paper describes the results of investigation of the line $L\beta_2$ in 77 Ir, 81 Tl, and 92 U. In 77 Ir the line $L\beta_2$ has such a great intrinsic breadth that $L\beta_{15}$ cannot be separated from it although the dispersion and resolving power of the instrument are ample. In 81 Tl a better but not complete resolution is obtained, due to the fact that in this case $L\beta_2$ is considerably narrower. In 92 U a practically complete resolution is obtained with the crystals both in the first order since here the lines are intrinsically narrower still. The average of two results for uranium gives $\Delta\lambda=1.85$ X.U. or $\Delta\lambda/\lambda=0.24$ percent. Calculation from the combination principle using M-series wave-lengths by Lindberg (Zeits. f. Physik **50,** 82 (1928)) gives $\Delta\lambda=1.93$ X.U. The ratio of the intensity of β_2 to β_{15} should be 9 to 1 by the Burger-Dorgelo rules; the average of 1 value for 81 Tl and two for 92 U gives 9 to 0.9 which is within the experimental error.

90. The band spectrum of silver chloride. Brooks A. Brice, *New York University.*—A system of bands in the ultra-violet due to AgCl has been obtained with a special discharge tube by viewing the region immediately above a trough-shaped Pt electrode covered with the fused salt. Excitation is by means of an induction coil or a transformer. Hydrogen is present at 1 to 2 mm pressure. Lines of H and Cl and Ag also occur. The bands are not obtained when AgBr or Cu_2Cl_2 are used on the electrode, or when bare Pt electrodes are used. The bands are shaded to the red, and extend from λ3140 to λ3226. Three sequences are observed, the bands of each sequence being closely grouped. The intensity distribution indicates a small change in the moment of inertia in the emission. The heads of the bands are given by

$$\nu=31570+n'(275.6-6.25n')-n''(344.7-1.86n'')$$

No evidence of electronic multiplicity is found. Four bands due to the fainter isotopic system $AgCl^{37}$ are observed. The theoretical isotopic displacements for the (0,1), (1,2) (2,3) (3,4) bands are 7.1, 8.5, 10.1, 11.9 cm^{-1} respectively. The measured values are 7, 9, 11, 10 cm^{-1}.

91. Fine structure of the beryllium fluoride bands. F. A. Jenkins, *New York University.*—The ultra-violet band spectrum of BeF, first observed by Datta, has been photographed with sufficient resolving power to permit the quantum analysis of the rotational structure. Each band has six branches, designated (in the order of decreasing frequency) R_2, R_1, Q_2, Q_1, P_2, P_1. Heads are formed by R_2, R_1, and Q_1. The combination relations between the R and Q branches have been found for the (0,0) and (1,0) bands, as well as the relations $R-Q\cong Q-P$ in the (0,0) band. These show a double initial set of terms, and a single final set. Hence the bands are probably ${}^2P\rightarrow{}^2S$, similar to those of the homologous molecules BO and CN. The system-origin is at $\nu=33{,}186.0$, and for the ${}^2P$ state $\Delta\nu=19.6$, approximately. Preliminary values of the band constants are, $B'=1.405-0.018\ n'$, $B''=1.474-0.015\ n''$. The internuclear distance in the ${}^2S$ normal state is therefore 1.365×10^{-8}cm. The relatively small value of $\Delta\nu/B$ in the upper state gives a large rotational distortion, the doublet separation contracting rapidly and approaching a nearly constant value of 2.0 cm^{-1} above $j_k=$about 30. The doublet separations are accurately the same for $R(j_k-1)$, $Q(j_k)$, and $P(j_k+1)$.

92. A new band system probably due to singly ionized HCl. Brooks A. Brice and F. A. Jenkins, *New York University.*—When a transformer discharge occurs in a continuous flow of HCl at a pressure of about 1 mm, a bright green glow is observed in the region close to the electrodes. Lines of H, and spark lines of Cl and Pt are obtained from this glow. A system of bands is obtained extending from λ2830 to λ3966. Their coarse structure shows them to be due to a hydride. The experimental evidence shows Cl to be the other element of the emitter. The same bands appear in a discharge in hydrogen with Pt electrodes covered with AgCl or Cu_2Cl_2, but not with AgBr, and not with bare Pt electrodes or bare Ag electrodes. Exact measurements of the heads are difficult because the origin is apparently very near the head, and the structure is coarse. On account of an unusual intensity distribution, it has not yet been possible to assign true vibrational quantum numbers. The bands form a doublet system with $\Delta\nu = 663$ cm^{-1}. The heads are given by

$$\nu = \begin{cases} 28446 \\ 27783 \end{cases} + 1561p - 36.3p^2 - 2569n$$

the observed values of (p, n) being $(-1,0)$, $(0,0)$, $(1,0)$, $(2,0)$, $(3,0)$, $(4,0)$, $(5,0)$, $(0,1)$, $(3,1)$. Preliminary examination of the structure indicates that of a $^2S \rightarrow {}^2P$ system, which is to be expected for HCl^+ on theoretical grounds.

93. Vibrational levels and potential energies of diatomic molecules. PHILIP M. MORSE, *Princeton University.*—An exact solution is obtained for the Schroedinger equation representing the motions of the nuclei in a diatomic molecule, when the potential energy function is assumed to be of a form similar to those calculated by Heitler and London and others. The allowed vibrational energy levels are found to be given by the formula

$$E(n) = E_e + h\omega_0(n + \tfrac{1}{2}) - h\omega_0 x(n + \tfrac{1}{2})^2$$

which is known to express the experimental values quite accurately in most cases. An empirical law is found relating the normal molecular separation r_0 and the classical vibration frequency ω_0, which is that $r_0^3\omega_0 = K$ to within a probable error of 4 percent for 21 cases. Constant K has the same value for all diatomic molecules and for all electronic levels. By means of this law, and by means of the solution above, a quite accurate representation of the potential energy function can be obtained for any electronic level where ω_0 and $\omega_0 x$ are known experimentally.

94. The explanation of a critical potential of oxygen ($O_2 \rightarrow O^+ + O$) and the intensities of the ultra-violet O_2^+-bands. E. C. G. STUECKELBERG, *Princeton University.*—Observations by Hogness and Lunn, Smyth and Stueckelberg give evidence that O^+ is formed from the neutral molecule by a single electronic impact of energy between 20 and 21.6 volts. Potential energy curves of several states of O_2 and O_2^+ were plotted by a method given by Philip M. Morse in the previous paper. The values of r_0 for the states of O_2^+ (not known experimentally) were calculated from the law $r_0^3\omega_0 = 3000$A cm^{-1}, mentioned in the previous paper. The most probable transition from the normal state of the neutral molecule to the initial state of the ultra-violet O_2^+-bands goes to a part of the curve of this state, where the vibrational energy is equal to the energy of dissociation. This explains the above experiments. The intensities of the ultra-violet O_2^+-bands were calculated by the method of Condon from the obtained energy curves. The good agreement with the observations by Johnson provides an additional check for the above assumptions and the law for r_0.

95. New terms of the oxygen arc spectrum. RUDOLF FRERICHS (*Fellow of The International Education Board*), *University of Michigan.* (*Introduced by R. A. Sawyer.*)—The oxygen arc spectrum consists of three systens, A, B, C, which are built up respectively from the three low terms, ^4S, ^2D, ^2P of the configuration $2s^2$, $2p^3$ of the oxygen ion. The system A was analyzed by Runge and Paschen and completed by Hopfield's discovery of the lowest ^3P term. It consists of triplets and quintets. Terms of the two other systems have not been found previously, although they are of especial interest since the green auroral line has been explained as forbidden transition between the lowest terms ^1S and ^1D of the systems C and B respectively. With the use of an intense source and a 6.5 meter concave grating the structure of some of the unclassified oxygen groups has been determined and some new groups have been discovered. A low term of the B system is a ^3D term (8702, 8690, 8682) which combines with the P term (21206) of system A. A combination of the ^3D term with the lowest ^3P term of system A is the diffuse triplet $\lambda\lambda$988–990 given by Hopfield. The ^3D term also combines with negative terms of the B system, two of which give the two triplets given by Runge and Paschen at $\lambda\lambda$6260 and 5410. A strong incompletely resolved group of fine lines at λ8230 gives an additional negative ^3D term. The investigation is being continued.

96. Some multiplets in the spectrum of doubly ionized copper, Cu III. R. C. Gibbs and Alice M. Vieweg, *Cornell University.*—The lowest terms in the spectrum of doubly ionized copper arise from the electron configuration $3d^9$, and successively higher terms from the configurations $3d^84s$, and $3d^84p$. Aided by analogy with the arc spectrum of cobalt, Co I, and the first spark spectrum of nickel, Ni II, some of the quartets and doublets, as well as intercombinations, arising from the transition $3d^84p$ to $3d^84s$, have been identified in copper. Several lines arising from the transition $3d^84p$ into the lowest configuration, $3d^9\,(^2D_{23})$, have also been classified in the region of 800A. The authors expect to extend this analysis into the spectrum of Zn IV, and possibly Ga V.

97. The infra-red arc spectra of carbon and nitrogen. S. B. Ingram, *National Research Fellow, University of Michigan.*—The spectrum of a carbon arc in air at sufficiently high current densities brings out strongly the arc spectra of carbon, nitrogen and oxygen. Using as a light source such an arc run at 125 amperes the wave-lengths and approximate intensities of about one hundred and twenty lines between 9000A and 20000A have been measured. The apparatus consisted of an infra-red spectrometer with a plane grating, a linear vacuum thermopile, and a Moll thermo-relay to amplify the galvanometer current. The wave-lengths appear to be accurate to about 2A and in the second order lines as close as 6A have been resolved. About ninety of the observed lines have been classified as combinations between terms in C I and N I. A number of new terms have been fixed in both of these spectra and many of the terms provisionally identified by Fowler and Selwyn in C I and Compton and Boyce in N I have been definitely confirmed. The relative values of these terms which previously depended on extreme ultra-violet measurements have been revised to conform to the more accurate infra-red data.

98. The infra-red absorption spectrum of chlorophyll and xanthophyll. R. Stair and W. W. Coblentz, *Bureau of Standards.*—Through the generosity of Dr. F. M. Schertz who isolated the material, we have been able to study the infra-red absorption bands in leaf pigments (chlorophyll, xanthophyll, carotin) using a mirror spectrometer and rock-salt prism. The xanthophyll was dissolved in carbon disulphide, and also examined in a thin film melted on a plate of rock-salt. Absorption bands were located at 1.3, 3.05, 3.45, 4.3, 6.0, 6.9, 7.3, 8.05, 8.45, 8.80, 9.05, 9.60, 9.75, 9.9, 10.4, 10.9, 11.3, 11.6, 11.9, 12.1, 12.5, 12.9, 13.2, 13.4, 13.8, 14.2 μ. The chlorophyll films were formed by evaporation from an alcoholic solution, on plates of fluorite and rock-salt. Absorption bands were located at 1.3, 3.05, 3.5, 3.8, 4.7, 6.0, 6.2, 6.5, 6.9, 7.3, 7.8, 8.2, 8.6, 9.1, 9.6, 10.1, 10.4, 10.8, 11.1, 11.9, 12.6, 12.9, 13.4, 13.7 μ. The chemical constitution of xanthophyll is unknown. Hence the band at 3μ is of interest since it is found in compounds containing OH and NH-groups. The bands are 3.4, 6.9, and 7.3μ are found in compounds containing CH_2 and CH_3-groups. None of these numerous absorption bands are so deep as found in molecules having a simpler chemical structure.

99. The infra-red absorption spectrum of carbon tetrachloride as related to the Raman spectrum of scattered radiation. W. W. Coblentz and R. Stair, *Bureau of Standards.*—Langer (Nature, March 9, 1929) has shown that it is not the frequency of a certain infra-red absorption band, but the difference between the frequencies of pairs of infra-red absorption bands, that corresponds to the Raman shift between the modified lines and the exciting line. In carbon tetrachloride the absorption band at 12 to 14μ (obtained with a rock-salt prism) is very complex and further measurements with a larger dispersion are contemplated. In the rest of the spectrum the agreement between the latest observed and Langer's calculated values are in good agreement, as follows: Calc., 13.14, 12.69; 10.24, 9.97; 9.30, 9.07; 8.20, 8.02; 6.57, 6.46μ. Obsd., 13.10, 12.67; 10.22, 9.95; 9.32, 9.08; 8.20, 8.02; 6.57, 6.45μ. Between the wave-lengths 6 and 12μ there are no conspicuous absorption bands other than the pairs just noted, and there is no doubt that the calculated values refer to these bands. Other absorption bands occur at 14 to 15μ.

100. The near infra-red absorption bands of organic compounds. E. K. Plyler, *University of North Carolina.*—An experimental study has been made of the infra-red absorption bands of some organic compounds of the methyl, ethyl, propyl and butyl groups. In the region from 1μ to 7μ there were similarities in the bands of all the different compounds. These observed bands were identified with combinations and overtones of four assumed fundamental frequencies at about 3.4μ, 6.8μ, 10μ and 15μ. These fundamental bands are probably produced by the vibrations of the C-H linkage. In some compounds such as the alcohols additional bands appeared which were attributed to other groups of atoms in the molecule. A study of the experimental work of Barnes, Ellis, and Sappenfield support the classification of the bands given in the present work.

101. A transmission-reflection grating for the infra-red. A. H. PFUND, *Johns Hopkins University.*—This type of grating consists of a large number of equidistant and parallel metallic ribbons, separated by air spaces and mounted so that the flat sides of the ribbons stand perpendicular to the "plane of the grating." By allowing radiations to fall on the grating with its lines vertical under an angle of incidence such that incident radiation is just refused direct transmission, a "blaze" of light is reflected from the ribbon surfaces. This blaze, which is similar to that obtained from echelette gratings, has a very large fraction of the incident radiations concentrated in superposed orders. Applications to infra-red investigations are discussed.

102. Series relationships in Be I. R. F. PATON AND R. E. NUSBAUM, *University of Illinois.*—Recent work on the spectrum of beryllium with a high vacuum tungsten furnace, together with data obtained by Sanders and Albers in the vacuum spark, has led to the discovery of the sharp and diffuse series of singlets for this element. These results, and those on the triplet series of Be I, indicate that the combination line $2^1S_0-2^3P_1$ should occur at about 4550 ± 5A. A strong line at 4554 ± 1A was observed in the furnace spectrograms but could not be assigned to beryllium finally, as a strong line of barium has this wave-length and other barium lines showed faintly. With greater resolution and a low pressure arc as a source the beryllium line has been resolved from the barium line and its wave-length (4553.07A) determined. This establishes a relationship between the singlet and triplet series of Be I and makes possible a more exact determination of the term values for this atom.

103. The equilibrium between surface and volume concentrations of dissolved substances. J. M. EGLIN, *Bell Telephone Laboratories, Inc.*—The composition of the surface of a solution is not the same as that of the solution as a whole. There is an equilibrium between the solute in the bulk of the solution and that adsorbed on the surface. This equilibrium is similar to the one between a vapor and the mass of that vapor adsorbed on the surface of a solid. An equation has been developed to fit the vapor-solid case from a study of the evaporation of thin films of barium on tungsten, and also from theoretical considerations. Applying this equation to the surface-volume equilibrium of a solute in a liquid, and more particularly to the surface tension changes resulting therefrom, a relation giving the surface tension as a function of the volume concentration of solute has been found. This relation is $\theta_i = |\Delta\sigma| \epsilon^{-a-b(\Delta\sigma)}$ where $\Delta\sigma$ is the change in surface tension from that of the pure solvent, θ_i is the volume concentration of solute, and ϵ, a, and b are constants. This result is found to fit observed data as well as the best empirical equation so far developed; viz. that of v. Szyszkowski.

104. Anode spots and their relation to the absorption and emission of gases by the electrodes of a Geissler discharge. C. H. THOMAS AND O. S. DUFFENDACK, *University of Michigan.*—In a Geissler discharge containing H_2, N_2, or CO_2 at pressures of 0.5 to 12 mm and electrode separations of 5 to 30 cm, the anode glow breaks up into a number of bright hemispherical spots, more or less symmetrically arranged, when the polarity of a direct current discharge is reversed. Mackay found under different conditions a similar effect in helium (Phys. Rev. **15**, 309, 1920). One necessary condition for the formation of spots is that the anode evolve gas under electron bombardment. This assumption is proved correct by the absence of spots on a thoroughly degassed anode and by the formation of spots in oxygen on an anode previously saturated with CO. As many as 75 spots arranged in 5 concentric rings have been observed on an anode 34 mm in diameter. Conditions governing the number, size, and duration of the spots have been determined. The formation of anode spots has been used to prove that the cathode and anode absorb and emit gas, respectively, at rates which are functions of the current density, gas pressure, kind of gas and electrode temperature. Spots form on anodes of all the metals tried; iron, nickel, copper, brass and aluminum. The phenomena indicate that the gas penetrates the metal to a considerable depth.

105. The gas content of sputtered films. L. R. INGERSOLL, *University of Wisconsin.*—Using a special deposition tube, which allows the cathode to be withdrawn without altering vacuum conditions, films of nickel have been sputtered in residual atmospheres of argon and helium and their gas content investigated. This is large, although, in general less than one molecule per metal atom. Upon heating, the gas is emitted copiously at 300–400°C—just the (baking) temperature range for which, as previously shown (Phys. Rev. **26,** 86 (1925); **32,** 649 (1928)), such films become magnetic and also become much better conducting. It seems probable that this gas content is primarily responsible for the abnormal magnetic and other properties of such sputtered films. These films also possess to a remarkable extent the ability to absorb or "clean up" hydrogen when a certain critical temperature is exceeded. This temperature depends on the previous heat treatment given the film and may be as low as 100°C. The amount of hydrogen absorbed is many times that required for a monomolecular layer and the process is probably one of solution. Preliminary experiments indicate no effect of this hydrogen on the crystal lattice.

106. Thermal conductivity of Pyrex glass as a function of temperature. HERMAN E. SEEMANN, *Cornell University.*—Preliminary measurements of the thermal conductivity of Pyrex glass indicate that this property increases linearly with the temperature, within experimental error, from 0.0025 cal./cm deg. sec. at 0°C to about 0.0046 cal./cm deg. sec. at 600°C. The specimen was in the form of a hollow cylinder, closed at one end with a hemispherical cap. Energy to maintain a steady temperature gradient was supplied by means of an electrically heated filament mounted axially inside the specimen. Thermal contact with the specimen was made with molten metal baths inside and outside. Temperatures were measured with thermocouples. Details of the method have been published in connection with similar work on clear fused quartz (Phys. Rev. **31,** 119, (1928)). A radiation correction for the measurements on Pyrex glass is being considered.

107. The Pierce acoustic interferometer as an instrument for the determination of velocity and absorption. W. H. PIELEMEIER, *Pennsylvania State College.*—Sputtered quartz crystals of known natural frequency were used as sources in a Pierce acoustic interferometer. The reaction of the returning waves on the crystal driver is a periodic function of the mirror displacement, causing a cycle of change in galvanometer deflection each half wave-length. Curves show that multiple reflections take place at the mirror and at the crystal where the pressure antinodes in the gas cause deflection maxima. Indications that wave velocity depends on intensity are 1st, asymmetry of the deflection peaks; 2nd, *increasing* asymmetry with increasing mirror displacement; 3rd, non-uniform peak spacing; 4th, abrupt changes in logarithmic decrement of peak height. Air and CO_2 were tested at frequencies from $3(10)^5$ to $12(10)^5$ c.p.s. The average peak spacing indicates a slightly higher velocity than for audible sound. Absorption measurements indicate that air and CO_2 become more absorbent with rising frequency, CO_2 being nearly opaque at $12(10)^5$ c.p.s. The observed absorption by air at this frequency agrees well with Lebedew's theory and with a torsion vane determination which was used as a check. At the lower frequencies the determinations are not so reliable because the absorption is rather small.

108. Application of microphotometers for the analysis of photographic sound records. J. TYKOCINSKI-TYKOCINER, *University of Illinois.*—Variable density sound records may be used in connection with many acoustic problems. In 1923 (Transactions of the Society of Motion Picture Engineers, **17,** p. 112) the author suggested the use of microphotometers for analysis of photographic sound records. Thanks to the cooperation of O. S. Duffendack, University of Michigan, and H. Siedentopf, University of Goettingen, the author has obtained microphotometric reproductions of his early sound records made in 1922 by modulating the light of a mercury arc discharge. Records taken on negative and positive cinema films and representing sounds of a violin, man's voice, woman's voice and also variations of an alternating current 830 cycles were thus investigated by the Moll thermoelectric microphotometer and also by a modified Koch-Kruss photoelectric microphotometer. Both instruments gave satisfactory results showing the quality and intensity of the recorded sounds. Imperfections of the records can be traced by this method to their origin. Poor modulation of the light source and faults due to the graininess of the film or to photographic processes can be detected by comparing microphotometric curves with those obtained with a sonometer or phonodeik actuated directly by the sound. Variable density records produced by an alternating current and analyzed by a microphotometer, show this method to be equivalent to an oscillograph for higher frequencies.

109. Some experiments on rubber at various temperatures. Paul C. Mitchell and W. W. Stifler, *Amherst College.*—Several cylindrical specimens of rubber were subjected to torsion and stretching when at room temperature, when immersed in ice-water, and when frozen in liquid air. The changes in length between room and liquid air temperatures were also observed. As would be expected, the numerical values vary with the composition of the specimen Typical results for one sample at liquid air temperature are:—Young's modulus $=1.5\times10^{10}$ dynes/cm^2; rigidity modulus $=1.8\times10^{10}$ dynes/cm^2; mean coefficient of expansion between 22°C and $-188°\text{C}=1.65\times10^{-4}$.

110. Solution of elastic vibration problems with solid damping. A. L. Kimball, *General Electric Co.*—It has been previously demonstrated, experimentally, for various types of solids of different physical properties, that the internal friction, active in damping out vibrations of these solids is independent of frequency of vibration, and depends only upon amplitude. (Phys. Rev. **30,** 948, (1927)). The dissipation per unit volume per cycle is expressed by the formula $\Delta W_1=\xi\sigma_m^2$ where σ_m is the maximum stress amplitude of the vibration cycle, and ξ a friction constant. Approximately sinusoidal elastic vibrations (free or forced) with this "solid damping" can be analyzed mathematically for any case susceptible of analysis on the basis of ideal viscous friction. This is accomplished by assuming that the actual hysteresis loops of internal friction, of lenticular form, are replaced by elliptical loops of exactly the same area. On this assumption a vibration with solid friction can be exactly represented by a differential equation involving viscous friction terms derived from the law $\eta d\epsilon/dt$ where $\eta=$frictional force per unit area per unit velocity of strain. The coefficient η must be looked upon as a parameter and is evaluated on the basis of the law $\Delta W_1=\xi\sigma_m^2$ previously given. For simple vibrating systems η is found equal to $(\xi E^2)/(\pi\omega)$, where E is Young's modulus and ω is the angular frequency of the applied stimulus.

111. Quantitative measurements of wind tunnel turbulence. H. L. Dryden and A. M Kuethe, *Bureau of Standards.*—Apparatus has been developed for quantitative measurements of the mean amplitude of the fluctuations of air speed about a mean value in turbulent air flow. The basic element is a fine wire (0.017 mm in diameter) electrically heated, the temperature and resistance of which vary as the air speed varies. A special compensating circuit is used to compensate for distortion introduced by the lag of the hot wire. The compensation is effective for frequencies up to 100 cycles per second. With this apparatus it has been found that the turbulence is different in different parts of the same wind tunnel. Furthermore the wind force on certain types of bodies is found to vary and to correlate with the amount of turbulence. It therefore appears possible to adopt a suggestion of Prandtl to use the force on a sphere as a measure of turbulence and to make the measurement a quantitative one as soon as the variation of the force on the sphere with the turbulence has been determined. A full account of this work will appear in the Technical Reports of the National Advisory Committee for Aeronautics.

112. The velocity of sound in Rochelle salt crystals. Elias Klein, *Naval Research Laboratory.*—Numerous crystal slabs, their widths lying in the *bc* plane and their lengths carefully oriented with respect to the crystallographic axes, were allowed to excite oscillations in an electrical circuit the frequency of which was determined entirely by the dimensions of the crystal. The velocity was calculated from the length of the crystal and the frequency of the circuit as obtained from a heterodyne frequency meter. Over 200 plates of various sizes cut at 45° with the b and c axes yielded an average of 4.15×10^5 cm/sec. The velocity in plates whose lengths are parallel to the c axis is not greatly different from that in plates parallel to the b axis. For long thin crystals they are approximately 5×10^5 cm/sec. This investigation is one of a series which was initiated to determine certain physical properties of piezo-active Rochelle salt *dynamically* as compared with its *static* characteristics which Valasek and others have found to pass through marked changes at 23°C. The present experiment shows no abrupt changes at this critical temperature and indicates that the velocity of sound in crystal plates is independent of temperature between 15° and 28°C

113. The extension, period, and modulus of rigidity of a spring wound in the form of a truncated cone. GYFFORD D. COLLINS AND OLIN B. ADER, *Duke University*.—On the assumption that the whole of the extension of a spring was due to torsion, the effect of shear being negligible (being about 0.2 percent in the spring used in this experiment), O. B. Ader has derived an expression for the extension of a truncated conical spring in the following form:

$$z=2MgN(R+r)(R^2+Rr+r^2)/3nr_1^4$$

in which z is the extension produced by an axial load Mg, N is the total number of coils in the spring, R and r the radii of the two end coils, n the rigidity modulus, and r_1 the radius of the wire of which the spring is made. The period of the spring is given by $T=2\pi[(1+xm/M)(z/g)]^{1/2}$ in which x is the fraction of the mass of the spring accelerated, m the mass of the spring, and z the extension produced by the load M. The fraction x varies from 1/7 in a conical spring (r equal to 0) to 1/3 in the helical spring (r equal to R).

The rigidity modulus may be calculated from

$$n=8\pi^2MN\left(1+x\frac{m}{M}\right)(R+r)(R^2+Rr+r^2)/3r_1^4T^2$$

where the symbols have the same meaning as above. All these expressions have been checked experimentally with good agreement. Further, the period is noticeably different when the spring is inverted, due to the difference in the fraction of mass accelerated, since all the other factors are constant. In the spring used the fraction was 0.2034 when the small end was up, and 0.5075 when inverted, the mass of the spring was 67.091 gm, and the load varied from 50 to 450 gm.

114. Raman effect for HCl liquid. E. O. SALANT, *National Research Fellow*, AND A. SANDOW, *New York University*.—Pure HCl liquid, at −100°C, shows the Raman effect when illuminated with a mercury arc. The modified scattering indicates an absorption band at 3.6μ for HCl liquid.

115. Note on the Raman effect in gases. E. C. KEMBLE AND E. L. HILL, *National Research Fellow, Harvard University*.—Recent experiments of Wood on the Raman effect in HCl gas show that the spectrum correlated with the 3.4μ vibration-rotation band is a sharp line at the position corresponding to the missing line of the band. He also finds some six lines, of whose genuineness he is uncertain, close to the exciting wave-length, but which he correlates with alternate lines of the pure rotation absorption spectrum. A theoretical consideration of the dispersion formula using matrix elements appropriate to a diatomic molecule in a Σ state shows that the Raman spectrum for a vibration-rotation band should consist of a Q branch, appearing as a single line at the position of the "missing line," together with "double R"-form and "double P"-form branches corresponding to $\Delta j=\pm2$. No true R and P branches exist. The apparent absence of the transitions $\Delta j=\pm2$ in the Raman vibration-rotation spectrum is presumably due to weak intensity. The pure rotation Raman spectrum should consist of a double-R branch in conformity with the observations. Detailed intensity calculations are in progress.

116. The Raman effect in gases and liquids. R. W. Wood, *Johns Hopkins University.*—(I) Lines of modified wave-length have been obtained in the radiations scattered by HCl, NH_3 and other gases at atmospheric pressure with exposures of only five hours. A "light-furnace" of improved type was employed in conjunction with an F·2 spectrograph. HCl gave the "missing line" corresponding to vibration without change of rotation, unaccompanied by the vibration-rotation lines shown in absorption. There was, in addition a group of lines very near the exciting line which can apparently be identified with the alternate lines of the pure rotation band found by Czerny in the region between 40μ and 100μ. NH_3 also gave a single line identified with the absorption band at 6.5μ, other strong absorption bands not being represented.

(II) Improved technique in the excitation of the Raman effect shown by liquids—Monochromatic excitation by a helium lamp and a method of identifying the infra-red absorption bands without wave-length measurements.

117. Singlet spectrum of Ge III. R. J. Lang, *University of Alberta.*—The author's previous analysis of the triplet spectrum of Ge III has been extended to include the following combinations for singlet terms: 4^1S-4^1P, 4^1P-4^1D, 4^1D-4^1F and the intercombinations $4^1S-4^3P_1$, 4^3D-4^1F, 4^3P-4^1D, $4'D-4^3F$, 4^1P-4^3D. Assuming a term value $F=63000$ the ionization potential is 32.6 volts. Some of the terms from the $(4p4d)$ configuration have also been found.

118. The theory of incoherent scattering. R. M. Langer, *National Research Fellow, Bureau of Standards.*—In a note to Nature (March 9, 1929) it was indicated that the wave mechanics as treated by Dirac seems to be capable of explaining the observations in scattering experiments. Since the note was sent in, others (Czerny in Naturwissenschaften, and Rasetti, Ellis, and Wood in Nature) have reported experiments which give difficulty on the commonly accepted point of view. These experiments confirm the suggestion in the note cited. For example, CO being diatomic has only one series of vibration states and therefore as Rasetti found, gives frequency shifts in scattered light which also occur in the infra-red. On the other hand, CO_2 has several series and therefore combination frequencies appear in scattering as noticed by Rasetti. The line observed by Wood at the frequency of the Q branch in HCl is of course to be expected since it does not correspond to a zero rotation change as it would in the infra-red. The absence of the P and R branches would be harder to account for especially as the diffuse shifted lines in CCl_4 at 761 and 788 cm^{-1} seem to be P and R bands. The evidence for this is that if we use the 27 cm^{-1} difference between them to calculate the moment of inertia we find $J=6.35\times10^{-39}$. This corresponds to a molecular radius $r=2.1\times10^{-8}$ cm which is very plausible since $CHCl_3$, which is similar but larger, has $r=2.4\times10^{-8}$.

119. The first spark spectrum of gallium. R. A. Sawyer, *University of Michigan,* and R. J. Lang, *University of Alberta.*—The gallium spectrum has been excited in a hollow cathode discharge in helium and photographed both with the vacuum spectograph and in the quartz and visible regions. Many new lines have been measured in the gallium spark spectrum. The chief triplet series have been established permitting the computation of term values. Several of the prominent singlet lines have also been identified.

120. The first spectrum of krypton. William F. Meggers, T. L. de Bruin and C. J. Humphrey, *Bureau of Standards.*—A new list of estimated intensities and measured wave-lengths has been obtained for more than 200 lines (3302.54 to 9751.77A) characterizing the first spectrum of krypton photographed with concave grating and with quartz spectrographs. Analysis of these new data has resulted in the identification of the main spectral terms analogous to those of the similarly constructed neon and argon spectra. Practically all of the Kr I lines have been classified in series of various types. From the series limits and combinations absolute term values are derived and the ionization potential of 13.940 volts is deduced for Kr. The general features of the Kr I spectrum closely resemble those of the preceding rare gases, Ne I and A I, and are found to be in excellent accord with the theoretical expectations. This analysis shows that the krypton line (5649.56A) which has been proposed as a primary standard of wave-length has relatively low intensity and involves a metastable level. These objections do not apply to the stronger line 5870.92A, but none of the lines can be recommended as primary standards until they have been reexamined for hyperfine structure.

121. The vector coupling in the nickel-, palladium-, and platinum-like spectra. JULIAN E. MACK, *National Research Fellow, Princeton University.*—The spectra of the platinum-like isoelectronic sequence offer evidence of an extreme departure from the normal "Russell-Saunders" type as might be expected from the position of platinum in the periodic table. Comparison of relative energies and g-values shows almost a complete transition from normal or LS coupling to jj coupling, with increasing nuclear charge and increasing atomic number, in the d^9s and d^9p configurations of the nickel-, palladium-, and platinum-like spectra. New assignments are given in Pt I and new levels in Tl IV, and Pb V. The problem of assigning conventional names (values of L and S, total orbital and spin angular momenta) to energy levels showing other than LS coupling, is closely related to the problem of coordinating levels with respect to series limits. For these problems to have any meaning, it is necessary to consider quantum numbers and atomic numbers as continuous variables.

122. Spectral terms of platinum and classification. PAUL J. OVREBO, *West Virginia University.*—Forty-nine new terms have been found for platinum. Of these seventeen are low, twelve intermediate and nineteen upper levels. Combination of these and previously known levels give 250 lines of which 150 are newly described lines. This leaves about 95 lines to be classified, excepting the lines of very low intensity. A number of combinations have been found between low and high levels. The term 29,600.8 combines with high, intermediate and low terms; 31,900.5 combines with low as well as other intermediate terms, while 44,760.9 acts as both intermediate and high levels. A number of the new levels have been classified by means of combinations. A. C. Hausmann's classification of the old low levels from the Zeeman effect has been used as a basis for these predictions of classification. In this work the tables of platinum wave-lengths of W. F. Meggers and Kayser have been assumed to be accurate to 0.05A.

123. Spectral relations between certain iso-electronic systems and sequences in the "iron group." H. E. WHITE, *Cornell University.*—Recent identifications in the spectra of V II, III, IV, V, Cr III, IV, V, Mn IV, V, Fe V are sufficient to bring out a number of interesting relations between the various electron configurations and the corresponding energy levels in these elements. The combination of ordinary energy level diagrams, for each of the elements in a sequence of iso-electronic systems, with a Moseley diagram brings out several new regularities among the iron group of elements. Such diagrams drawn for each of the four sequences of iso-electronic systems (1) K I, Ca II, Sc III, Ti IV, V V; (2) Ca I, Sc II, Ti III, V IV, Cr V; (3) Sc I, Ti II, V III, Cr IV, Mn V; (4) Ti I, V II, Cr III, Mn IV, Fe V appear to be almost identical. The combination of the ordinary energy level diagrams of neutral vanadium V I, with singly ionized vanadium V II, doubly ionized vanadium V III, triply ionized vanadium V IV, and quadruply ionized vanadium V V, with a Moseley diagram brings out a new relation between the spectra of one element in its successive stages of ionization. The above mentioned diagrams are obtained by plotting downward the square root of the term values (values computed from the series limits as zero) against atomic number.

124. Atomic levels and wave-lengths in the spectrum of the vacuum iron arc. KEIVIN BURNS AND FRANCIS M. WALTERS, JR., *Carnegie Institute of Technology.*—In the interval 2800A to 8800A some 600 lines in the spectrum of the vacuum iron arc have been compared directly with neon standards by simultaneous exposure. The atomic levels, including a large number hitherto unpublished, have been derived from these wave-lengths, and by means of these levels 1200 lines have been computed between 2100A and 9000A. Several hundred lines have been classified for the first time. The new classifications rest partly on the new levels, and partly on published levels whose combinations have been observed in the ultra-violet. The region of spectrum containing numerous precise standards has been extended from 3370A to 2100A. The intensities of the classified lines have been plotted according to the level values for both iron and titanium, and these intensity diagrams have proven to be very useful in assigning the types to newly found levels.

125. New terms in he spectrum of Al I. R. F. Paton and W. D. Lansing, *University of Illinois.*—The spectrum of Al was investigated in the tungsten vacuum furnace described by Paton and Rassweiler (Phys. Rev. **33,** 16 (1929)). The lines of the sharp and diffuse series were obtained in absorption and emission, confirming previous work. In addition the two well-known lines 3057.15 and 3050.07 appeared in emission at the same temperature as the first lines of the diffuse series, and with comparable intensity. These lines, along with a weaker one at 3060.20 measured in the vacuum spark are assigned to the transition $3^2P-3p'\ ^2D$, where the $3p'\ ^2D$ term arises from the configuration $3s3p^2$. A pair observed by Sawyer and Paschen at 1910.91 and 1906.57 are assigned to the transition $3^2p-3p'\ ^2S$. The term values are $3p'\ ^2D_3=15468$, $3p'\ ^2D_2=15504$, $3p'\ ^2S_1=-4166$. All these term values are based on the $^1S_0$ state of the Al II core. These identifications are confirmed by the irregular doublet law and the Moseley law.

126. A theory of the magnetic field associated with sun-spots. Ross Gunn, *Naval Research Laboratory.*—Theory of sun-spot magnetic fields based on the ion drift produced by ions spiralling around a nonhomogeneous magnetic field. The Hale-Bjerknes theory is retained almost completely. It is shown that the small initial symmetrical magnetic field produces currents in such a direction that regeneration is possible and that the currents flowing in the steady state are ample to account for the observed fields. The computed fields are found to be proportional to the square root of a logarithmic function of the radius of the sun-spot and the depth of the conducting layer.

127. Quantum mechanics of chemical reactions. R. M. Langer, *National Research Fellow, Bureau of Standards.*—An important class of chemical reactions can be treated as a simple quantum mechanical problem in which a system changes from one configuration to another. Reaction, i.e., configuration change, takes place only when the two configurations have states of equal energy. Since in general the states of equal energy will be higher vibration states, only molecules having more energy than the average will react. This explains the success of the "Activation hypothesis." However, the old form of this hypothesis is incorrect in several respects. For example, molecules may have energy in excess of the measured activation energy and still be incapable of reaction because the final configuration has no state of the same energy. Metathetical reactions, decompositions, including radioactive decompositions, and other classes may be treated in this manner. Most interesting is the possibility that sometimes the function of a catalyst is to change the energy levels so that there is an equality where there was none before.

128. The Clausius' equation of state. Herbert J. Brennen, *Department of Chemistry, Northwestern University.*—I have recently pointed out [Proc. Nat. Acad. Sci. **15,** 11–18 (1929)] that equations of state must contain, in general, (at least) three volume parameters and hence, van der Waals' equation, which contains only two such parameters, *a* and *b*, must, in general, be mathematically absurd. Therefore Clausius' equation, which has long been condemned as having one too many such parameters becomes no more logical than that of van der Waals. It is shown that the values of the "reduced" parameters can be very easily calculated from the observed critical ratio, RT_c/P_cV_c; if this ratio is 8/3, the value of the third reduced parameter is zero and hence the equation becomes that of van der Waals; if the critical ratio is 3.75, the mean of a large number of substances, the value of the reduced volume of the molecules is 1/16, whereas the experimental value is approximately 1/4; if the critical ratio is above 4.0, we obtain the absurd result that the volume of the molecules is negative. Hence Clausius' equation must be rejected.

129. Ionization of caesium vapor by line absorption. F. L. Mohler and C. Boeckner, *Bureau of Standards.*—Further experiments on the effect discovered by Mohler, Foote and Chenault (Phys. Rev. **27,** 37 (1926)) have been undertaken. Ionization by light on the red side of the limit is produced largely, if not entirely, by absorption by the principal series lines beyond the third line. Measurements of the line effect relative to the photo-ionization produced by light on the violet side of the limit show no measurable change of the effect with temperature between 150°C and 230°C at constant pressure. A comparatively small change with vapor pressure can probably be explained by absorption in the layer of vapor outside of the ionization chamber. Residual gas in the tube reduces the effect. Measurements of the reduction of the photo-ionization by a separate absorption cell containing caesium are being made. A column of vapor 30 cm long at a pressure of 0.015 mm reduced the effect at 3600 to ten percent, while on the violet side of the limit the change is unmeasurable (less than one percent).

130. Incoherent scattering in Rochelle salt. R. M. LANGER, *National Research Fellow, Bureau of Standards,* AND ELIAS KLEIN, *Naval Research Laboratory.*—The spectrum scattered by crystalline Rochelle salt differs in character from that of calcite and quartz; the latter substances show sharp as well as hazy lines while the modified lines observed in Rochelle salt are all very diffuse. Furthermore, there are two broad continuous bands, which conicide with those obtained with pure water and water solutions. These bands are undoubtedly due to water of crystallization and correspond with two which are found in infra-red absorption (Coblentz). However, the scattered lines do not correspond with the infra-red absorption maxima observed by Coblentz nor with the reflection maxima noted by Pfund. But the combinations among these seem to account for most of the numerous (about ten) frequency shifts which is in accord with the theory (Nature, Mar. 9, 1929) of the effect. The shifts range from about 500 to 3000 wave-numbers. Measurable plates were obtained by an exposure of one half hour.

131. Lattice energetics of plastic flow in metals. R. H. CANFIELD, *Naval Research Laboratory, "Bellevue," Anacostia, D. C.*—Previous work of the author having supplied data on the width of the negative part of the energy diagram for metals, ("Lattice energetics of thermal vibrations in metals," December meeting) an attempt has been made to obtain a formula for the stress at which plastic flow commences in a metal crystal or polycrystalline aggregate. The assumption made is that the elastic energy in the grain is made available to augment the work of the external force in overcoming the resistance to sliding in a single plane. The formula involves the geometry of the lattice and the plane and direction of slip, and is in good agreement with experiment for polycrystalline Armco iron.

132. The formation of spiral nebulae. H. B. MARIS, *Naval Research Laboratory, Washington, D. C.*—It is shown that a star cluster 1.3×10^{22} cm in diameter, as our galaxy, moving through intergalactic space filled with gas of density 10^{-26} grams cm^{-3} will sweep up this gas and leave a cone of low density in its wake. Due to the gravitational attraction of the surrounding gas the cone expands, the outward velocity of its wall being 2 km sec^{-1} after 10^8 years and 650 km sec^{-1} after 10^9 years. At this time the diameter of the cone is 10^{24} cm, which is about the average distance between the spiral nebulae, and it is assumed that the expanding walls are broken up by other galaxies, etc. The condensations of galactic size and mass thus formed contract under gravitation with little increase in temperature for, say, 10^8 years. With increasing density diffusion becomes important and the temperature of the entire mass rises rapidly until radiation pressure stops the gravitational fall and gives the component parts of the total mass outward velocities of hundreds of km sec^{-1}, such as are observed in the spiral arms of the expanding nebulae. Temperatures of 10^{10} degrees would be reached even at the surface and conditions suitable for the emission of penetrating radiation would prevail.

133. The distribution of electrons between the plate and grid of a three electrode tube as determined by positive caesium ions. J. M. HYATT, *Union College, Schenectady, N. Y.*—It is impossible to determine the exact distribution of primary electrons to the grid and plate of a tube on account of secondary electron emission. It can be shown that the paths of positive ions are the same as those of electrons at the same potentials. Hence, if the distribution of positive ions is determined, taking into account the emission of secondary electrons, the electron distribution becomes known. The source of the positive ions was a tungsten filament in the bulb of a radiotron UX201A containing caesium vapor. The emission and plate currents were observed at given negative grid potentials as the plate potential was varied from +45 to −600 volts. The part of the observed plate current due to secondary electrons from the grid and plate was calculated and the true positive ion current determined. The fraction of the positive ions caught by the plate increased to 0.86 for a plate potential to grid potential ratio (E_p/E_g) of 0.70 and remained constant for higher ratios of $E/_pE_g$. The ratio of the open to the closed areas of the grid was found to be 0.87. This indicates that the electron distribution may be calculated from the dimensions of the grid in this general type of tube.

134. An extension of the spark spectrum of copper. Gerald Kruger, *Cornell University,* (*Introduced by R. C. Gibbs*).—It has been shown that the ground term of copper II is a ^1S which arises from $3d^{10}$ electrons. The next higher terms are $3d^94s\ ^1D^3D$ and still higher are found the terms $3d^94p\ ^3(PD^1F)\ ^1(PD^1F)$. One term of the $^1S_0$ series, two terms of the $^1D^3D$ series, and one term of the $^3(PD^1F)\ ^1(PD^1F)$ series have been found. It was the object of the present work to extend the $^1D^3D$ series so that an accurate calculation of the limit would be possible. A Schueler lamp of the hollow cathode type was used as a light source. The spectrum was photographed by using a vacuum spectrograph which was so designed that the region (0–2600A) could be photographed on one plate. A grating (15000 line per inch) giving a dispersion of 11.12A per mm was used. Two higher members of the $^1D^3D$ series have been found and the limit of the series calculated on this basis. These calculations show that the $^1S_0$ lies 163738 cm^{-1} below the $^2D_2$ level of Cu III from which the ionization potential was calculated to be 20.2 volts. This places the first members of the $^3D_{123}$ series at 141813 cm^{-1}, 140894 cm^{-1}, and 139743 cm^{-1} respectively. In addition, several lines in the region 90000 cm^{-1} and 110000 cm^{-1} have been found, which have the $^3D^1D$ separation, but they have not been completely classified.

135. The fine structure and satellites of the *K*-alpha lines of the light elements. C. B. Bazzoni, L. Y. Faust and B. B. Weatherby, *University of Pennsylavnia.*—The x-ray spectra of certain light elements have been measured including boron, oxygen and carbon both free and in various compounds. A grating on glass 1179 lines per mm furnished by Professor R. W. Wood was employed in a special vacuum spectrograph. The lines were analyzed with a densitometer involving a Moll vacuum thermocouple. The lines are complex the width of boron $K\alpha$ being about three Angstroms comprising primarily a doublet with four or more accessory peaks on the long wave side and several on the high frequency side. The wave-length for the principal peak is 68.12A. In addition this line when obtained from boric oxide is accompanied by satellites at 72.2, 66.0, 65.1 and 74.7. It is suggested that these lines may represent boron $K\alpha$ radiation plus or minus the quanta associated with the stimulation or ionization of atoms of other elements involved in the molecular structure. This proposition is still under consideration. Measurement of the $K\alpha$ of carbon gives 44.9A for the principal apex. The carbon line has been densitometered in three orders showing details of fine structure in the third order. The breadth of this complex line is approximately 2A.