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PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE WASHINGTON MEETING, APRIL 30, MAY 1 AND 2, 1931

The 170th regular meeting of the American Physical Society was held in Washington, D.C., at the Bureau of Standards on Thursday and Friday, April 30 and May 1, and at the National Academy of Sciences on Saturday, May 2, 1931. The first session began at ten o'clock on Thursday morning. The presiding officers were W. F. G. Swann, President of the Society, Paul D. Foote, Vice-president, Joseph A. Becker, Lyman J. Briggs, Arthur H. Compton, Karl K. Darrow, Henry G. Gale, Enoch Karrer and L. P. Sieg. At the Bureau of Standards on the first and second days of the meeting the registration was 388. A fair estimate of the total attendance at the sessions was between four and five hundred.

On Thursday afternoon the Society omitted its regular sessions from one-thirty to three-thirty o'clock to meet with the newly formed American Association of Physics Teachers. At this session Dr. A. W. Hull of the General Electric Company presented an invited address on "Qualifications of a Research Physicist."

On Thursday evening a public forum was called at the National Academy Building to discuss methods of promoting interest in all branches of physics. This meeting was called by L. W. McKeehan, chairman of the Committee on Sections and was presided over by F. K. Richtmyer.

On Friday evening the Society held a dinner at the Hotel Washington. The President presided at this dinner and the after-dinner speakers were George K. Burgess, Arthur H. Compton, Charles Darwin and F. Henning. R. H. Fowler was also a guest of the Society at the speakers table. The attendance at this dinner was 243.

On Saturday afternoon at the National Academy Building there was held a special colloid program. The papers at this session were invited. The presiding officer of this meeting was Enoch Karrer of the B. F. Goodrich Company.

Meeting of the Council. At its meeting held on Thursday, April 30, 1931, sixteen persons were transferred from membership to fellowship and thirty-seven were elected to membership. *Transferred from Membership to Fellowship:* James H. Bartlett, Jr., David G. Bourgin, V. L. Chrisler, S. Goudsmit, Robert J. Havighurst, Paul Kirkpatrick, W. W. Nicholas, Linus Pauling, Shirley L. Quimby, Richard Ruedy, A. G. Shenstone, Ernest C. G. Stückelberg, George E. Uhlenbeck, N. H. Williams, Mark W. Zemansky and R. V. Zumstein. *Elected to Membership:* Edward B. Baker, M. C. Banca, William E. Berkey, Margaret F. Blackford, Robert L. Boyer, Percy H. Carr, Nickola

Chako, Thomas A. Elkins, David W. Epstein, Richard Evans, O. Rex Ford, Gladys M. Francis, Garret A. Hobart 3rd, Cleveland B. Hollabaugh, Howard B. Holroyd, Jun Koana, C. M. Lewis, Walter G. Marburger, A. T. McPherson, Paul C. Mitchell, George C. Munro, Robert J. K. Murray, Leon S. Nergaard, Paul A. Northrop, Syoten Oka, Allan E. Parker, Clifford M. Potter, Norman A. Shepard, William B. Shockley, Leland B. Snoddy, Daniel S. Stevens, G. R. Tatum, Sigeo Uneno, Forrest Western, John A. Wheeler, E. P. Wigner and Robert L. Womer.

The regular scientific program of the Society consisted of 163 papers, numbers 11, 25, 34, 40, 44, 47, 48, 49, 50, 68, 71, 95, 108, 120, 127, 131, 144, 152, 153, 155, 157, 158 and 163 were read by title. The abstracts of these papers are given in the following pages. An **Author Index** will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

1. Dissociation of water vapor in electrical discharge. ERNEST G. LINDER, *Cornell University.*—By use of Townsend's ionization equation and Aston's result for the potential distribution in the Crookes dark space, the number of electrons produced at each point in the dark space can be obtained. From this, may be calculated the total energy of all the electrons generated by each primary electron, i.e., $\int_0^S(V_1-V)dn$, where S = length of dark space, V_1 = cathode potential drop, V = space potential, n = number of electrons. Using experimental values of S and V_1 and Townsend's constants, it is thus found that for discharge currents of 1–25 m.a. the average energy per electron runs from 53.8 to 79.2 volts, these values being from 17.8 to 14 3 percent of the corresponding total cathode drop energies The amount of dissociation in the dark space and negative glow for the above currents is from 4.78 to 5.90 molecules of water per electron, which gives an almost constant value of 11 volts per dissociation. The results suggest that dissociation is due to excitation of the molecule. Probe measurements in the positive column give an electron density of 7.4×10^7 electrons per cm^3, and a mean energy of 3.71 volts. If a probability of dissociation by electron impact equal to 0.0024 be assumed, the dissociation in the positive column can be accounted for.

2. The electro-optical shutter and spark breakdown. FRANK G. DUNNINGTON, *University of California.* (*Introduced by Ernest O. Lawrence*).—The use of the electro-optical shutter in investigations of rapidly varying phenomena necessitates knowledge regarding its manner of functioning and limitations. Using a typical experimental set-up as an example, theoretical cut-off curves have been calculated: 1st, assuming an instantaneous drop of the controlling voltage (i.e. spark gap), and 2nd, assuming the controlling voltage decays according to a definite law. These indicate an effective cut-off time (90% to 10% transmission) of from 2.5 to 4×10^{-9} sec. and a total lag of 4 to 9×10^{-9} sec. Experimental results show a complete change in the appearance of the spark in 5×10^{-9} sec., thus indicating an effective cut-off time somewhat less than this value. Other results set a lower limit on the total lag of about 7×10^{-9} sec. The effective working of the shutter is dependent on the following major factors: (1) purity of nitrobenzene used in Kerr cell; (2) resistance of leads to cell; (3) voltage applied; (4) capacity of cell; (5) steepness of voltage wave used to control shutter. Contrary to previous beliefs, theory and experiment show the best control voltage is only slightly under that giving 100% transmission. A graphical survey giving the step by step development of the breakdown of a gap in an initially homogeneous field has been made for pressures from 20 to 76 cm and gap lengths from 1 to 10 mm.

3. The effect of pressure on the rate of fall of potential in condensed discharges. J. C. STREET AND J. W. BEAMS, *University of Virginia.*—The experimental method was essentially the same as one recently described (Street, Bulletin American Phys. Soc. Feb. 1931) and somewhat similar to Toepler's (Archiv für Elektrot. **14,** 305, 1925) though different in important essentials. Electrical impulses produced by the discharge under investigation traveled along two parallel symmetrical lead wires to their open ends where they were reflected. The maximum potential across the two ends when measured as a function of the length of lead wires gave a curve from which the rate of fall of potential across the discharge was determined. Our results show that in the first part of the breakdown the resistance can best be represented as a function which decreases exponentially with time. When the potential was very slowly applied (static breakdown) the following are some of the results obtained for the decrease of potential with time:

Pressure in cm of Hg	Time of fall from 100 to 20%
38	4.7×10^{-8} sec.
54	2.5
75	1.7
95	1.1
115	.8
139	.8

The results are in general accord with the calculations of Schilling (Archiv für Elektrot. **25**, 97, 1931). Incidentally they indicate how to obtain a maximum rate of discharge for Kerr cells and illustrate how they are damped when used with short leads.

4. On the formation of an arc or spark on interrupting an electric circuit. THOMAS J. KILLIAN, *Massachusetts Institute of Technology.*—There seem to be two possible sources of the spark or arc which results when a physical circuit, carrying unidirectional current, is opened. J. Slepian (J.A.I.E.E., Oct., 1926) has suggested that the initial ionization is due to the temperature rise of the last contact point of the separating electrodes. At high breaking speeds this theory is subject to certain theoretical and experimental difficulties. If no conduction current flows immediately after the contacts are opened the charging current will cause the potential difference and the electric intensity between the contacts to increase. It is shown that the electric field may attain 10^6 to 10^7 volts cm^{-1} at which values "field" currents may flow. When the potential difference between the electrodes is such that the electrons, which have been drawn from the metal by these intense fields, may produce ionization an arc or spark results. An analysis of oscillograms taken at various current densities and opening speeds seems to show that this mechanism may initiate the discharge. This may indicate a method of studying "field" currents at high densities which until now have only been studied at extremely low densities.

5. Vacuum spark discharge. L. B. SNODDY, *General Electric Co.* (*Introduced by A. W. Hull.*)—Impulsive breakdown between pure copper electrodes in high vacuum has been investigated by means of the cathode ray oscillograph and the rotating mirror. (See J. W. Beams, Review of Scientific Inst. **1**, 667, 1930). The mirror photographs of the discharge show a luminous spot at the anode lasting from 1 to 4×10^{-7} sec. and luminosity at the cathode starting slightly later (1 to 2×10^{-7} sec.) than that at the anode and continuing throughout the discharge. The anode does not remain luminous unless the current is very large. The breakdown has two stages; the first a pure electron discharge, lasting less than 5×10^{-7} sec., followed by a low voltage copper vapor arc. The volt-ampere characteristic of the high voltage stage follows the well known law for auto-electronic emission. From the volt-ampere curves the area of emission at the cathode can be computed (Stern, Gossling and Fowler, Proc. Royal. Soc. **124**, 699, 1929). For two gaps investigated the areas were approximately 3×10^{-3} $\overline{\text{cm}}^2$ and 1×10^{-5} $\overline{\text{cm}}^2$. Using these areas and the rate of potential rise as determined by the oscillograph it is shown that in each case the anode spot at the time of breakdown reaches a temperature of approximately 2600°C. Photomicrographs of the anode show craters of area agreeing well with the computed areas. Current densities, determined from the circuit constants and measured areas of the cathode craters, range from 10^8 amps/$\overline{\text{cm}}^2$, at 5×10^{-7} sec. after breakdown, to 8×10^3 amp/$\overline{\text{cm}}^2$, at which value the arc goes out.

6. On the temperature of cathode in vacuum arc. R. Tanberg and W. E. Berkey, *Westinghouse Elec. & Mfg. Co., East Pittsburgh. (Introduced by Thomas Spooner.)*—Pyrometric and spectroscopic tests show that the metal cathode spot in a vacuum arc is not at an extremely high temperature. The temperature of a copper cathode is measured by an optical pyrometer and found to be about 3000°K in a 20 ampere arc. Spectroscopic examination of the cathode spot shows only a faint continuous spectrum indicating that the temperature of the cathode is not high. A temperature of the above magnitude is shown to be sufficient to give the rate of vaporization required under extreme assumptions. The results show that the high speed of the vapor stream issuing from the cathode region cannot be due to high temperature of the cathode itself.

7. The cathode fall of an arc. R. C. Mason, *Westinghouse Elec. & Mfg. Co., East Pittsburgh.*—To explain the mechanism of a mercury-pool arc, in which the cathode is at a relatively low temperature, Langmuir has suggested that electrons are extracted from the cathode by a very high field. Presumably, the same theory will apply to all arcs in which the cathode is not hot enough for appreciable thermionic emission. An analysis is presented in this paper showing that, under the same conditions, an arc in which the high field is operative should have a cathode fall several volts greater than an arc with a thermionic cathode. Upon either the classical Schottky theory, or the quantum mechanical theory of high field emission, the energies of electrons at the boundary of the cathode fall space will be several volts less in the high field arc than in the thermionic arc; so, to produce sufficient positive ions for space charge purposes, the cathode fall of the former must be greater than that of the latter. A test is thus suggested for the Langmuir theory of an arc.

8. Measurements on the vapor stream from the cathode of a vacuum arc. W. E. Berkey and R. C. Mason, *Westinghouse Elec. & Mfg. Co., East Pittsburgh.*—The velocity of the vapor stream issuing from the cathode region of a vacuum arc between copper electrodes is calculated from (1) the energy received by a vane 3 cm in front of the cathode, as measured by the rate of rise of temperature; (2) the momentum imparted to the vane, as determined by the deflection of the vane. The mass used in the calculations is that of the copper deposited on the vane. The average velocity of the vapor, computed from data obtained by either method, is over 10^6 cm per second, confirming Tanberg's momentum measurements. There is some evidence that the vapor is ionized to a considerable degree. Radiation from the arc, or energy of recombination on the vane, can account for only a small part of the total energy received by the vane.

9. A method for the comparison of magnetic susceptibilities of feebly magnetic salts. L. G. Hector and Albin N. Benson, *The University of Buffalo.*—A method depending upon induced current phenomena may be employed for comparing the magnetic susceptibilities of substances whose electrical conductivity is small. The present method depends upon the comparison of the alternating electromotive forces developed in two coils each of which is coupled to a field coil. A tube filled with the salt to be examined is then placed in one of the pick-up coils and a change in the coupling between the pick-up coil and the field coil is thereby produced. By means of a variable resistor shunted about one field coil a balance between the induced e.m.f. is restored. Comparison of the two induced alternating e.m.f. was first attempted by means of a vacuum tube voltmeter, but slight irregularities in wave form and shifts in phase resulted in uncertainty in the readings. In the latest method, current from each pick-up coil is rectified by thermionic tubes and the rectified current is further smoothed out by filters. The potentials developed across the last condenser bank in each filter are then compared by means of a direct current galvanometer.

10. Block structure and magnetic viscosity. Francis Bitter, *Westinghouse Elec. & Mfg. Co., East Pittsburgh.*—As a result of the work of Becker (Zeits. f. Physik **62**, 253, 1930) and Powell (Proc. Roy. Soc. **130**, 167, 1930) it is now possible to write the expression for the potential energy of a single crystal as a function of the direction of magnetization in the crystal, say $\Phi(\theta, H)$. This expression depends on the crystalline field, or (s, l) interaction, and on the distortion of the lattice, and has, in general, several minima as a function of θ. If the crystal is made up of regions of spontaneous magnetization, the equilibrium distribution of orientations is given by an expression of the form exp. $(-\Phi_v(\theta, H)/KT)$ where Φ_v represents the potential energy of such a region. This distribution cannot in general be established in a reasonable time because of the existence of several maxima of Φ_v. If, however, we know the distribution of orientations, f, at a time $t=0$ (say complete demagnetization, or saturation) then the distribution at a time t resulting from a change in H is given by the diffusion equation

$$a\nabla\cdot(f\nabla\Phi_v) + b\nabla^2 f = \partial f/\partial t.$$

This equation has not been solved except for special and simple forms of Φ_v. A closer inspection, however, shows that a gradual "creeping" of magnetization will not, in general, occur unless the depth of the Φ_v minima is comparable with KT. Since the depth of these minima depends on the volume of a region, magnetic viscosity phenomena in single crystals may eventually be used to determine the volume of the regions of spontaneous magnetization and so check the hypothesis (Phys. Rev. **37**, 91, (1931)) that they are identical with Zwicky's blocks.

11. Magnetic properties of magnetite crystals at low temperature. CHING-HSIEN LI, *University of Illinois.*—Thin circular plates cut parallel to the 100, 110, and 111 planes of the magnetite crystal were prepared. Both the perpendicular and parallel components of magnetisation at low temperatures down to that of liquid air were investigated by the method of torsion. It was found that the magnetic property of the crystal was abruptly changed at about −160 degrees centigrade. It seems that the elementary magnetic elements within the crystal are very easily rotated in the magnetic field at that particular temperature. This particular temperature corresponds exactly to the temperature at which the heat capacity of magnetite is suddenly increased to a maximum point as was found experimently by R. W. Millar two years ago. Weiss' theory of the molecular field as applied to this change of specific heat and the corresponding change of magnetic property is in the process of investigation.

12. Effect of heating on residual magnetism. R. L. SANFORD, *Bureau of Standards, Washington, D. C.*—Experiments with a 0.63 percent carbon steel show that if the structure is lamellar pearlite, consisting of alternate plates of iron and iron carbide, the residual induction reverses sign at a temperature of approximately 200°C and regains part of the magnetization in the original direction upon cooling. If the temperature is raised to 800°C, the residual induction disappears and does not reappear on cooling. If the material is remagnetized in the original direction while at a temperature of approximately 265°C, the residual induction decreases upon cooling and finally reverses at a temperature of about 30°C. Hardened steel does not reverse but the presence of very fine lamellar pearlite produces a reversal. Precipitated carbide produced by reheating a hardened specimen does not cause the reversal. The lamellar structure appears to be necessary for the reversal. The first reversal can be satisfactorily explained as the result of the thermomagnetic transformation of the carbide plates which first reverse the magnetization in the adjacent iron plates and then become nonmagnetic at the so-called A_0 point. The reversal after remagnetization at the high temperature is not so easy to explain.

13. Annual variations in magnetic storms. H. B. MARIS, *Naval Research Laboratory, Bellevue, Anacostia, D. C.*—A new list of magnetic storms for the years 1839 to 1930 shows an annual variation in the frequency of disturbances with two equal maxima about a week following the equinoxes and two equal minima at the solstices. The ratio of the maximum to the minimum frequency is nearly two to one. The distribution of frequency F is given approximately by the equation, $F=k(3+\cos 2\theta)$, where θ is the position of the sun on the ecliptic. Three groups of storms showing annual recurrence interrupt the normal distribution curve. The first, 1840 to 1865 had a maximum about February 20, the second group started April 10, 1854, and was intermittently persistant with a two year period till 1875 and the third group started May 16, 1913, and is almost unbroken since then. The change from maximum to minimum frequency between equinox and solstice is explained as the result of three effects. The ultraviolet flair, which is assumed to come from the solar latitude where sun-spots are observed, should increase in intensity as the earth increases its solar latitude. This would be expected to give a ten percent change in storm intensity. Expansion of the upper atmosphere as it is heated by the solar flair causing the storm will move the conducting Heaviside layer across the earth's magnetic field with a dynamo effect which will decrease by about fifteen percent from equinox to solstice.

Winds blowing from day toward night will have a maximum dynamo effect in driving atmospheric electric currents at equinox.

14. Magnetic properties of copper-nickel alloys. E. H. Williams, *University of Illinois.*—The magnetic susceptibility of alloys of copper and nickel in proportions ranging from 0.1 to 70 percent nickel have been studied. Although copper is only weakly diamagnetic it requires 0.8 or 0.9 percent nickel to neutralize this diamagnetic effect and 56 percent nickel is required before the alloy shows ferromagnetic properties at ordinary temperatures. For amounts of nickel from one percent up to 30 percent the alloy, while paramagnetic in most respect, does not obey any law of paramagnetism with regard to temperature. As the temperature is increased the susceptibility first increases and then decreases, the maximum occurring in the neighborhood of the Curie point for nickel. In the case of alloys containing more than 30 percent nickel the susceptibility decreases with increase of temperature for temperatures above 20°C. So far as the phenomena of increasing paramagnetic susceptibility are concerned there is at present no explanation. It has been suggested that a few atoms or molecules of nickel do not lose their magnetic identity in the alloy and that these atoms with their spinning electrons become more mobile as the temperature is increased. One objection to this is that the susceptibility is independent of the field.

15. The origin of thermionic electrons from oxide coated filaments, R. W. Sears and J. A. Becker, *Bell Telephone Laboratories, Inc.*—The following experiments show that the emission is determined by the condition of the oxide surface and not the core-metal surface as proposed recently by Lowry (Phys. Rev. **35**, 1367, (1930)) and also Riemann and Murgoci (Phil. Mag. **9**, 440, 1930). (1) When barium is deposited on the oxide surface either by evaporation from an external source or by electrolysis of the oxide itself, the emission changes even though the temperature is so low that the barium could not diffuse to the core surface. (2). A removal of the oxide coating while the filament is at room temperature causes the emission as determined at low temperatures, to decrease by a factor of 6000 or more. (3). When space charge limited current is drawn to a plate, the potential of a point in the oxide is always positive with respect to the core surface by an amount directly proportional to the current. If the current were determined by the core surface this potential should be negative and should not vary linearly with the current. The experimental facts adduced to prove a limitation by the core surface are not conclusive and can be explained on the view proposed here.

16. Theoretical interpretation of experimental Richardson plots. W. H. Brattain and J. A. Becker, *Bell Telephone Laboratories, Inc., New York.*—The theoretical equation for the saturation current is

$$\ln i - 2\ln T = \ln A + \int_1^T \frac{b}{T^2}dT - (b)_{T=1} = \ln A - \frac{a}{T} \tag{1}$$

$A = 4(1-r)\pi mk^2e/\mathrm{h}^3$, "$b$" is defined in terms of L_p, the total heat of evaporation per mole at constant pressure. $b = (L_p/R) - (5T/2)$ "a" is defined by Eq. (1). It is related to the free energy If "a" and "b" are functions of T, an experimental plot of $\ln i - 2\ln T$ vs. $1/T$ will, in general, not be a perfect straight line. At any value of $1/T$ a tangent can be drawn. Its slope is $-b$ or $[-a+T\,da/dT]$ and the intercept is $[\ln A - da/dT]$ or $[\ln A + (b-a)/T]$. Actually, db/dT is usually so small that the mean straight line through the experimental points is practically coincident with the tangent at the mean value of $1/T$. If, as Herzfeld suggests, "a" $= h\nu_0/k$; the slope of the Richardson plot equals $-(h/k)[\nu_0 - T\,d\nu_0/dT]$ where the slope, ν_0, and $d\nu_0/dT$ all refer to values taken at the same temperature; the logarithm of the universal constant A is equal to the intercept $+(h/k)(d\nu_0/dT)$; also, the term "work function" cannot, in general, be used for both the slope of the Richardson plot and $h\nu_0$.

17. Influence of space charge on current fluctuations. E. W. Thatcher and N. H. Williams, *University of Michigan.*—Current fluctuations of two fundamental types are recognized in a circuit containing a thermionic element: (1) Those due to the discreteness of the carriers, governed by probability relations applied to their departure from the cathode and collection at the anode. (2) Those due to thermal agitation of electricity in the circuit, analogous to the Brownian fluctuation of particles in colloidal suspension. The influence of electron space charge on these fluctuations has been investigated with especially designed tubes. Precise measurements in this region have hitherto been unattainable on account of the inherent "mixed" nature of the emission from metal surfaces. Abnormalities arising from this source in tungsten and thoriated tungsten have been studied and controlled. A new treatment of the shot effect as applied to pure electron emission yields an expression for the ratio of the mean square value of the fluctuation voltage under given space charge conditions to that under strict temperature limitation of the current:

$$\frac{\overline{V_s^2}}{\overline{V_t^2}} = f(i_0/i)e^{-\omega^2/2\alpha^2}$$

I_0 is the space current, i the saturation current associated with a particular emitter temperature, and their ratio characterizes the space charge situation. The influence of the frequency term has been shown to be vanishingly small over a range of frequencies from 50,000 pps. to 500,000 pps. The function "f" has been experimentally determined for various situations of current limitation.

18. Supersonic satellites. W. H. Pielemeier, *Pennsylvania State College.*—As the path length in a Pierce acoustic interferometer was increased, satellites, or minor peaks, became more prominent in the curves which correlate the *excess of plate current over bias current*, $(I_p - I_B)$, and the *mirror position*, (x). With the exception of the satellites these curves have a striking resemblance to the curves which correlate the *calculated square of the pressure amplitude in the air at the crystal surface* and the *mirror position.* A wave velocity independent of intensity was assumed for the calculation. If it is assumed that the velocity of the waves decreases to the limiting value, $V = (\gamma p/d)^{1/2}$, with diminishing intensity, not only the shape of the satellites, but also their position is thereby explained. Measurements were made with several crystals. For each of the frequencies tested the acoustic velocity as determined by the satellite positions differed by less than 0.06 percent from the above limiting value. In every case the velocity, as determined by the major peaks, *exceeds* the theoretical value by more than 0.5 percent. Such a large shift could scarcely be a frequency shift as the resonance positions are approached.

19. Canonical transformations and the vibrations of a loaded string. R. B. Lindsay, *Brown University.*—The classical method of discussing the transverse motion of a finite string of negligible weight fastened at the ends with tension τ and loaded with particles of equal mass m and equally spaced at distances a is that in which the Lagrangian equations for a system of n degrees of freedom are set up and integrated by means of determinant analysis. It is here shown that if we denote the coordinate and conjugate momentum of the sth particle by q_s, p_s and perform the transformation to the new system Q_s, P_s defined by the transformation function

$$S = \sum_{k=1}^{n}(m/2)^2\omega_k^2 \cot Q_k \left[\sum_{s=1}^{n} a_{sk}q_s \right]^2,$$

where $a_{sk} = 2 \sin (sk\pi/n+1)/(m(n+1)\omega_k)^{1/2}$ and the ω_k form a set of parameters, the Hamiltonian

$$H = 1/2m \cdot \sum_{k=1}^{n} p_k^2 + \tau/2a \cdot \sum_{k=1}^{n+1}(q_k - q_{k-1})^2$$

(with $q_0 = q_{n+1} = 0$) transforms into $K = \sum_{k=1}^{n}\omega_k P_k$ with $\omega_k = 2(\tau/ma)^{1/2} \cdot \sin k\pi/2(n+1)$. The canonical equations now lead to $P_k = \text{const}$, $Q_k = \omega_k t + \beta_k$ and the usual solution is at once obtained from $p_k = \partial S/\partial q_k$ in the form

$$q_s = \sum_{k=1}^{n} a_{sk}P_k^{1/2} \sin (\omega_k t + \beta_k)$$

$$p_s = m \sum_{k=1}^{n} \omega_k a_{sk} P_k^{1/2} \cos (\omega_k t + \beta_k) \quad \text{where}$$

the ω_k appear as the characteristic frequencies (multiplied by 2π). The generalization to the continuous string is immediate. The transformation $q(x) = 2/M^{1/2} \cdot \sum_{k=1}^{\infty}(P_k/\omega_k)^{1/2} \sin Q_k \cdot$

sin $k\pi x/l$ where l is the length and M the mass of the whole string, carries the Hamiltonian functional into $H=\sum_{k=1}^{\infty}\omega_k P_k$ where now $\omega_k = k\pi(\tau/Ml)^{1/2}$. The energy fluctuation and quantization of the loaded and continuous strings are investigated.

20. The elastic constants and the thermal expansion of a sample of rubber between room temperature and −30°C. W. W. Stifler, *Amherst College*, and Paul C. Mitchell, *Missouri Valley College*.—A method has been developed by which the coefficient of linear expansion, Young's modulus, and the coefficient of rigidity can be measured on the same sample of rubber at any temperature from that of the room down to −30°C. For a particular sample, the thermal expansion proceeds quite regularly in this range but the coefficients of elasticity increase rapidly as the temperature is lowered. For example, at 22°C, Young's modulus is 1.30×10^8 dynes per cm^2 and at −30°C it is 3.56×10^8 dynes per cm.^{2}

21. Columns with variable end restraints. L. B. Tuckerman and Wm. R. Osgood, *Bureau of Standards*.—Because of its importance in aircraft construction, the Bureau of Aeronautics of the United States Navy has supported an investigation of the strength of columns with variable elastic end restraints, the investigation covering the range of lengths for which the failure is partly elastic and partly plastic. A theoretical analysis led to the conclusion that satisfactory corrections could be made for a rigid end mounting, which greatly simplified the test apparatus. The test results are found to be expressed advantageously in terms of the dimensionless variables

$$\sigma = P/(FcA), \quad \lambda = [l/(\pi r)](F_c/E)^{1/2}, \quad \kappa = [(2K)/(Pl)] + 2s/l,$$

where P = the maximum axial load which can be carried by the column. A = the cross-sectional area of the column, F_c = the short-column strength of the material, E = the modulus of elasticity of the material, l = the length of the column, r = the radius of gyration of the cross-section with reference to the gravity axis perpendicular to the plane of bending, K = the coefficient representing the end restraint, s = the length of the rigid portion at each end of the column. The dimensionless variables σ, λ, and κ render comparable test results on materials with different but affine stress-strain curves. Only by the use of these variables has it been found possible to coordinate all the test results which have been obtained. The variables λ and σ have been used previously in other column investigations. (L. B. Tuckerman, S. N. Petrenko, and C. D. Johnson, "Strength of Tubing under Combined Axial and Transverse Loading," N.A.C.A. Technical Note No. 307, pp. 3, 4, June, 1929.)

22. Methods for measuring the coefficient of restitution. Lyman J. Briggs, *Bureau of Standards*.—A comparison is made of the following methods for determining the coefficient of restitution of elastic spheres, such as golf balls, when subjected to large deformations: 1. Ballistic method, in which the ball is struck by a flat-nosed projectile, and ball and projectile are caught in separate ballistic pendulums (Thomas). 2. Normal rebound of a ball dropped from a known height onto a massive flat plate, correction being made for air resistance during both fall and rebound. 3. Photographic method, in which the relative speed of ball and projectile after impact is determined from two spark photographs. 4. Rebound from a smooth inclined plate, involving measurement of the angles of incidence and reflection.

23. Velocity of sound in metal rods by a resonance method. Lehman C. Shugart, *Lehigh University* (*Introduced by C. C. Bidwell.*)—A small coil is fastened to the end of the test rod and placed in a strong radial magnetic field. The coil is connected to the output of an audio-frequency oscillator. To the other end of the rod is fastened a carbon microphone button. At resonance frequencies corresponding to the fundamental or any overtone of the rod very sharp peaks are obtained in the microphone current. A correction must be made for the effective length of the rod due to the attachment of the driving coil and the microphone button. To get this correction, observation of the first overtone for a rod of twice the original length is made. The slight change in frequency enables the computation of the effective length. The equation is $v = 2nl + 4\Delta nl$. Value of velocity of sound for brass, steel and aluminum check very closely with the best published data. The method is being used for the determination of values in other materials where data are lacking and especially for liquid metals. These may be contained in thin steel tubes, the peak for the resonance frequency in the liquid being easily distinguishable from that for the steel tube.

24. The vibrations of a plate with fixed center. ROBERT CAMERON COLWELL, *West Virginia University.*—A Chladni plate clamped at the center is usually set in vibration by bowing it at the edges. The sand figures formed in this way have been known for many years. If, however, a mechanical oscillator actuated by a vacuum tube is applied at different points on the plate, many new figures are formed. A few of these will be shown and a brief mathematical treatment given.

25. The arc spectrum of nitrogen. O. E. ANDERSON AND K. R. MORE, *University of British Columbia.* (*Introduced by G. M. Shrum.*)—The arc spectrum of nitrogen has been excited with low voltage, hot cathode arcs in mixtures of nitrogen with helium, neon and argon. Duffendack and Wolfe (Phys. Rev. **34**, 409, 1929) have used helium for the excitation of this spectrum, but it has usually been assumed that the lines could not be excited in argon. Since in these experiments the lines were observed in argon with an intensity of the same order as with helium, it has been necessary to revise the usual explanation of the excitation processes. When currents of the order of 1.5 amperes were used, the best results were obtained with 0.1 mm of nitrogen in 1.5 mm of argon. The spectrum has been examined in the region 3400–6000A. As some of the weaker lines were obscured by the nitrogen band structure, which varied with the nature of the admixed gas, it has not been possible to show that all the lines excited by helium were present in the argon mixture. A comparison of the intensities of the lines carried out with a Moll registering microphotometer showed that the strong NI lines were as intense as the moderately intense argon lines.

26. Activation of N_2-Hg mixtures by illumination with light from a quartz Hg arc. B. L. SNAVELY AND LOUIS A. TURNER, *Princeton University.*—Illumination of a mixture of nitrogen and mercury (5 mm N_2, 0, 001 mm Hg) in a quartz bulb containing a 0.6 mil tungsten filament produces a lowering of the resistance of the filament if it is originally at 400°C. This is the same effect which Kenty and Turner (Phys. Rev., **32,** 799 (1928)) found to be produced by active nitrogen and is presumably attributable to atomic nitrogen. Apparently the excited mercury atoms activate the nitrogen in some way. The effect is obtained only with the water-cooled arc, showing that the absorption of the 2537 line is involved. The effect is not obtained in similar helium-mercury mixtures. Rough preliminary measurements indicate that the magnitude of the effect is proportional to the first power of the intensity of the light.

27. The dissociation of excited iodine molecules by collision with argon atoms. LOUIS A. TURNER AND E. W. SAMSON, *Princeton University.*—By means of the absorption of the resonance line of the iodine atom ($\lambda = 1830$A.) it has been shown that iodine atoms are produced upon illumination of an iodine-argon mixture (0.3 mm I_2, 5 cm A) with continuous light of wave-length greater than 5100A., from a carbon arc. Absorption of such light should produce excited iodine molecules and not lead to direct optical dissociation. Apparently the excited molecules dissociate upon collision with argon atoms, as we might infer from the quenching of the iodine fluorescence by argon, as observed by Franck and Wood.

28. On the excitation of continuous spectra by bombardment of gases and vapors with cathode-rays. WILLI M. COHN, *University of Berlin.* (*Introduced by Otto Glasser.*)—It has been observed that gases or vapors which are bombarded by cathode rays, will emit under certain conditions a blue light the spectrum of which is continuous and has a maximum of intensity (photographically determined) at 4500A. The spectrum has been observed from 6200 to 3000A. The spectra received are not dependent on the kind of the ions generated. The light emitted is not polarized, but x-rays are generated. A working hypothesis is given in which is shown that the emission of the continuous spectrum may be produced by a mechanism similar to that of the continuous x-ray "Bremsspectrum."

29. Continuous spectrum from tungsten bombarded by 800 volt electrons. LAURISTON S. TAYLOR, *Bureau of Standards.* (*Introduced by F. L. Mohler.*)—Foote, Meggers and Chenault have reported a continuous spectrum from metals bombarded by 1000 volt electrons (J. O. S. A. **9**, 541, 1924). Preliminary measurements have been made of the intensity distribution of this radiation in the ultraviolet, from tungsten at voltages from 500 to 1200. At 800 volts the intensity $J(\lambda)$ increases regularly with decreasing wave-length, being about 3 times greater at 2800A than at 3700A. Between 500 and 1200 volts, the intensity distribution remains much the same and the intensity increases 2-fold. These results may be subject to an uncertain correction for electrons striking the stem instead of the target face.

30. Radiation from metals bombarded by low speed electrons. F. L. MOHLER AND C. BOECKNER, *Bureau of Standards.*—A paper presented at the New York meeting (No. 28) describes continuous spectra emitted by metals bombarded by large electron currents at low voltage, using the metal in the form of a small probe surface in a caesium or helium discharge. Measurements have been made with Be, Al, Cu, Ag, W, Pt, and Th in caesium discharges. Above 5 volts all except Ag and Cu give a spectrum of nearly equal energy per unit wave-length range. Ag is abnormally bright for wave-lengths longer than 3300A and Cu has a minimum in the green and yellow. Absolute intensities remain of the same magnitude with the same exceptions. The curves of isochromatic intensity versus voltage are very different. For Ag the intensity increases almost linearly from the threshold to 10 volts and more slowly beyond; for W it increases at an accelerated rate to 7 volts, is nearly constant to 12 and increases beyond. The Al curve has a high maximum at 12 volts and increases again above 16 volts. These variations (notably the Al maximum) are more pronounced at shorter wave-lengths. The intensity differences between Ag and W remain qualitatively similar in Cs and He discharges.

31. The blue-green fluorescence of mercury vapor. PAUL D. FOOTE, ARTHUR E. RUARK AND R. L. CHENAULT, *Gulf Research Laboratory and University of Pittsburgh.*—Visual photometric measurements were made on the blue-green fluorescence of Hg vapor excited only by the core of 2537. At the temperatures employed (21 and 33°C) the green glow cannot be seen in the absence of foreign gas. On adding a few millimeters of nitrogen to bring $^3P_1$ atoms down to $^3P_0$, it is bright. The intensity of the fluorescence increases to a maximum at 13 millimeters of nitrogen and then slowly fades as the pressure is increased. Using calibrated wire gauze screens to vary the intensity I of the exciting light, it was found that the fluorescent intensity J is definitely not a linear function of I. It obeys the equation $j+aj^{1/2}=bi$, where $j=J/J_0$ and $i=I/I_0$; J_0 and I_0 are the values obtained without screens; and a and b are constants for a given temperature and nitrogen pressure. Whatever be the molecule involved in the emission of the 4850 band, these experiments indicate that a $^3P_0$ atom is essential to its formation. The observed dependence of j on i can apparently be explained by assuming the active molecule contains two metastable atoms.

32. Direct measurement of τ. H. D. KOENIG AND A. ELLETT, *State University of Iowa.*—Ever since the well known experiments of Dunoyer (Le Radium **10**, 400, 1913) there has existed the interesting possibility of measuring the time between absorbtion and subsequent remission of radiation by an atom by observing the displacement taking place in this period because of thermal agitation. And it is equally well known that for such thermal velocities as are available in the laboratory the displacement in 10^{-8} secs. (the order of magnitude of the time usually involved) is too small to be measured. The depolarization of cadmium resonance radiation by very weak magnetic fields shows that τ for the 2^3P_1 state of Cd is unusually large. A beam of cadmium atoms was shot through a narrow perpendicular beam of λ3261 radiation. The illuminated part of the beam was screened from the camera. Atoms excited in the light beam and radiating after they had passed beyond the screen produced a blackening on the film densest just beyond the screen and perceptible for a distance of four millimeters. No blackening appeared below the screen showing that the spread above it was not due to secondary resonance. Photometer curves of the blackening are not yet available, but it is evident that τ is of the order of magnitude of 10^{-6} secs.

33. The average life for the line 2733A of ionized helium. LOUIS R. MAXWELL, *Bartol Research Foundation, Swarthmore, Pa.*—The line 2733A. ($6\rightarrow3$) of ionized helium is made up of five lines (neglecting spin) whose average lives have been calculated according to the method of

Sugiura. The results obtained using Kupper's (amplitudes)^2 are: $6_1 \rightarrow 3_0$(2.59×10^{-9} sec.), $6_1 \rightarrow 3_2$ (2.59×10^{-9} sec.), $6_0 \rightarrow 3_1$ (9.06×10^{-9} sec.), $6_3 \rightarrow 3_2$ (1.52×10^{-8} sec.) and $6_2 \rightarrow 3_1$ (7.44×10^{-9} sec.). The experimental method used by the writer for determining the average life of excited ions has been applied to this line (2733A) and it is found to exhibit a displacement under the action of the transverse electric field which is slightly greater than would be calculated on the basis of the above values for the mean lives of the fine structure lines. This difference is probably caused by transitions into the sixth quantum state from higher excited states which would produce an apparent longer mean life and hence give too great an experimental displacement. However the experimental results obtained agree approximately with the above calculated values for the average life.

34. Mean life of the mercury line λ2537. Paul H. Garrett and Harold W. Webb, *Columbia University.*—The mean life of the mercury line λ2537 was measured by the alternating voltage method previously described (Phys. Rev. **24**, 113, (1924)). The radiation was excited in a quartz tube by impact with electrons from a hot cathode. The photoelectric system was contained in a separate tube also of quartz. The surface was zinc evaporated on a nickel plate. Measurements of the apparent life were made with diminishing mercury vapor pressures until further reduction of pressure produced no change in the measured rate of decay of the radiation. At these low pressures (below 3×10^{-4} mm for the geometry used) the absorption and re-emission of the radiation was negligible and the true life of a single excitation process was measured. This was found to be 1.08×10^{-7} sec. with an estimated precision of one percent.

35. Life of the nitrogen molecule in its first excited vibrational state. M. L. Pool, *Ohio State University.*—Curves showing the rate of decay of the metastable 2^3P_0 state of the mercury atom in a quartz resonance cell, containing carefully purified nitrogen at room temperature, are not accurately exponential. The rate of decay in the neighborhood of 10^{-4} sec. after terminating the optical excitation is more rapid than later. A high concentration of nitrogen molecules excited to the first vibrational state of the zero electronic state might be expected, due to collisions of the second kind with the 2^3P_1 state in mercury. It is assumed that in addition to usual diffusion and dissipative impacts with unexcited nitrogen, the decay of the number of metastable mercury atoms may be influenced by dissipative impacts with these excited nitrogen molecules whose number decreases with time by diffusion and by dissipative impacts. An equation for the number of metastable atoms is then obtained of the form exp $[\alpha t + A(\exp \beta t - 1)]$. Evaluation of the constants from experimental data gives the following: Life of N_2 in first excited vibrational state, 1.2 to 1.9×10^{-4} sec. depending upon pressure; probability of dissipative impact, 1.5×10^{-4}; maximum life of 2^3P_0 state of Hg, 30×10^{-4} sec; probability of dissipative impact, 3.5×10^{-6}.

36. High dispersion in the near infrared. J. D. Hardy, *National Research Fellow, University of Michigan.*—Using a Pfund type of spectrometer, with a five inch 1500 line grating and especially long focus mirrors, it has been possible to obtain an experimental resolving power of 20,000 in the region between one and two mu. Using the grating in the first order, the 10830A helium line was resolved into two distinct components, of separation 1.1A. The effective slit-width in the 1.5μ region could be made as small as 0.2A and due to the excellence of the optical system the grating remained completely filled with light. Several other helium doublets have been resolved and the relative intensity of the two components compared. While testing out sources for hollow-cathode-exitation several lines in the neon spectrum were discovered. For the most part they have been classified as belonging to already established series.

37. Polarized fluorescence studied by means of a nicol, photocell and amplifier. D. R. Morey, *Cornell University.* (*Introduced by C. C. Murdock.*)—It becomes a difficult matter to measure the percent of plane polarized light in weak radiations by means of visual devices. This is a serious disadvantage in the study of fluorescence, for polarization measurements yield valuable information on the fluorescent process. A high quality nicol, with ends perpendicular to the length, rigidly fastened to a photoelectric cell may be made to analyze radiations too weak for visual instruments. The types of cell and amplifier to be used are somewhat dependent on the nature and intensity of the source. Using such an instrument, the effect of inhibitors (KI, KCN, NaBr, etc.) on the polarization of fluorescent bands has been studied. The results strengthen the present view on the nature of fluorescence.

38. Total emissivities at low temperatures and departures from Lambert's cosine law. E. R. Binkley, *Lehigh University.* (*Introduced by C. C. Bidwell.*)—Emissivity of oxidized copper, nichrome, brass, cold rolled steel, and of aluminum were measured with a special form of total radiation pyrometer which had a slit opening and linear thermopile, permitting observations at nearly grazing angle. Observations were made at temperatures 100°C, 200°C, 300°C, 400°C, 500°C, on each surface and at each temperature at angles ranging from 0° to 85°. The instrument was calibrated on a camphor blacked surface assumed at 98% black body. Lambert's cosine law is found to hold at angles of observation above 60° but an increasing deviation is found for all surfaces when the angle is reduced below 60°, the deviation at 85° becoming as much as 30% for copper, 39% for rolled steel, 56% for nichrome. The value of normal emissivities for the various surfaces at 500° were as follows: copper 0.74; nichrome 0.95; brass 0.68; cold rolled steel 0.93; aluminum 0.29. There was found to be a rise in emissivity with temperature.

39. Absorption and temperature emission of neodymium in various solvents. R. W. Wood, *Johns Hopkins University.*—A solid solution of neodymium oxide in fused quartz was drawn out into fibres about 0.3 mm in diameter, and a fiber mounted vertically in a bunsen flame. It glowed brilliantly and when viewed through a direct vision prism exhibited a spectrum consisting of a green, yellow and red band with perfectly dark regions between them. (Experiment shown.) This is undoubtedly the best example of a highly selective temperature radiator ever observed. Seven bands have been photographed between the blue and 0.9μ. An interesting study has been made of solutions of various colored salts in liquid anhydrous ammonia. The rather wide band in the yellow of neodymium ammonium nitrate splits up into five narrow bands. These have been compared with the bands shown by the crystals at liquid air temperature and in solid ammonia. Some results of interest in connection with ray filters have been secured with the ammonia solutions and it seems possible that a suitable filter for giving a comparison spectrum in stellar spectra made with the objective prism may be constructed along these lines. Exhibition of stereoscopic photographs illustrating the orbital motion of the electron in the Stark effect.

40. Paschen-Back effect and hyperfine structure of Bi II. J. B. Green, *Ohio State University.* (*John Simon Guggenheim Memorial Fellow, Univ. of Tübingen.*)—The Zeeman effect in Bi II has been studied in a field of 34,000 gausses. The hyperfine structure of Bi II shows some very large separations and the Zeeman patterns yield very interesting results, since the field strengths available give separations that are about midway between "weak" fields and "strong" fields. In particular, λ5719, a $1\rightarrow 0$ jump in j, gives a completely resolved pattern in the perpendicular polarization, consisting of twenty components, twelve for $m_i=1$ and eight for $m_i=-1$, thus verifying the nuclear moment of $i=4\ 1/2$ for Bi. Fisher and Goudsmit's results for the hyperfine structure in Bi II were used.

41. Effect of combined electric and magnetic fields on the helium spectrum II. J. S. Foster, *McGill University.*—In electric and magnetic fields crossed at right angles, the diffuse and fundamental series of helium show a fine structure which is sensitive to changes in the electric field. Effects are similar for members of a single series and differ little from the normal Zeeman effect in the sharp and principal series. The splitting has been found to be less than normal in the $p-p$ combination series. A full account of this research will soon appear.

42. The Stark-effect in xenon. H. W. Harkness and J. F. Heard, *McGill University.* (*Introduced by J. S. Foster.*)—Earlier results with complex spectra have been interpreted to show that displacements of spectral terms by electric fields are inversely proportional to the corresponding hydrogen difference provided the latter are not too small. This view altogether fails to account for the present observation. Instead, a qualitative explanation of most displacements is afforded through the separations of the xenon term from its neighbor in the manner indicated in the approximation made by Pauli. Some of the red lines show more complex patterns than have been found in the other rare gases. In contrast with helium and neon these patterns indicate that the m values are determined as components of the j, which is retained as a unit. For example, the line $2p_8-6d_4^1$ (j:4→3) shows four π components and five σ components, i.e. all that could be observed if the separations in the $2p_8$ state are small.

43. Asymmetry observed in the Stark-components of Hα. D. R. McRae, *McGill University.* (*Introduced by J. S. Foster.*)—A special grating, with a dispersion of 3.8A/mm., having a very intense first order spectrum on one side, has been used to resolve the Stark components of Hα as seen from a Lo Surdo source. An asymmetry is observed in the displacements of the components, which is in general qualitative agreement with the calculations of Schlapp. There are certain discrepancies, however, which have not been explained. An asymmetry in the relative intensities of the components has also been observed. This asymmetry decreases with lower gas pressures, or with increasing propertions of helium, neon, or xenon in the discharge tube, until there is agreement with theory when traces of hydrogen are present in these gases. It may be shown that altering the number of atoms in the initial states does not explain completely the observed asymmetry. Since the probabilities of transition agree with experiment in the cases mentioned it seems that the presence of neighboring hydrogen atoms or molecules may in some way alter the intensities by an action such as collisions of the second kind; but it is difficult to see how this could be carried out in the selective manner required to explain the observations.

44. The electric field, atmosphere and effective temperature of the sun. Ross Gunn, *Naval Research Laboratory, Washington, D.C.*—The study of important electromagnetic effects in the solar atmosphere undertaken in previous papers is continued. It is shown that the large observed spread of effective temperatures of the sun's radiation can be accounted for by the presence of electric and magnetic fields in the solar atmosphere. The magnitude of the electric field at a level where the magnetic field is 25 gauss, calculated from the observed spread of temperatures, is found to be 0.015 volts/cm and agrees well with 0.013 volts/cm calculated earlier from the observed anomalous motions of the solar atmosphere. Gravitational equilibrium is found to be unnecessary in all regions of the atmosphere and it is shown that the "support" and stability of the chromosphere and its anomalous eastward motion are evidences of precisely the same electromagnetic mechanism. An electric field of the value given above is shown to account qualitatively for certain bright line spectra of the sun. The strange observed relation between bright line spectra and rapid axial rotation of stars, just announced by Dr. Struve of the Yerkes Observatory, confirms in a striking manner some of the conclusions of this and earlier papers.

45. Some new relations in the photographic effects of alpha-rays. T. R. Wilkins and R. Wolfe. *Institute of Applied Optics, University of Rochester.*—Jacobsen has recently shown that the number of grains made developable in a photographic plate is proportional to the density provided this number does not exceed 200,000 per sq. mm. The number of developable grains was assumed equal to the number of alpha-particles. In the present work alpha-rays of various speeds have been used with Eastman Slow Lantern plates. For a given exposure time the density is found to be proportional to the number of alpha-rays at least up to 1.5×10^6 per sq. mm determined by a direct scintillation count (density 1.39). It would seem that the lack of linearity in previous work has been due to a variable exposure time. The slopes corresponding to increased exposures are a linear function of the exposure time up to 40 hrs. Thus there is a very marked reciprocity defect in the density amounting to approximately 50% for a 60 hr. exposure. Equations connecting the number of grains per cc of the emulsion with the number of alpha-particles have been obtained. Provided that the reciprocity correction for a given emulsion has been determined, the photographic plate offers a splendid quantitative means for alpha-ray counting.

46. Continuous ultra-γ spectrum explaining cosmic-ray ionization-depth curve data. Charles M. Olmsted, *Buffalo, N.Y.*—It is shown that the ultra-γ cosmic-radiation data published by Millikan and Cameron, (Phys. Rev. **37**, 235 (1931)) may be completely explained by a continuous spectrum of energy falling off suddenly on the short wave side of 0.000013A (as determined by the Klein-Nishina formula; $\mu=0.03$) and extending on the long wave-length side with evenly varying intensity to beyond 0.0008A. Tables of values of intensity of ionization for different values of μ and λ are given. Tables comparing the computed values of ionization at various depths with the values observed by Millikan and Cameron are given. It is shown that the absorption curve computed from the continuous spectrum coincides with the observed curve as closely as does the curve computed by Millikan and Cameron from a group of four bands having frequencies corresponding to the formation out of hydrogen of helium, oxygen, silicon, and iron. The location of the short wave end of the spectrum at a frequency corresponding to the union of electron and proton, together with the shape of the intensity curve, is discussed from the point of view of astrophysics.

47. Wave packets. D. G. Bourgin, *University of Illinois.*—(I) The formal character of wave packets follows from the equivalence of harmonic and damped waves in representing disturbances. Real integrals are thus replaced by equivalent complex contour integrals. A true "stationary phase" principle depends on certain "sattel-punkt" contours and is described physically as the resultant of a group of damped harmonic waves of varying amplitudes but identical phases. The "Kelvin stationary phase" principle is misnamed since there, amplitudes, not phases, are constant. Huyghen's principle for odd, non-isotropic negligibly absorptive spaces may be generalized by correlating "paths," extensions of rays, with classes of spatially damped waves. (II) Flamm, Phys. Zeits. Dec. 1928 and others attempt to construct permanent atom packets of the form

$$\psi(x,t) = \sum_{\infty}^{\infty}\left(\nu_0 \int_0^{1/\nu_0} \psi(0,T)e^{2\pi i n\nu_0 T}dT\right)e^{2\pi i[x/\lambda_n - n\nu_0 t]} \tag{1}$$

with independent λ's (considered atomic characteristic values). This procedure is incorrect for not only is $\int_{\infty}^{\infty}\int\psi\bar{\psi}$ infinite but, under some convergence restrictions (1) in its space dependence is an "almost periodic function" i.e. each set of regional values is almost reproduced an infinite number of times contrary to the assumption "nür in einem beshränkten Bereich . . . merklich von Null vershieden."

48. Wave mechanics of electrons in uniform crossed fields. Milton S. Plesset, *Yale University.*—We consider the motion of electrons in a uniform magnetic field H in the z-direction and a uniform electric field E in the y-direction. We take for the vector potential $\mathbf{A} = -\mathbf{i}Hy$ and for the scalar potential $V = -Ey$. With these potentials the wave equation does not contain x explicitly, and the solution may be written as $\psi = e^{2\pi i a x/h}\,\Phi_n(u)$ where $\Phi_n(u)$ is the n^{th} orthogonal function of Hermite (the characteristic function for the simple harmonic oscillator);

$$u = (2k)^{1/2}[y - \pi/k^2h^2(\pi meE - akh)];\ k = \pi eH/hc.$$

The energy is related not only to the values of the fields E and H and to the integral values n, but to the arbitrary constant a as well. The component of the current density in the y-direction vanishes identically; and for the component of the current density in the x-direction we have a function of y alone which is

$$j_x = e^2H/mc[\Phi_n(u)]^2(y + \pi a/kh).$$

Thus j_x vanishes at the n roots of Φ_n and at $y = -\pi a/kh$; for this latter value the current reverses its direction.

49. Oscillations due to corona discharges on wires. R. E. Tarpley, J. T. Tykociner and E. B. Paine, *University of Illinois.*—An experimental arrangement was used in which the electric constants of the circuit containing a corona tube corresponded to much higher frequencies than could be recorded by a reflecting mirror oscillograph. By amplifying the corona currents 300 to 3000 times it was found with this oscillograph, which was insensitive to circuit oscillations, that corona discharges produce a new type of oscillations whose chief characteristics are as follows: The frequency (2000–10,000 cycles) is independent of circuit constants. The amplitude decreases with increasing applied potentials. The wave has a complex form of distinct ripples superimposed upon the charging a.c. or upon the steady part of applied d.c. The wave form depends on the pressure and nature of the gas and on the polarity of the wire. The wave form varies for different gases but the character of the oscillations remains the same for air, CO_2 and N_2. The wave form becomes simpler with decreasing gas pressures especially with

CO_2. At high pressures the oscillations appear superimposed on the corona humps of the charging current at moments when the wire is the cathode, but at lower pressures oscillations appear only when the wire is the anode. No oscillations are obtained with oxidized or corroded wires. Details of the investigation will be published in a bulletin of the Eng. Exp. Station, University of Illinois.

50. Detection and comparative measurement of ionization in dielectrics by means of oscillations. J. T. Tykociner and E. B. Paine, *University of Illinois.*—In the study of dielectrics subjected to high potentials, minute voids and adsorbed gas bubbles give rise to ionization. The latter causes a redistribution of the electric field with the result that impulses of varying intensity are produced in the adjacent circuit. These impulses are made use of in a method for determining the potential at which ionization sets in and for comparing its intensity at varying applied voltages. If the circuit whichcontains the dielectric is aperiodic and is coupled to an amplifier supplied with a detector and current indicator, the impulses may be separated from the charging a.c. A more sensitive arrangement is obtained by tuning the circuit to a convenient frequency. Impulses in form of damped oscillations are then produced which are entirely free from the a.c. component of the charging source. With four stages of amplification, a thermionic detector and a thermionic voltmeter early stages of ionization in various dielectrics and the dependence of the ionization in various dielectrics on the applied voltage was studied. It was found that oscillations of any chosen frequency (100 to 30,000 k.c.) can be produced in a circuit by corona discharges in condensers, paper cables and rubber insulated conductors and their intensity measured by this method. The complete investigation will be published in a bulletin of the Eng. Exp. Station of the Univ. of Illinois.

51. Some properties of foreign and domestic micas. A. B. Lewis, E. L. Hall and F. R. Caldwell, *Bureau of Standards, Washington, D.C.*—A number of samples of mica, fairly representative of the major sources of the world's supply of mica, have been tested for their dielectric constant, power factor, dielectric strength, and ability to withstand elevated temperatures. Average values are given for the dielectric constant and power factor at radio frequencies, and for the dielectric strength at 60 cycles. The data indicate the deviations from these average values which must be expected in commercial lots of mica. It is shown that stains and inclusions seriously affect the power factor of a sample, but have much less effect on the dielectric strength. Most of the samples were unaffected by exposure to temperatures up to 600°C, but above that temperature only the phlogopites can be said to have successfully withstood the elevated temperatures. On the basis of these data it was not possible to distinguish between micas of like commercial grades obtained from different geographical localities.

52. Cathode sputtering in a commercial application. H. F. Fruth, *Western Electric Company, Hawthorne Station.* (*Introduced by O. S. Duffendock.*)—Three sputtering units, each one having six cathodes were designed and operated by one man. These units are used to produce the gold contact surfaces on broadcasting microphone diaphragms. In order to get good continuity, adherance, and uniformity a special method of preparing and cleaning the surface was developed. To produce a uniform quality surface and sputtering rate a bleeder valve to control the vacuum to ±0.05 mm was developed. Sputtered gold surfaces on duralumin microphone diaphragms proved to be more free from pinholes, blisters and corrosion and gave better service than those made by electrolytic plating. On account of a lighter coat possible the diaphragms can be stretched to a higher natural frequency and show less fatigue.

53. Wave form of pulsating D.C. currents produced by FG-67 thyratrons. Wayne B. Nottingham, *Bartol Research Foundation.*—A cathode ray oscillograph has been used to study the wave form in different parts of an "inverter" circuit using two General Electric FG-67 Thyratrons. (For the simple inverter circuit see Fig. 41, Hull, Gen. Elec. Rev. **32,** 398, 1929). With the cathodes heated by independent 60 cycles, A. C. windings an "output" can be taken from the lead between the cathode and the negative terminal of the D. C. plate supply. The current flowing in this lead can be made of the "square-top" type up to a frequency of about 6000 cycles per second. The circuit conditions including the plate potential are critical at the highest frequencies while at 500 to 1000 cycles, it is easy to obtain the desired wave form with a wide range of current and potential conditions. Under the best conditions the time required for the current to rise from zero to its full value was probably not more than 30 microseconds and a slightly shorter time was required for the current to fall from full value to zero. The exact wave form depends on the inductance, capacity and resistance of the D. C. supply. This system has been developed to heat a filament for the investigation of thermionic emission with low accelerations and retarding fields, but undoubtedly has other possible applications.

54. The starting-time of thyratrons. A. W. Hull and L. B. Snoddy, *General Electric Company.*—Starting-time is defined as the time between the application of grid or plate voltage, and the attainment of full arc current. This time has been studied by means of high frequency alternating voltage, condenser discharge, and cathode ray oscillograms. The observed times depend upon vapor pressure, and upon anode and grid voltages, and lie between one-tenth (0.1) microsecond and 4 microseconds under practical conditions for all commercial thyratrons. Times of the order of one thousandths (0.001) second, as reported by Nottingham, (Journal Franklin Institute **211**, 271, March 1931) have not been observed.

55. Magnetic induction in a projectile shot into a steady field. L. Thompson and N. Riffolt, *Naval Proving Ground, Dahlgren, Va.*—For the solution of the equation of interior ballistics it is essential to define the powder burning and bore dissipation functions appropriate to the system. These can be identified by experimental firing which obtains pressure and displacement of projectile as time distributions. The present experiment measures projectile displacement by use of gun coils, mounted at intervals along the bore. A steady current is established in the coils before the round is fired. As the base of the projectile passes from a coil the transient electromotive forces develop a small change in the primary current, the oscillographic record of the secondary impulse having a form facilitating accurate time evaluation. Absolute position at the instant of current maximum, can be checked for new conditioning by means of external screens times of contact being superposed on the record. The coils are the basis, also, for an empirical method of measuring ejection velocities at high angles of projection, and aboard ship. Magnetic lag measurement for this cycle of short duration, .001 second or less, may be practicable with a coil set external to the gun, utilizing difference between flux values for projectile at rest and in motion and with compensation for eddy current.

56. A method for precise speed control developed in connection with an absolute measurement of resistance. Frank Wenner and Chester Peterson, *Bureau of Standards, Washington, D.C.*—Any absolute measurement of resistance inherently involves a measurement of length and of time. In one of the methods on which we are working in the Bureau of Standards time enters as the speed of rotation of a direct-current motor. It is not necessary that the speed over very short periods of time be highly constant, but over periods of about 10 seconds and longer the average speed should be constant and known to within one part in 200,000. On the shaft of the motor there is a 1000-cycle generator whose electromotive force is synchronized with a 1000-cycle electromotive force obtained from a piezoelectric oscillator. Synchronization is secured by rectifying and amplifying the instantaneous sum of the two electromotive forces. The amplifier output current has an average value depending upon the phase angle between the two electrical systems. This current actuates a relay controlling power applied across a heavy inductance in one of the armature leads. As a consequence, the average speed of the motor is constant to the same precision as the oscillator frequency, which is stable to within a few parts in ten million. The method of control requires an oscillation of the speed about the average. This oscillation is of short period and small amplitude.

57. Resistance-temperature law for oxides. J. A. Osteen, *Lehigh University.* (*Introduced by C. C. Bidwell.*)—Bidwell showed that the resistance temperature law for certain variable conductors (oxides, etc.) was of the form $\rho = Ae^{Q/RT+aT}$. Plotted in the form $(-1/\rho)(d\rho/dT) = [Q/(RT^2)]-a$ he obtained for Fe_2O_3 straight lines with a break near the recalescence point, the two lines having the same y intercept but different slopes. This law was also followed by metallic germanium. The present paper extends this work to zinc oxide and beryllium oxide. Beryllium oxide yields two straight lines showing a transition at 750°C. Zinc oxide yields two straight lines with a transition in the interval 250°C–500°C. The two zinc oxide lines have different slopes but the same y intercepts. With successive heatings to 1050°C there occurs continued decreases in the slope of the line for the $500°\mathrm{C}-1000°\mathrm{C}$ range but no change in the y intercept. The line for the range $0°\mathrm{C}-250°\mathrm{C}$ changes on successive heatings to 1050°C and finally stabilizes to a value of slope and intercept which repeats on succeeding runs. On the suggestion that the indicated transformation was due to impurity, new material of special purity prepared by the New Jersey Zinc Company was studied. The behavior of this material was found to agree closely with that of the earlier specimen but gave a more clean cut transformation.

58. High resistances made from metallic oxides. E. R. MANN AND D. R. MOREY, *Cornell Univ.* (*Introduced by C. C. Murdock.*)—The object has been to find a simple and rapid means of making high resistors (10^8 to 10^{12} ohms) of good quality. Resistors are made by mixing metallic oxides in suitable binders of an insulating nature. In all specimens, an ageing process occurs. In certain cases, most of the ageing occurs within a few hours and the resistors show but small and slow changes thereafter. In this there is the advantage of the use of the resistor within a short time after it has been made. A further advantage lies in the extreme ease of making. In the matter of size and ultimate constancy these resistors are not superior to some other types made by more painstaking and laborious methods, yet they will serve excellently for many purposes. A large change with temperature is present in most specimens. They have been tested for deviations from Ohm's law and for small fluctuations under working conditions.

59. A new theorem concerning temperature-compensated millivoltmeters used with shunts for the measurement of current. H. B. BROOKS, *Bureau of Standards, Washington, D. C.*—Millivoltmeters are essentially permanent-magnet moving-coil galvanometers for laboratory or switchboard use. The moving coil is of copper or aluminum wire of high temperature coefficient, hence for a given applied voltage the resulting current and deflection will vary greatly with changing temperature. Millivoltmeters are partly or wholly compensated for temperature by connecting a manganin coil in series with the moving coil. To obtain complete compensation in this way requires, on the average, about 200 millivolts at the millivoltmeter terminals for full-scale deflection. This is undesirably high, and the Swinburne method is therefore used to get complete compensation with about 50 millivolts for full-scale deflection. Either kind of compensated millivoltmeter, used with a shunt for current measurements, is compensated (as an ammeter) only when the resistance of the shunt is small relatively to the resistance of the manganin coil in the millivoltmeter. One maker of high-grade compensated millivoltmeters does not care to supply shunts with a rating of less than 30 times the full-scale current of the millivoltmeter. A simple theorem has been found which applies to either type of compensated millivoltmeter and removes the limitation against low-range shunts.

60. An experimental study of the natural widths of the x-ray lines in the L-series spectrum of uranium. JOHN H. WILLIAMS, *University of California.*—The rocking curves of $UL\alpha_1$ in three different anti-parallel positions of the double x-ray spectrometer give a natural width which is practically independent of the dispersion. The natural widths of $UL\alpha_1$ and $UL\beta_1$ have been observed as a function of voltage and no significant dependence was noted. The half widths at half maximum of twelve lines in the uranium L-series spectrum were studied and the results are:

Line	α_1	α_2	β_1	β_2	β_3	β_4	β_5	β_6	γ_1	γ_2	γ_3	γ_6
$\Delta\lambda$ in X.U.	0.439	0.494	0.299	0.369	0.382	0.726	0.252	0.487	0.242	0.57	0.47	0.233
ΔV in volts	6.56	7.20	7.17	8.04	9.40	16.1	5.94	9.71	7.96	19.7	16.2	8.18

Possible correlations with the electron transitions are suggested and the predominance of nuclear effects are evident from the greater widths of lines involving the elliptical orbit L_I. The large natural widths of the lines excludes the possibility of observing the effects of nuclear spin suggested by Breit. The actual shape of the line $UL\alpha_1$ has been investigated and found to approximate that predicted by the classical theory.

61. The width of soft x-ray lines. WILLIAM V. HOUSTON, *California Institute of Technology.*—The most direct experimental evidence as to the distribution of energy levels in a solid crystal comes from the observations on soft x-ray lines. The work of Söderman and others in the extreme ultraviolet shows that while spark excitation gives sharp lines, excitation of a solid target by electron bombardment gives very broad lines. The shape of these lines, when proper account is taken of the transition probabilities, gives the distribution of the upper, occupied energy levels of the solid. Although it is difficult to infer the energy level distribution from the observations, because of the unknown transition probabilities, it is easy to determine the line shape to be expected from various models. The simple Pauli-Sommerfeld model of perfectly free electrons, gives the correct order of magnitude for the width of the lines, but does not give a very good approximation to the observed shape. If Bloch's method of starting with the functions of the individual atoms is used, the agreement in both shape and width is rather good. The lines of those elements whose outer shells are incomplete, show the sharp falling off on the short wavelength side which is characteristic of the Fermi statistics.

62. Crystal structure of lithium iodate. F. A. BARTA AND W. H. ZACHARIASEN, *University of Chicago.*—The structure of lithium iodate was determined by using the oscillation and powder methods. Lithium iodate is hexagonal with 2 molecules per unit cell of $a=5,469\text{A}\pm0.003\text{A}$, $c=5.155\text{A}\pm0.005\text{A}$. The space group assigned is D_6^6 and the atom positions are: 2Li in $(00\tfrac{1}{4})$ $(00\tfrac{3}{4})$, 2I in $(\tfrac{1}{3}\,\tfrac{2}{3}\,\tfrac{1}{4})$ $(\tfrac{2}{3}\,\tfrac{1}{3}\,\tfrac{3}{4})$ and 60 in $(u\,u\,0)$ $(0\,\bar{u}\,0)$ $(\bar{u}\,00)$ $(\bar{u}\,\bar{u}\,\tfrac{1}{2})$ $(0\,u\,\tfrac{1}{2})$ $(u\,0\,\tfrac{1}{2})$ with $u=\tfrac{1}{3}$. The structure is based on hexagonal closest packing, with the lithium and iodine atoms both lying within oxygen octahedra. The atomic distances are Li -0 and I $-0=2.23$A with lithium octahedra sharing faces with each other, one lithium and one iodine octahedra sharing only edges and two iodine octahedra only corners.

63. The refractive indices of potassium chlorate crystals, and the structure of the ClO_3 group. W. H. ZACHARIASEN, *University of Chicago.*—The method developed by W. L. Bragg (Proc. Roy. Soc. London **105,** 370 and **106,** 346 (1924)) has been used in order to calculate the refractive indices of $KClO_3$ crystals from the atomic arrangement. The Cl^{+5} dipole of the ClO_3 group was given one degree of freedom, along the trigonal axis of the radical. The calculations give agreement with the observed birefringence if the height of the Cl^{+5} dipole above the plane of the oxygens is .99A. X-ray determination gives a displacement of .49A. The scattering power for x-rays depends almost entirely upon the K and L electrons. The x-ray method therefore gives us the position of the Cl^{+7} core, whereas the optical calculations fix the position of the dipole. We must suppose the dipole to be formed by a displacement of the core and the two outer electrons. The observations thus indicate that the two valence electrons of Cl^{+5} are displaced with respect to the core, in a direction away from the oxgyen plane. This result is in agreement with the picture of the ClO_3 group given by the author in different publications. The calculated and observed birefringence and refractive indices are:

	Observed	Calculated
α	1.410	1.420
β	1.517	1.535
γ	1.524	1.535
$[(\beta+\gamma)/2]-\alpha$	0.111	0.115

64. The structure of the NO_2 group. G. E. ZIEGLER, *University of Chicago.*—The structure of $NaNO_2$ was determined in order to test W. H. Zachariasen's prediction (in press, Jour. Am. Chem. Soc.) that the NO_2 group would be angular with 120° between the N$-$0 bonds. Powder crystal, rotating crystal, and Laue data were used. The lattice is body-centered, orthorhombic, space-group C2v$-$20, with a unit cell $a=3.55$A, $b=5.56$, $c=5.37$ containing 2 molecules. From visually estimated intensities the positions of the atoms are:

Na	$0,\ u,\ 0;$	$\tfrac{1}{2},\ u+\tfrac{1}{2},\ \tfrac{1}{2}$	$u_{Na}=210°$		
N	$0,\ u,\ 0;$	$\tfrac{1}{2},\ u+\tfrac{1}{2},\ \tfrac{1}{2}$	$u_N=30°$		
O	$0,\ 0,\ u;$	$0,\ 0,\ -u;$	$\tfrac{1}{2},\ \tfrac{1}{2},\ u+\tfrac{1}{2};$	$\tfrac{1}{2},\ \tfrac{1}{2},\ \tfrac{1}{2}-u$	$u_0=70°$

(360° $=a$, b, or c respectively)

Distances between atoms: $N-O=1.13$A, O$-$O same group$=2.09$, O$-$O different groups >3.3, Na$-$O two O's 2.53, Na$-$O four O's$=2.46$. $h=$displacement of N from O$-$O line$=0.46$ A. The angle between the N$-$O bonds$=130°$. The observed data definitely disagree with a colinear NO_2 group.

65. Precision wave-length measurement with the double crystal x-ray spectrometer. Arthur H. Compton, *University of Chicago.*—An x-ray spectrometer was designed with the first crystal mounted on an auxiliary table supported by the frame of the spectrometer, and with the second crystal mounted on the central table of the instrument, whose position is read from a precision circle. The ionization chamber (of 25 cc capacity, filled with krypton) is on an arm whose position is read by a second precision circle. The instrument was built by the Societe Genevoise de Physique. The first crystal was adjusted to throw the $K\alpha_1$ line of molybdenum over the main axis of the spectrometer, and measurements were made with the second crystal in the (1, −1), (1, +1), (1, −4) and (1, +4) positions (Allison's notation). The reflection maxima from calcite (corrected to 18°C) occur at $\theta_1 = 6°42'35.5''$ and $\theta_4 = 27°51'32.9''$ with a probable error of 0.25″ due chiefly to errors in reading the circle. Using an apparent grating space for the first order of 3.02904A at 18°C, we get $\lambda = 707.832 \pm 0.002$ mA. Larsson obtained 707.831 ±0.003 mA using Siegbahn's photographic method. Comparison of θ_1 and θ_4 gives for the index of refraction in calcite, $1 - \mu = (2.10 \pm 0.15) \times 10^{-6}$, in good accord with Hatley's more direct measurement of 2.04×10^{-6}.

66. Absolute wave-lengths of the copper and chromium K series. J. A. Bearden, *Johns Hopkins University.*—A consideration of the objections to the measurement of x-ray wave-lengths by ruled gratings shows that the method should be reliable if the apparatus is in precise adjustment and the gratings of good quality. In the present experiments 5 gratings were used which were ruled on two ruling engines. The method of the experiment was similar to that given by the writer in the Proc. of the Nat. Acad. of Sci. **15,** 528, (1929). The results from different gratings on the same wave-length agree very satisfactorily. The final results of 172 plates are given in the following table.

Spectral Line	Crystal λ	Grating λ	Limiting Error	Grating λ −Crystal λ
Cu K_β	1.38914A	1.39225A	±0.00014A	+0.224%
Cu K_α	1.53838	1.54172	± .00015	+ .217
Cr K_β	2.08017	2.08478	± .00021	± .222
Cr K_α	2.28590	2.29097	± .00023	+ .222

From these results, the grating constant of calcite is $d = 3.0359 \pm 0.0003$A, and Planck's constant h as determined by Duane, Palmer and Yeh is $h = 6.573 \pm 0.007 \times 10^{-27}$ erg sec. The mean value of the dispersion of x-rays as determined by Stauss (Phys. Rev. **36,** 1101, (1930)) and Larsson (Inaugural Dissertation, Uppsala, 1929) gives $e/m = 1.769 \times 10^7$ e.m.u. g^{-1}. The values of these constants are independent of any imperfection in the crystal grating. If the crystal lattice is assumed "perfect" then we have, Avogadro's number $N = 6.019 \times 10^{23}$ mol. per mol. the charge on the electron $e = 4.806 \times 10^{-13}$ e.s.u. and $h = 6.623 \times 10^{-27}$ erg. sec.

67. Absolute measurement of the Cu L_α line. Carl E. Howe and Mildred Allen, *Oberlin College.*—Two photographic plates at different distances from a plane glass grating of 600 lines/mm are exposed simultaneously to the radiation from a copper target. Wave-lengths are computed from the plates and the constants of the apparatus. Over sixty determinations indicate for the wave-length of the L_α line of copper a value close to 13.326A ±0.01 (mean deviation) ±0.001 (probable error). This differs by 0.15% from 13.306A as obtained by Larsson from crystal measurements.

68. Theory of the diffuse scattering of x-rays by solids. G. E. M. Jauncey, *Washington University, St. Louis.*—The classical theory of x-ray scattering has been applied to the scattering of x-rays by the electrons in the atoms of a solid. The case in which the solid consists of atoms of one kind has been considered. The interaction of the waves scattered by each electron with these scattered by every other electron in the solid has been considered. The analysis is simplified by the fact that the orbital periods of the electrons in the atoms are very much shorter than the vibrational periods of the atoms, due to thermal agitation. The final formula obtained is $S = 1 + (Z-1)(f'^2/Z^2) + (F^2/ZN)X$ where S is the scattered intensity per electron relative to the scattered intensity from a single isolated electron, Z is the atomic number, F the atomic structure factor including the effect of thermal agitation f' is related to f the true atomic structure factor (without thermal agitation), N is the total number of atoms, and X is a certain double summation. The value of X has not been obtained for an amorphous substance, but it has been evaluated for the case of a simple cubic crystal by Jauncey and Harvey in another paper (No. 153).

69. Hyperfine structure and width of x-ray spectral lines. F. K. RICHTMYER AND S. W. BARNES, *Cornell University.*—In a recent letter to the Physical Review (Sept., 1930) we reported measurements which seemed to indicate that the $K\alpha_1$ line of W(79) has a hyperfine structure of the type predicted by Breit. The measurements were made with a two-crystal spectrometer of special design. It now appears, after further critical and extensive study, that the apparent separation must have been due to some (as yet) unknown instrumental peculiarity. The numerous measurements made in connection with this study permit a determination of the width of W$K\alpha_1$. The average of several measurements in second, third and fourth order, after applying corrections for rocking curves of the crystals in the parallel position, gives a half width of 0.154 X.U.

70. Survey of the satellites of the $K\alpha_{1,2}$ doublet, the $K\beta_1$ and $K\beta_2$ lines. O. REX FORD, *West Virginia University.* (*Introduced by R. C. Colwell.*)—In a paper on the satellite structure of the x-ray diagram lines $L\alpha_1$ $L\beta_1$ and $L\beta_2$ for the elements Rb (37) to Sn (50) Richtmyer and Richtmyer, by a careful timing of exposures, were able to show that the number of satellites were more numerous than previously reported. These results called for a survey of the satellite structure of the K-diagram lines. Such a survey extended the range of the elements over which the satellites $K\alpha_3$, $K\alpha_4$ and $K\alpha'$ could be measured. An entirely new satellite of the diagram line $K\beta_1$, designated by $K\beta^\circ$, was found for the elements Ca(20) to Cr(24). The satellite $K\alpha_3$ was found to consist of two components over the range of elements Al(13) to Cl(17) instead of a singlet as previously supposed. Microphotometer records of the spectrograms show a very significant reversal in the relative intensities of the $K\alpha_3$ and $K\alpha_4$ satellites at the element P(15). That the square root of the difference in frequency between a satellite and its parent line is a linear function of the atomic number is shown to be approximately true for satellites of the $K\alpha_{1,2}$ doublet. This relation is not valid for satellites of $K\beta_1$ and $K\beta_2$.

71. Effect of piezoelectric oscillations on the Laue patterns of quartz. G. W. FOX AND P. H. CARR, *Iowa State College.*—In an attempt to determine the amplitude of vibration of the atoms in a quartz lattice brought about by piezoelectric oscillations, a series of Laue photographs have been made of both Curie and thirty-degree cut plates, using the white radiation from a standard Coolidge tube. This tube had a tungsten anode and carried a current of four milliamperes at 95 kilovolts. Eastman standard x-ray film was used with no sensitizing screens. On examination, the patterns produced by each plate, oscillating and non-oscillating, appear identical except in one respect: the pattern of the oscillating plate is several times as intense as that of the non-oscillating. A four-hour exposure of a non-oscillating plate to radiation of the above mentioned type, produces but the rudiments of a pattern, whereas, the same plate oscillating produces a very beautiful intense pattern for the same time of exposure. The effect is quite independent of the piezoelectric frequency and does not depend on whether the plate vibrates according to the shear mode or the transverse mode. It is hoped that the work in progress will establish the cause of this peculiar intensity difference.

72. Calculation of the resolving power attainable in x-ray spectroscopy by photographic methods. SAMUEL K. ALLISON, *University of Chicago.*—If w_c, the (half) range of glancing angle over which a crystal will reflect monochromatic x-rays has been determined by the double spectrometer method, it is possible to calculate what resolving power is attainable from this crystal by photographic methods. Equations are set up giving the resolving power in terms of a, the slit width, and R, the distance from slit to photographic plate. Some results are: (1) No appreciable increase in resolving power is obtained by making $a/2R<\frac{1}{4}w_c$. (2) If $a/2R>2.5w_c$ the resolving power does not involve w_c. (3) The resolving power attainable in the first order by photographic methods is $1/2^{1/2}$ of that attained in a double spectrometer in the (1, 1) position with crystals of equal perfection, as stated by Valasek (Phys. Rev. **36**, 1523 (1930).) (4) The resolving power of the instrument used by Valasek in his experiments on the molybdenum K spectrum in the first order was about 5350, whereas that of a double spectrometer in the (1, 1) position with crystals of the perfection of those used by Allison and Williams (Phys. Rev. **35**, 1476 (1930)) is about 8100. The calculations are extended to include measurements of widths of spectrum lines by photographic methods.

73. Indices of refraction and absorption in the case of soft x-rays. ELMER DERSHEM, *University of Chicago.*—Measurements of the absorption of the $K\alpha$ line of carbon in carbon, nitrogen, oxygen and neon indicate that for elements such that $\lambda_K < 44.6\text{A} < \lambda_{L_\text{I}}$ the atomic absorption coefficient is given by the following equation: $\mu_a = 1.65Z^{4.4} \times 10^{-23}$. The linear absorption coefficient of fused quartz may be calculated from its density and the absorption coefficients of its constituents and is found to be 47,200. The index of absorption κ, is found from the equation $\kappa = \mu\lambda/4\pi = 1.68 \times 10^{-3}$. The Drude-Lorentz dispersion formula yields the value, $\delta = 1 - n = 4.8 \times 10^{-3}$. Reflected intensities computed from these values are somewhat higher than those found experimentally. Good agreement is secured if κ is assumed to be 2.5×10^{-3}. The results indicate that the value of δ computed from the Drude-Lorentz formula is the correct one but that surface films or imperfections reduce the reflected intensity in much the same manner as an increase of absorption. Other measured values of atomic absorption coefficients for the $K\alpha$ line of carbon are as follows: A, 30.1×10^{-19}: Kr, 43.4×10^{-19}: Xe, 14.5×10^{-19}: Au, 40.7×10^{-19}. The bearing of these results upon x-ray absorption formulas is discussed.

74. Change in x-ray wave-lengths by partial absorption. J. M. CORK, *University of Michigan.*—Experiments have been carried out to duplicate those of Dr. B. B. Ray, in which a beam of x-rays traversing an absorbing medium gave in the direction of transmission a modified line of longer wave-length. The shift in wave-length corresponded to the x-ray photon elevating an electron to an outer atomic level and passing on unchanged in direction with diminished energy and hence a longer wave-length. Using the $K\alpha$ lines of copper and the $L\alpha$ line of tungsten with absorbing screens of beryllium, boron, carbon, oxygen and nitrogen under a variety of conditions, it has been impossible to show the existence, in any case, of a modified line.

75. X-ray absorption measurements in mercury vapor. FRED M. UBER, *University of California.* (*Introduced by Robert B. Brode.*)—The mass absorption coefficients, μ/ρ, of mercury in the wave-length region 0.74 to 1.4A were determined by an ionization method. The absorber was in the form of superheated vapor, whose density was calculated on the assumption of perfect gas behavior. The absorption chamber was entirely of pyrex glass, and was combined with the x-ray tube into a single unit. Electrometer deflections of several millimeters per second were obtained with the tube currents ranging from 6.5 to 17.5 m.a. and with the voltage low enough to prevent excitation of wave-lengths corresponding to the second order reflection. Readings were taken for several positions of the crystal before removing the absorbing vapor from the path of the beam. The magnitudes, δ, of the three L absorption discontinuities, where δ is defined as the ratio of μ/ρ on the short and long wave-length sides of the limit, are $\delta L_\text{I} = 1.18$, $\delta L_\text{II} = 1.39$, $\delta L_\text{III} = 2.45$. The mass absorption coefficient can be expressed by the relation $\mu/\rho = A\lambda^c$. The constant A assumes a different value for each branch of the curve, but the value of c does not vary from 2.6 by more than 0.1 for all four branches. The value of μ/ρ at 1.4A is in accord with what one would expect from Allen's values for gold and lead, which indicates that no appreciable error is introduced by using the perfect gas equation for superheated mercury vapor.

76. Lattice parameter of copper by a precision instrument. C. S. BARRETT AND H. F. KAISER, *Naval Research Laboratory, Washington, D. C.*—A precision x-ray camera for large angle diffraction, a modification of the instrument of Sachs (Phys. Zeit. **60**, 481, 1930), has been constructed. A photographic plate is used, avoiding film shrinkage. A specimen is used whose surface is plane, parallel to the photographic plate, and perpendicular to the x-ray beam. The distance from specimen to plate is measured by a micrometer. The instrument is applicable to specimens prepared for metallographic examination, and is convenient for high temperature studies. The parameter of copper was determined for material from Adam Hilger Ltd. analyzing

Oxygen 0.040%, Nickel 0.002%, Iron 0.003%, Arsenic 0.004%, Lead 0.001%, Calcium 0.001%, with spectroscopic analysis indicating in addition only slight traces of magnesium, caesium, and sodium. The specimen was prepared with a polished surface, annealed two hours in vacuum, and etched lightly. Copper and brass anticathodes were used. Wave-lengths assumed were Cu $K\alpha_1 = 1.53739$A, Cu $K\alpha_2 = 1.54126$A, Zn $K\alpha_1 = 1.43206$A, Zn $K\alpha_2 = 1.43587$A. The mean value of 18 observations of a_0 for copper at 20°C was 3.6078 ± 0.0001. This value agrees closely with that of Ageew, Hansen, and Sachs, (Phys. Zeit. **66**, 350, 1930), 3.6081A and yields a calculated density of 8.93 in accord with measured densities, 8.94 ± 0.01 (I.C.T. Vol. II, p. 456).

77 Lattice parameters of solid solutions of silicon in copper. H. F. Kaiser and C. S. Barrett, *Naval Research Laboratory, Washington, D. C.*—Measurements of a_0 for α-Cu-Si alloys containing less than 0.06% total impurities were made on the precision instrument described above. The alloys were homogenized by a 48 hour anneal at 750°C in vacuum, terminated by a quench in water. After a polish, they were given a 3 hour anneal at 725°C in purified hydrogen and again quenched in water. Subsequent polishing and etching was done with great care to provide a surface free from cold work, and exposures were made within 24 hours; these precautions were taken to avoid decomposition of the solid solutions. Alloys containing 5.91% and 6.36% Si, however, showed by their diffraction patterns and by their a_0 values that there was precipitate present. The parameters found were as follows in A.U. at 20°C: 1.09% Si = 3.6103; 3.01% Si = 3.6128; 5.02% Si = 3.6150; 5.91% Si = 3.6151; 6.36% Si = 3.6157. Densities calculated from these parameters and compared with densities as measured by Norbury (Trans. Farad Soc. **19**, 586, 1923–24) indicate that the solid solution is of the simple substitutional type, and agree well with Norbury's densities when calculated on this theory. That the silicon atom expands the copper lattice in spite of its smaller radius is not regarded as an anomaly, since the elements differ in crystal structure. Studies of orientation of the precipitate are being conducted.

78. The x-ray analysis of vesuvianite. B. E. Warren, *Massachusetts Institute of Technology.*—Vesuvianite $H_2Ca_{10}Al_6Si_9O_{38}$ is a complex, tetragonal silicate with $a = 15.60$A $c = 11.83$A space group D_{4h}^4 and four molecules in the unit cell. The cell contains 260 atoms and involves 44 parameters. The analysis is of particular interest as an extreme case of a complex structure, and illustrates the extent to which our present knowledge of the physical chemistry of the silicates has progressed. The structure is determined by means of a close relationship which is discovered between vesuvianite and the cubic crystal garnet $Ca_3Al_2Si_3O_{12}$. Two quadrants in the vesuvianite unit cell are identical in structure to the corresponding two quadrants in garnet except that they are rotated 45° about c. Quantitative measurements of the integrated reflexion with a Bragg ionization spectrometer for 40 planes give structure amplitudes in good agreement with those calculated from the structure. The structure contains SiO_4 and Si_2O_7 groups, and the coordination numbers are Si-4, Al-6, Ca-8.

79. Atomic scattering power of copper and oxygen in cuprous oxide. G. A. Morton, *Massachusetts Institute of Technology. Rockefeller Institute for Medical Research.* (*Introduced by B.E. Warren.*)—The atomic F-curves for copper and oxygen for the $K\alpha$ radiation of copper have been determined from cuprous oxide, and are compared with the F_{Cu}-curve from metallic copper and F_O-curve from NiO. Measurements were made on samples of finely powdered Cu_2O pressed into suitable briquets, using an x-ray powder spectrometer to measure reflected intensity. The structure factor F for the reflecting planes is calculated from the power of reflexion. The atomic scattering factors as a function of $\sin\theta/\lambda$ are found from these F values. The F_{Cu}-curve and F_O-curve as obtained from Cu_2O and those from metallic copper and oxygen in NiO are found to be the same over the overlapping portions of the curves.

80. An x-ray determination of crystal orientation in nickel, copper and aluminum, produced by cold rolling. C. B. Hollabaugh and W. P. Davey, *The Pennsylvania State College.*—High purity nickel, copper and aluminum, free from all preferred orientation, were cold rolled in such a way as to produce no appreciable temperature rise and the orientations were determined after each pass using the method of Davey, Nitchie and Fuller (Mines and Met.

Tech. Pub., 243, E88). Nickel and copper showed identical orientations both as to limits of ranges of preferred orientations and mean positions. The number of passes through the rolls determines the probability that a crystal fragment will be within the preferred range, but does not affect the limits of the preferred range. Aluminum shows a related preferred orientation, but with widely different angular limits which depend on the number of passes through the rolls. This work, with similar work on silver previously reported, shows, contrary to the accepted belief, that except for copper and nickel, the common face-centered cubic metals show differences in preferred orientation both with respect to the limits of preferred range and with respect to the mean position of orientation. The preferred positions are similar only in that they all show one face diagonal of the cube always in a plane parallel to the direction of rolling and perpendicular to the rolling surface.

81. X-ray evidence as to the size of a gene. OSWALD BLACKWOOD, *University of Pittsburgh.*—To explain certain facts of heredity, geneticists postulate the existence of bodies called genes in the chromosomes of living cells. The diameter of these bodies in the cells of the fruit fly (Drosophila) is roughly estimated to be 600A. The writer has computed the approximate number of ions produced in such a gene when exposed to x-rays of known intensity for a known time. Using Patterson's experimental value for the percentage of exposed flies showing a certain mutation about one per cent of the atoms in a gene are found to be "sensitive," (i.e. their ionization is assumed to be accompanied by mutation). If the sensitive material were concentrated in a spherical nucleus, its diameter would be about one-fifth that of the gene. The hypothesis that natural mutations are caused by cosmic or natural gamma-rays seems improbable since the ionization produced in this manner is about three billion times smaller than that due to the x-rays as used by Patterson. The period for one per cent mutation would therefore be about one million years instead of a few weeks.

82. Parallax stereoscopic x-ray pictures. KENNETH S. COLE, *Columbia University.*—Shadow parallax "stereograms" and "panoramagrams" can be made with visible light or x-rays by several types of relative motion of a point source of radiation, the object, a suitable grating, and the photographic plate. Viewed with a similar grating, either a stereoscopic or pseudoscopic effect may be obtained, also, small movements of the object can be followed in the "panoramagram." Stereoscopic x-ray "vision" can be obtained with a fluorescent screen and two gratings.

83. The lethal effect of intense x-rays on the organism colpidium colpoda. HARRY CLARK, MORDEN BROWN, AND JOHN THOMAS, *Stanford University.*—Several single-cell organisms have been studied by various investigators. The curves showing the relation between the number of survivors of a group and the time of radiation have been fitted usually by the use of Poisson's exponential series, the number of terms required lying between 1 and 8 with one exception. The results are generally interpreted as statistical evidence of a definite lethal number of quantum-hits, which must fall inside a small "sensitive volume" within the cell, although normal biological variation is sometimes considered. Although Crowther, working with colpidium colpoda, used 49 terms for immediate death, the range of individual lethal doses was still very wide. Using silver radiation at 50 kv, several times more intense than Crowther's and well controlled, we have found evidence of an approach to a critical lethal dose, the same for all individuals, which would exclude normal biological variation. To reconcile this result with Crowther's, we suggest that the processes to recuperation, which are known to be very rapid, are less rapid in the sensitive volume than elsewhere. Less intense radiation produces death by injury to the sensitive volume; more intense rays operate predominantly on other parts of the cell.

84. The extension of Clapeyron-Clausius equation to dissociation within the gaseous phase. J. L. FINCK, *Washington, D. C.*—This paper is a study of the thermodynamic analogies between the liquid-vapor state and the gaseous state in which dissociation occurs. It is noted that the associated gaseous component corresponds to the saturated liquid and that the dissociated gaseous component is the analogue to the saturated vapor. By means of a hypothetical mechanism, consisting of a piston and cylinder, which contains the gas, and two semi-permeable membranes, it is possible to separate the gas into two phases, one containing the associated component and the second the dissociated component. This permits dissociation to take place by an isothermal-isopiestic process, analogous to the evaporation of a liquid. By means of this hypothetical process it is shown that Clapeyron-Clausius equation must take the form $\Lambda = \theta(v_2 - v_1)(\delta p/\delta\theta)_x$, where Λ is the heat of dissociation, v_1 and v_2 the specific volumes of the associated and dissociated components, each taken at p, θ, and x is the degree of dissociation. Calculations based on experimental data for NH_3, H_2O, and CO_2 gases check the experimentally determined values for Λ to 1 percent and less. Some remarks are made with regard to superheated and supercooled states.

85. The mechanics of effervescence. C. J. Craven and Otto Stuhlman, Jr., *University of North Carolina.*—Small bubbles of gas rising through a liquid originating at various depths, great compared to their dimensions, arrive along a spiral path, at the surface with the same terminal velocity. They roll under the surface film, come to rest and burst, projecting fragments of liquid into the air. These fragments rise to different heights. For a given radius of bubble, temperature remaining constant, the separate fragments follow a near Maxwellian distribution when distribution in height is examined as a function of diameter of bubble. After the maximum height is passed the above distribution becomes less regular, probably due to distortion in shape of the larger bubbles. Bubbles rising through water at 21°C, having diameters up to 0.16 cm burst into three fragments, from 0.16 to 0.20 cm they burst into two fragments. Bubbles larger than this burst irregularly.

86. The absorption of audible vibrations in the air. Vern O. Knudsen and L. P. Delsasso, *University of California at Los Angeles.*—Recent measurements on the absorption of high pitched sound in air show (1) that the absorption is several times greater than that accounted for by viscosity, heat conduction and radiation losses, and (2) that the absorption decreases as the amount of water vapor in the air increases. By making reverberation measurements in two rooms which have the same boundary material (painted concrete) but different "mean free paths," it is possible to eliminate the surface absorption, and thus determine the absorption in the air only. Measurements obtained to date, both in the two room experiments and in the free atmosphere, indicate that at a frequency of 4096 cycles, for example, the attenuation constant at 21°C and 20% relative humidity is about 0.00009 and at 70% relative humidity is about 0.00005 C.G.S. units. In a mixture of air and CO_2 (4% by volume) there was evidence of a slight increase in absorption owing to the presence of CO_2. The data have a bearing upon problems in sound signaling and in architectural acoustics, and may have a bearing upon the absorption of energy within the molecule.

87. The flow of gases through porous materials. H. G. Botset and M. Muskat, *Gulf Research Laboratory, Pittsburgh, Pa.*—An experimental study has been made to establish quantitatively the characteristics of and laws governing the flow of gases through consolidated and unconsolidated porous materials of fine texture. Experiments were performed with columns of glass beads, homogeneous and heterogeneous unconsolidated sands, as well as with samples of actual sandstones. With the sandstones linear flows were made both perpendicular and parallel to the bedding plane. Radial flows through annular sections of the sandstone were also made. In all cases it was found that the gradient of the squares of the pressures is proportional to a power of the mass velocity. In the various cases the exponent was found to lie between the limits 1 and 2 corresponding respectively to completely viscous and completely turbulent flow in straight cylindrical tubes. For a given sand however it remains fairly constant over a considerable range in the mass velocity. On the basis of these results a theory was developed for the production from and pressure decline in a closed sand reservoir of uniform thickness producing into a well under conditions of radial two-dimensional flow. The theoretical predictions check qualitatively with the limited field data that are available.

88. Molecular flow and the formation of beams. A. Ellett, *State University of Iowa.*—The streaming of air at low pressure through short circular tubes is shown to give rise to an angular distribution of the molecules emerging from the tube in fair agreement with the calculations of P. Clausing (Zeits. f. Physik **66,** 471, 1930). Measurements were made by means of a Pirani gauge.

89. The Brownian motion of strings and elastic rods. G. A. Van Lear, Jr., and G. E. Uhlenbeck, *University of Michigan.*—The method introduced by Ornstein is applied to calculate the Brownian-motion mean-square deviation for strings and for elastic rods, the surrounding medium being a gas. For the string, a varying tension and elastic binding at the ends are supposed, and a formula is obtained for the mean-square deviation of any point at time t, having started with a given deviation of that point; the result contains infinite series. This result is specialized to: (1) the string with fixed ends and constant tension, and (2) the string hanging under gravity. In case (1), for the mid-point, and for a limited time interval, the series are summed; for $t \rightarrow \infty$, the result is given for all points, agreeing with that given by Ornstein for the mid-point. Elastic rods are treated similarly, and similar results are obtained. The effect of gravity, when the rod is vertical, is introduced by a simple and consequent perturbation method, and a formula is obtained for the mean-square deviation of the lower end; this agrees closely with Houdijk's experimental results. The time dependence given by the complete formula cannot yet be tested, for Houdijk gives only limiting values in his publication.

90. Pirani gauge applied to the measurement of small pressure changes. R. M. Zabel and A. Ellett, *State University of Iowa.*—The application of the Pirani gauge to the measurement of small pressure changes is discussed. Both nickel and tungsten wires are used as filaments in the gauge. Nickel wire not only has the greater sensitivity but possesses several other advantages. The theory of the gauge is developed so that it is possible to predict the affect of change in length or diameter of the gauge wire upon the sensitivity of the gauge. To obtain maximum sensitivity the wire should be made as long as convenient and its diameter adjusted so that its resistance is approximately equal to the resistance of the galvanometer. Both theory and experiment indicate that the sensitivity of the gauge is increased by increasing the area of the wire or by decreasing the temperature of the walls of the gauge. The theory also predicts that there is an optimum temperature to which the wire should be heated for maximum sensitivity of the gauge. The observed and computed values of the optimum temperature are compared. The maximum sensitivity attained is a galvanometer deflection of 1 mm for a pressure change of air equivalent to $5 \pm 1 \times 10^{-9}$mm of mercury.

91. Application of transient network theory to gas flow in vacuum systems. Donald S. Bond, *University of Chicago.* (*Introduced by Harvey B. Lemon.*)—With complex vacuum systems employing connecting tubing of only moderate diameter, the instantaneous pressure at any point may be calculated with considerable simplicity by employing the electrical analogy. Resistance is defined (by Knudsen's equation) in terms of tube dimensions; capacity (both lumped and distributed), in terms of volume. The network which simulates the most general type of closed vacuum system consists of n T-mesh circuits with resistance and capacity only. The solution of the n mesh equations gives the potential drop (or pressure) across each capacity of the form $e_j = \Sigma a_{jk} \exp(-b_k t)$. The solution can be carried out numerically for any number of meshes. Using curves of this form, which check with experiment at low pressures, it has been possible to correct McLeod and ionization manometer readings to give true pressures at any part of the system. These have been used in the evaluation of true pump speeds. The agreement has given a check on the region over which Knudsen's low-pressure equation is valid.

92. Time-pressure characteristics of some diffusion and molecular pumps. Peter J. Mills, *University of Chicago.* (*Introduced by Harvey B. Lemon.*)—Observations on various pumps were made of the time rate of change of pressure during the evacuation of a 4 liter volume and of the equilibrium pressure reached when this same 4 liter volume was leaking at a measured rate. The high vacuum pumps included single and multistage, air and water cooled, glass and steel diffusion pumps; and molecular pumps. Most of the diffusion pumps were mercury filled but several were tested with a filling of oils of low vapor pressure. Various backing pressures were obtained from several types of force pumps. Pressures, read on a pair of McLeod gauges and on an ionization manometer, gave apparent speeds from which true pump speeds were calculated by the method outlined in the preceding abstract.

93. The theoretical pressure distribution on wing sections. THEODORE THEODORSEN, *National Advisory Committee for Aeronautics, Langley Field, Virginia.* (*Introduced by J. S. Ames.*)—This paper presents a simple and exact method of calculating the lift distribution on thin wing sections. The angle at which the flow enters the leading edge smoothly is shown to play an important rôle in the theory, and is termed the ideal angle of attack. The lift distribution at this particular angle, termed the "basic distribution," is shown to be a characteristic property of the section. It is shown that the lift of a wing section may be considered to consist of (a) the basic distribution and (b) the additional distribution, the latter being identical for all sections. It is further shown that the additional lift intensity in potential flow of a noncompressible liquid is infinite at the leading edge, and the conclusion is made that the present theory of thin wing sections is applicable only at the ideal angle of attack. The theory is adapted to describe some of the properties of the actual or thick wing sections, and it is established that the essential parameter occurring in this analysis is the radius of curvature at the leading edge. The approximate magnitude and location of the maximum lift intensity is determined.

94. The effect of the presence of a grid upon certain characteristics of the airflow at the surface of an airfoil. MERIT SCOTT, *Cornell University.*—In a previous paper it was reported that the heat dissipation per unit area from the surface of an airfoil, as measured by resistance strips mounted parallel to the span and flush with the surface, is a characteristic of the airflow. An integral relation was set up from which it was shown that the coefficient of heat dissipation is proportional to the velocity gradient at the surface of the airfoil and hence to the viscous resistance. The effect of the presence of a grid, whose position with respect to the airfoil is varied, upon the above mentioned characteristics, has now been observed. It is found that systematic changes in these quantities may be followed as various parameters in the problem are altered. Mathematical treatment appears to be too involved for the present; but qualitative explanation is being attempted in terms of types of flow, the Prantl boundary layer, the Rayleigh surface of separation, etc.

95. Some examples of dimensional analysis. JAKOB KUNZ, *University of Illinois.*—The dimensional analysis has been applied to the following cases. (1) A solid body moves in a viscous medium, so that the motion is essentially determined by the viscosity, a characteristic length of the body, and the velocity, but independent of inertia, i.e., the density. The analysis leads to the formula $F=R\mu vC$. Stokes analysis gives $C=6\pi$. For higher velocity we assume that the viscosity has very little influence and that on the contrary the forces are determined by vortices and waves mixed up, or on the density ρ. The analysis leads to $F=v^2\rho l^2C$, Jonkowski-Cutta found $F=v^2\rho A\sin\alpha\cdot k$ for the lift of an airplane. (2) When the velocity of a projectile approaches that of sound, then the force depends probably on the compressibility of the medium. The force of resistance appears in the form $F=pl^2(v/c)^nC_1$, where c is the velocity of sound. (3) In an analogous way we proceed to study the motion of a fluid in a tube under a pressure gradient P. For a slow laminar motion under the influence of viscosity μ we obtain $P=(v/r^2)\mu C$, which is Poiseuille's law. In the case of turbulent motion we obtain $P=v^2r^{-1}\rho C$, where C is a dimensionless constant. Finally if the velocity is very large, approaching that of sound, P appears in the form: $P=p/r(v/c)^nC$.

96. The Auger effect in atomic spectra. A. G. SHENSTONE, *Princeton University.*—In most complex spectra there are two distinct series limits, the corresponding ions being of different structure. A term built on the ion of higher energy may be above the lower of the two limits. It is then possible for the atom to dissociate spontaneously into an ion plus an electron if there is a correct relationship between the qauntum numbers of the term and those of the ion and electron. The transition probabilities may be expected to be governed by rules similar to those which are applicable in predissociation of molecules. The effect is shown in the terms from the structure d^9s,s in CUI. The terms are ^4D, ^2D, ^2D and the lines due to all the components with $J=1\frac{1}{2}$ or $2\frac{1}{2}$ are absent or extremely weak in low-pressure sources, and very diffuse under high pressure. The ionization transition must be to the ion d^{10} plus a d-electron. The fact that the coupling is not completely Russell-Saunders accounts for the presence of the effect in ^4D. The structure $d^9s,\ d$ also shows the same type of effect, but the observations are as yet incomplete. In BeI, the lines due to the negative term $3s2p\,^3P$ are absent in the spectrum from the Schuler tube but present in high-pressure sources. The negative terms of CaI should show the effect but there are no observations in proper sources.

97. Intensity relations in complex spectra. George R. Harrison and M. H. Johnson, Jr., *Massachusetts Institute of Technology, and Harvard University.*—A correlation is found between anomalous intensities in multiplets and the presence of neighboring states having the same J values as the perturbed terms. This indicates that the extension of the sum rules ordinarily assumed, in which all lines arising from a given state are summed, is incorrect, and that all similar terms having identical J values and lying near one another must be summed together. A general quantum-mechanical proof has been found that the following rule holds: The relative total intensity of all lines arising from transitions between all states J_1 and J_2 in two configurations is constant for any coupling. Where several configurations overlap the rule must be extended to include the new terms of similar J. Where relatively small departures from LS coupling exist only close-lying terms of similar J need be grouped together. Experimental verification is difficult as generally a large number of lines must be summed, but fragments often serve to test the rule. Confirmatory intensity measurements are presented which prove the interdependence of neighboring terms of common J, and it is shown that intensity anomalies are more sensitive indicators of departures from LS coupling than are the other anomalies associated with it.

98. Electrostatic interactions in (jj) coupling. D. R. Inglis, *University of Michigan.*—A method is developed for calculating the energy of electrostatic electronic interaction for the various states of an atom in (jj) coupling. The largest perturbation of spin-orbit interaction is first taken into account by using single-electron wave functions stabilized for this interaction. Antisymmetric combinations of products of these form the fundamental wave functions in the perturbation calculation of the electrostatic interaction. The energy is expressed in terms of the same integrals that Slater (Phys. Rev. **34,** (1293)) met in the case of (LS) coupling, and one new integral. Of this latter, the angular integrations are carried out and are presented in tabular form. Its radial integrals are the same as those of Slater. In addition to giving interval relations in (jj) coupling, the results help to solve the problem of determining the levels of a configuration for general coupling.

99. Many electron transitions. S. Goudsmit and L. Gropper, *University of Michigan.*—First and higher order perturbation terms of the spin-orbit and electrostatic interaction in the eigenfunctions of many-electron configurations explain the occurrence of many-electron transitions. By considering which terms can occur in first order perturbation the following selection rules were obtained. No more than three electrons can jump at a time. (*a*) When three electrons jump all can change their n by an arbitrary amount, one changes its l by ± 1, the others by δ and ϵ, $\delta+\epsilon$ being even. (*b*) When two electrons jump both can change their n arbitrarily, one changes its l by $\delta \pm 1$, the other one by ϵ. Breaking off the series expansion for $1/r_{ij}$ in the electrostatic interaction after the second term gives for δ and ϵ only the values 0, ± 1. The Heisenberg two-electron selection rule is therefore to be considered as a special case of (*b*). Qualitative rules have been derived to tell when many-electron transitions may be strong. Special selection rules were found for (j, j) coupling. The first order terms also cause anomalies in the intensities of one-electron transitions.

100. The arc spectrum of rhenium. William F. Meggers, *Bureau of Standards.*—The arc spectrum of rhenium has been photographed from 2100A in the ultraviolet to 8800A in the infra-red; it has more than 3,000 lines in this interval. About 25% of the lines show hyperfine structure of 2 to 6, or more, components. The centers of gravity of complex lines have been determined and are assumed to represent the effective wave-lengths for purposes of analysing the gross structure of the ReI spectrum. About 500 lines, including nearly all of the stronger ones, have been classified as combinations of terms belonging to quartet, sextet and octet systems. The normal state of the neutral Re atom is represented by $(5d^5 6s^2)a^6S_{2\frac{1}{2}}$. Series-forming terms have been identified which indicate that the ionization potential is approximately 7.8 volts.

101. Evidence regarding the structure of the arc and spark lines of nitrogen. P. G. Kruger

AND R. C. GIBBS, *Cornell University.*—Nitrogen arc (NI) lines (λ's 6484, 4151, 4109, and 4099A) have been excited in a liquid air cooled condenser type discharge. These lines were photographically examined with the aid of a Fabry-Perot interferometer whose resolving power, depending on the spacing of the mirror surfaces, was 10^6 or better. With the resolution and dispersion thus obtained, the above lines were found to be sharp and lacking in any evidence of structure. The total line widths have been found to be 0.015, 0.011, 0.010 and 0.010A respectively. Nitrogen spark (N II) lines (λ's 3995, 4601, 4607, 4614, 4621, 4630, 4643, 5666, 5675. 5679, 5686 and 5710A) have been excited in a liquid air cooled electrodeless ring discharge. The microphotometer curves of the interference patterns from these lines show evidence of structure, although the components are so near together that they have not been clearly separated. The total line widths of these lines are three or four times as large as the widths of the arc lines. This gives added support to the conclusion that the spark lines are definitely complex.

102. The spectrum of Li III. H. G. GALE AND J. B. HOAG, *University of Chicago.*—In accordance with the simple Bohr theory, the spectrum of Li III should show lines analogous to the Lyman series at 135.0, 113.9, 108.0, 105.5, 104.2 etc., and lines analogous to the Balmer series at 729.1, 540.0 Angstroms, etc. We have succeeded in photographing and measuring on several plates five lines of the first of these series and the first line of the second. The line at 135A has been measured in three orders. The first two lines of the first series were previously measured by Edlén and Ericson. The third, fourth and fifth lines of the first series and the first line of the second series have not been previously reported. The $K\alpha$ line of lithium (199.26A) is very strong on many of the plates and has been measured in four orders. The vacuum spectrograph is the same as that first used by Hoag. (Astro. Jr. LXVI, 225, 1927). An electric furnace was used at first to produce lithium vapor between metallic poles. Better success has been obtained recently by using poles of lithium stanide and also metallic lithium in nickel holders.

103. Hyperfine structures in the first spectra of krypton and xenon. C. J. HUMPHREYS, *Bureau of Standards, Washington, D. C.*—The stronger arc lines of krypton and xenon have been examined for hyperfine structures. Methods of observation include the use of a Hilger Fabry-Perot interferometer having quartz plates of 6 cm aperture, a number of fixed étalons, and two quartz Lummer-Gehrke plates. The results obtained by different methods show very satisfactory agreement. Structures of the following lines have been measured: Krypton, 5570.2890, 7685.2472, 8059.5053, 8104.3660, 8281.11, and 8508.8736A; Xenon, 4193.5296, 4500.9772, 4734.1524, 8231.6348, 8409.190, and 8819.412A. No definite numerical regularities in the spacing of components, such as have been reported in the case of neon, have been observed, although with one exception the xenon lines showing structures are due to combinations with the low $^3P_2$ level and the pattern consists of four components. The satellites of neon lines are supposed to be due to Ne isotope, 22. Krypton and xenon are reported to have 6 and 9 isotopes respectively and the fine structure might be expected to be more complicated. The existence of a reported satellite of the krypton line, λ5570.2890A, has been confirmed. It is hoped that, by use of some cooling agent such as dry ice, additional structures may be resolved.

104. On the spectra of singly ionized rubidium and caesium. OTTO LAPORTE AND GEORGE R. MILLER, *University of Michigan.*—The spectra of Rb II and Cs II were investigated by means of a hollow cathode tube and a hot spark in the visible and ultra-violet regions. The data obtained were compared with the analyses of Reinheimmer (Ann. d. Physik **71**, 162, 1923) and Sommer (Ann. d. Physik **75**, 163, 1924) respectively. The classifications of these authors were found to be essentially correct though lacking greatly in completeness. The present analysis established the configurations $4p^6$, $4p^55s$, $4p^54d$, $4p^55p$, $4p^56s$ and $4p^55d$ in Rb II and of the corresponding configurations in Cs II. Spectrograms of the hollow cathode discharge of Rb II in the visible region are of special interest because the limit of excitation furnished by metastable helium falls exactly between the various levels caused by $4p^55p$, thus providing a check on the interpretation of the classification. The energy diagram of Cs II shows as a characteristic feature the decomposition of the levels of the above mentioned configurations into two distinct groups due to the large separation of $5p^5\,{}^2P$ of Cs III. The value of the ionizing potential of Rb II is 27.3 volts and that of Cs II 23.4 volts. Both values are about two volts larger than those given by Mohler (Phys. Rev. **28**, 46, (1926)).

105. Term values in the arc spectrum of selenium, Se I. R. C. GIBBS AND J. E. RUEDY, *Cornell University.*—A partial analysis of the arc spectrum of selenium has been given by Runge and Paschen (Astrophys. Jour. 8, 70, 1898) in the region 4700–7100λ, and by McLennan, McLay, and McLeod (Phil. Mag. **4**, 486, 1927) in the region 1400–2300λ. The present work is an extension of the data throughout the region 1300–9100λ, with the classification of a number of new lines. It has been found possible to determine the term values of certain levels built on the lowest level of Se II, $4p^{3}\,{}^{4}S_{3/2}$, and to relate them to this limit. The ionizing potential between the lowest level of Se I, $4p^{4}\,{}^{3}P_{2}$, and this limit has been computed as 9.70 volts.

106. Series in the spectrum of Germanium II. C. W. GARTLEIN, *Cornell University.*—High excitation of the first spark spectrum of germanium, Ge II, has been obtained in a Schuler lamp with circulating helium gas and a quantity of metallic germanium of high purity in a carbon cathode. The spectrum was photographed in the region 500A to 2500A with a vacuum spectrograph, from 2500A to 4000A with a 75 cm focus quartz spectrograph, and from 4000A to 9000A with a Zeiss 3 prism glass spectrograph. The series $4s^{2}4p\,{}^{2}P^{0}{}_{\frac{1}{2},1\frac{1}{2}}-4s^{2}nd\,{}^{2}D_{1\frac{1}{2},2\frac{1}{2}}$ has been obtained for values of n from 4 to 11, and five members of the series $4s4p^{2}\,{}^{2}D_{1\frac{1}{2},2\frac{1}{2}}-4s^{2}nf\,{}^{2}F^{0}{}_{2\frac{1}{2},3\frac{1}{2}}$ have also been obtained. From these data the series limit has been calculated to be 128,535 ± 50 cm^{-1} above $4s^{2}4p\,{}^{2}P^{0}{}_{\frac{1}{2}}$ and gives about 15. 86 volts as the second ionization potential of germanium. Many new intercombination lines have been obtained. This work confirms the assignment of the low terms made by R. J. Lang (Phys. Rev. **34,** 696, (1929)) and shows the ionization potential to be slightly lower than the estimates of Lang and of Rao and Narayan (Proc. Roy. Soc. **A119,** 607, 1928).

107. A study of the vanadium I iso-electronic sequence. HELEN T. GILROY, *Cornell University.*—A study has been made of most of the spectra in the vanadium I iso-electronic sequence due to the possible electronic changes between the following configurations,—$3d^{4}4s$, $3d^{4}4p$, $3d^{5}$, $3d^{4}4d$, $3d^{3}4s^{2}$, $3d^{3}4sp$. Application of the regular and irregular doublet laws to this sequence indicates that a five-electron system, giving quartets and sextets may be added to the systems studied by Bowen and Millikan and Gibbs and White, all of which obey these laws. To illustrate the regular doublet law one $\Delta\nu$ between sextet or quartet levels has been selected from each electronic configuration and $(\Delta\nu/K)^{1/4}$ calculated. The increase in $(\Delta\nu/K)^{1/4}$ is nearly linear with increase in atomic number. Screening constants obtained from these same 'doublets' vary from 16.18 to 15.05 through the sequence from vanadium to cobalt. Moseley diagrams have been drawn for sextets and quartets from each configuration. Utilizing the values of the vanadium I and chromium II limits as estimated by Russell, square roots of term values $(\nu)^{1/2}$ were computed and plotted against atomic number for sextets and quartets. Wherever the electron change did not involve a change in total quantum number $\Delta(\nu)^{1/2}$ was found constant through the sequence to Ni VI.

108. Possible direct reading methods for measuring the current in the electrodeless discharge. CHAS. T. KNIPP, *University of Illinois.*—An inductive method is described for measuring the magnetic component of the electrodeless discharge. In this the gaseous electric current circulating through a reentrant discharge tube was piped, so to speak, aside where it made a loop of one turn and then returned. A low resistance coil of one turn of heavy braid copper wire was placed in the maximum inductive position about this loop. Its terminals were connected to a radio ammeter. With this arrangement the ammeter, on excitation of the electrodeless discharge, read 3 amperes. Further, replacing the ammeter by a 5 cm bridge of No. 38 Ni wire, the wire instantly was fused; and, finally, an aluminum disc suspended within the loop, by a thread attached to its edge, and with its plane parallel to the gaseous current set itself briskly at right angles to same. The magnitude of these effects came as a surprise. The energy was supplied by a 25 kv., 800 kc motor-generator set, which gave highly damped waves.

109. Electrodeless discharge characteristics of hydrogen and nitrogen. OTTO STUHLMAN, JR. AND HENRY ZURBURG, *University of North Carolina.*—Electrodeless arc discharges were obtained by means of a predominant electrostatic field in a spherical bulb placed in a long solenoid excited by undamped high frequency oscillations. Critical minimum potentials to strike the arc were obtained as a function of gas pressure for frequencies between 1.5 and 4.5 million cycles.

The characteristics conformed closely to Pashan's law. The critical points defined by the minimum values of X_m and P_m for a given frequency of excitation showed that the Log $(X/p)_m$ was a linear function of the frequency f, between discontinuities, interpreted as critical points of ionization. These critical ionization points were found to be interpretatable as arising through successive impacts. The results show that here as in Towsend's work at higher pressures X/p increases with decreases in p. X_m was found to decrease with increase in f except where the relation passed periodically through sharp maxima, indicating by their shapes differences in elasticity of impact between the two gases, nitrogen behaving like an inelastic gas and hydrogen like an elastic gas. Pressure-frequency relations indicated the existence of the same ionization discontinuities.

110. The ionization by electron impact and extra ionization potentials of nitrogen and carbon monoxide. JOHN T. TATE AND P. T. SMITH, *University of Minnesota.*—The total positive ion current in nitrogen and carbon monoxide has been measured as a function of the energy of the impacting electrons out to 750 volts. The number of positive charges per electron per cm path at 1 mm pressure of Hg and 0°C was calculated. The efficiency curves for the two gases are almost the same and are very similar to those obtained for the inert gases (Phys. Rev. **36,** 1293 (1930)) and Hg vapor (Phys. Rev. **37,** 808 (1931)). Nitrogen has a maximum efficiency of 10.25 ions at about 100 volts and carbon monoxide a maximum of 10.87 at 105 volts. Extra ionization potentials in nitrogen were found at 15.80 (first ionization potential), 16.01, 16.30, 16.45, 16.55, 16.68, 16.79, 16.88, 16.96, 17.08, 17.20 and 17.44 volts. In carbon monoxide they were found at 14.20 (first ionization potential), 14.36, 14.49, 14.61, 14.71, 14.82, 14.91, 15.36, and 16.38 volts.

111. Mobilities of Na^+ ions in H_2 as a function of time. LEONARD B. LOEB, *University of California.*—The mobilities observed for Na^+ ions from a Kunsman source in H_2 (Phys. Rev. **36,** 152 (1930)) lead to a study of the square wave-form oscillations used. These were shown to be unreliable above 5000 cycles. The previous observations were substantially confirmed with the square waveform tube oscillator and by commutator at low frequencies and by sinusoidal oscillations from two different sources and with two different approaches from 2000 to 40000 cycles. For times of ion transit greater than 5×10^{-4} seconds the mobility uncorrected for temperature was 16 cm/sec per volt/cm. From 10^{-4} to 10^{-5} seconds mobilities of 21 were observed. Between these times intermediate values were found depending somewhat on the purity of the gas. The density correction for gas temperature in the path is slightly uncertain. The average temperature lay between 115°C and 60°C, the best value being 80°C. The mobility constants for the values above are therefore 13.5 and 17.5 respectively. The normal values observed in H_2 from ionization processes are 8.4 cm/sec. The latter value has no significance as the nature of the positively charged molecular nucleus of the ion is not known. The 17.5 value possibly corresponds to the Na^+ ion, while the 13.5 cm/sec value corresponds to a Na^+ ion with an attached molecule.

112. Evidence of energy exchanges accompanying scattering of atoms by crystals. H. A. ZAHL AND A. ELLETT, *State University of Iowa.*—The distribution of mercury atoms scattered from NaCl, KCl, KBr, KI has been studied by means of an ionization gauge as a function of angle of incidence and temperatures of scatterer and incident beam. The direction of maximum intensity makes an angle with the crystal normal not equal to the angle of incidence but always slightly less. The distribution can be well represented by $A \cos \theta + B \cos m(\alpha - \theta)$ $(B = 0$ when $|m(\alpha-\theta)| > \pi/4)$. The departure from specular reflection $\gamma =$ (angle of incidence $-\alpha$) is greatest for high incidence, being 16° to 4° at an angle of incidence of 70° and about 5° at 45°. The values of A/B, m and γ depend on temperatures of crystal and beam. For rock salt at least, γ is less (more nearly specular) the colder the crystal and hotter the beam. Since any incident beam gives rise to diffuse scattering $(A \cos \theta)$ plus directed scattering $\{B \cos m(\alpha - \theta)\}$ centered about a line making a greater angle with the crystal surface than does the incident beam it follows that the scattering is accompanied by an energy exchange.

113. The dependence of reaction velocity on temperature. R. M. LANGER AND B. G. CALVERT, *Massachusetts Institute of Technology.*—In a reaction which goes according to the law

$N_E(t)=N_E(0)e^{-\lambda(E)t}$ where $\lambda(E)$ is an increasing function of the energy E, and $N_E(0)$ is the number of systems in state E given by Boltzmann's Law, there are three characteristic types of temperature dependence. (1) For low temperatures there is a range in which the temperature coefficient defined by Tolman's formula $(\overline{\overline{E}}-\overline{E})/kT^2$ is constant and exceedingly small. Then comes a region (2) where the temperature coefficient rapidly increases with temperature. For higher temperatures (3) the curve again flattens out and the reaction rate K which is an average of $\lambda(E)$ can be expressed in the form $K=(1/\tau)e^{-A/kT}$ where τ is of the order of the period of oscillation of the system. Enough is known about the function $\lambda(E)$ to show for example that in the case of ordinary chemical reactions the region of (3) has already set in far below room temperature and that τ is of the order of 10^{-14} sec. For the typical radioactive processes on the other hand the region of (1) extends above 10^6 degrees. The temperature coefficient at ordinary temperatures is about 10^9 times smaller than in the chemical case so that regardless of the closeness of energy levels in the nucleus and even if the nucleus were in thermal equilibrium which is not the case until very much higher temperatures) the difference in radioactive decay rate between 0° absolute and ten thousand degrees would be inappreciable $(\Delta K/K<10^{-4})$ even if there were no experimental difficulties in its determination.

114. Improved apparatus for temperature control. E. J. WORKMAN, *National Research Fellow, Bartol Research Foundation of the Franklin Institute.*—Temperature regulators involving the use of a grid controlled arc (thyratron) with a photoelectric cell and galvanometer *light* spot usually suffer from the effect of "hunting." This effect is inherent in the thermal capacity of the heated unit and is not reduced by increasing the galvanometer sensitivity. Such effects may be eliminated by placing in front of the photoelectric cell a rotating diaphragm having the form of an Archimedes spiral $[r(\text{inches})=1+0.08\theta]$. The rotating spiral is placed in such a position that the light from the galvanometer mirror falls intermittently on the photoelectric cell, and its duration of transmission is proportional to the galvanometer deflection. With the light beam intercepted in this way, the photoelectric cell causes a thyratron to give pulses of current of duration appropriate to the conditions of balance in the galvanometer circuit. This apparatus reduces the temperature fluctuations by a factor of from 10 to 50 times in comparison to the fluctuations obtained when the stationary diaphragm is used. Applications other than temperature control are discussed.

115. The isotopes of lithium, sodium and potassium. K. T. BAINBRIDGE, *National Research Fellow, Bartol Research Foundation, Swarthmore, Pa.*—Magnetic analysis of the positive rays of lithium from a spodumene source shows no change in the relative abundance of Li^7 and Li^6 with temperature. This is in agreement with Aston and Morand but at variance with the results of Dempster, Thompson, and the similar work of Hundley. A possible explanation of Hundley's results appears when the effects of space charge and the geometry of the tube are considered. In the present work, the ion currents were not limited by space charge, the ions when brought successively to the receiving slit described exactly the same path throughout, and the resolution was great enough to secure complete separation of the ion beams with freedom from background and strays. If Na^{21} or Na^{25} exist at all they are present to less than 1/3000 of Na^{23}. No evidence is secured of K^{40} or K^{43} to 1/300 to 1/1500 respectively of K^{39}. The presence of these isotopes has been predicted or suggested by Beck, Fournier, Kossel and others from nuclear regularities among the elements or to account for the radio-activity of potassium. The complete paper will appear in the Journal of the Franklin Institute.

116. The absorption coefficient for electrons in phosphorus and arsenic vapors. ROBERT B. BRODE AND METTA CLARE GREEN, *University of California.*—The absorption of electrons from a beam sent through the vapor has been observed for a range of electron velocities from 1 to 100 volts in phosphorus and from 4 to 200 volts in arsenic. In the phosphorus curve α has a minimum of about 345 cm^2/cm^3 at 2 volts, a maximum of about 380 at 4 volts, shows a definite decrease of slope around 16 volts and becomes about 150 at 100 volts. The actual magnitudes are not definite, due to uncertainties in vapor pressure data, to thermal effusion, and to transitions between yellow and red phosphorus during the measurements. No maxima or minima were observed in the arsenic curve. The values of α ranged from about 800 cm^2/cm^3 at 4 volts to about

250 at 200 volts. These values were taken using pressures from 1 to 3×10^{-3} mm of Hg. because outside these limits there were consistent departures from a linear relationship between log I/I_0 and pressure. At the temperatures and pressures used the molecular formulas are indicated by available data to be P_4 and As_4.

117. Neutralization and ionization of high velocity helium particles. PHILIP RUDNICK, *University of Chicago.* (*Introduced by A. J. Dempster.*)—A low voltage hot cathode arc and an accelerating potential were employed to produce high speed helium particles of homogeneous velocity corresponding to 7 to 22 kilovolts, which were then allowed to pass through helium gas. The equilibrium proportion of positive to neutral particles was found to increase with voltage in this range from 0.08 to 0.23. The mean free path for ionization of the high velocity neutral helium atom was found to vary approximately inversely as the square of the velocity from 19×10^{-4} cms to 6.5×10^{-4} compared with the kinetic theory mean free path of 17×10^{-6} cm. This is in agreement with Rüchhardt's hydrogen canal-ray measurements but differs from the behaviour of α particles where free path for change from single to double charge increases with the velocity. The mean free path for neutralization of the positive ions was computed to be 1.4×10^{-4}, practically independent of the velocity. The probability of capture of electrons by α rays has been found to depend very strongly on the velocity, in contrast to the approximate independence shown by these slower helium ions. These measurements were made by the method of Wien, with transverse electrostatic fields, using a thermocouple to detect the rays.

118. A method for producing high speed hydrogen ions without the use of high voltages. ERNEST O. LAWRENCE AND M. STANLEY LIVINGSTON, *University of California.*—A method for producing high speed hydrogen ions without the use of high voltages was described at the September meeting of the National Academy of Sciences. (Science **72**, 376 (1930).) The hydrogen ions are set in resonance with a high frequency oscillating voltage between two hollow semicircular plates in a vacuum, and are made to spiral around in semicircular paths inside these plates by a magnetic field. Each time the ions pass from the interior of one plate to that of the other they gain energy corresponding to the voltage across the plates. This method has now been tried out with the following results: Using a magnet with pole faces 10 cm in diameter and giving a field of 12,700 gauss, 80,000 volt hydrogen molecule ions have been produced using 2000 volt high frequency oscillations on the plates. A voltage amplification (the ratio of the equivalent voltage of the ions produced to the high frequency voltage applied to the plates) of 82 has been obtained. These preliminary experiments indicate clearly that there are no difficulties in the way of producing one million volt ions in this manner. A larger magnet is under construction for this purpose.

119. Photoelectric fatigue in cobalt. GEORGE B. WELCH, *Marshall College.*—The rate of photoelectric fatigue in cobalt, as a function of the incident radiation, is greater when a quartz-to-Pyrex graded seal is used on the apparatus than it is when the quartz window is attached with de Khotinsky cement. Sealing a side tube containing de Khotinsky cement into the apparatus causes the rate of fatigue to decrease. With nitrogen in the cell, the customary fatigue effects were observed. These experiments were made with pressures ranging from 10^{-7} to 10^{-5} mm of mercury, using the method described by the writer (Phys. Rev. **32**, 657 (1928)). Within these limits, an increase in pressure increases the rate of fatigue, an observation which receives some confirmation in experiments performed with electrolytically deposited sodium cells. An explanation is made on the basis of the "patch" theory. (Acknowledgment is made to the National Research Council and to Cornell University for material assistance in this work.)

120. Photoelectric effect of caesium vapour. F. W. COOKE, *University of Illinois.*—The measurements reported by Mr. E. M. Little, (Physical Review **30**, 109, (1927)), have been continued with a view to explaining the difference between the results of Little and F. L. Mohler. No effect has been found on the long wave-length side of the critical wave-length $318.4\mu\mu$. The effect is a maximum at this convergency frequency, decreases with increasing frequency, reaches a minimum and begins to increase again. The order of magnitude of the effect is the same as that of Mohler. Several disturbing effects had to be eliminated and the final effect was only obtained as a difference between a dark current and the current due to light.

121. Intensity of infrared absorption bands. Lorne A. Matheson, *University of Michigan.*—The intensity of absorption bands of gases in the near infrared has been determined by a new method. A beam of radiation of known spectral intensity is passed through the absorbing gas and the absorbed energy found by its resulting heat production causing a measurable expansion of the gas. Readings for various concentrations of absorbing gas are extrapolated to zero concentration. From the results one may calculate the matrix component of the electric moment corresponding to the vibration transition causing the band and the line width of the individual lines. Preliminary results have been obtained with CO.

122. Infrared absorption bands in formaldehyde vapor. Harold H. Nielsen and John R. Patty, *Ohio State University.*—Two of the principal regions of absorption in Formaldehyde vapor reported earlier at 3.5μ and 4.7μ have been further investigated with an echellette grating with a spacing of 3600 lines to the inch. The region at 3.5μ, earlier thought to be a band consisting of P, Q and R branches has been found under higher dispersion to consist of three overlapping bands with centers at 3.61μ, 3.52μ and 3.37μ. Two of these (3.61μ and 3.37μ) show P, Q and R branches. The average spacing between lines in these bands is about 3.5 cm^{-1}. The third band (3.52μ) has only one branch which constists of groups of closely spaced lines. The spacings between these groups is about 14.0 cm^{-1} or about four times that of the other bands. The region at 4.7μ is similar to those at 3.6μ and 3.37μ in spacing and structure. Due to better resolution in this region, what at 3.37μ appeared as a single line here appears as a group of very closely spaced lines incompletely resolved. Calculations on molecular models of slight asymmetry show very good agreement between theory and experiment for the case where the principal moments of inertia have the values: $A_z=2.7\times10^{-40}$, $A_y=18.0\times10^{-40}$, $A_x=21.0\times10^{-40}$ gm-cm^2.

123. The visible and ultraviolet absorption spectra of certain amino acids and their significance. Gladys A. Anslow and Mary Louise Foster, *Smith College.*—The absorption spectra of the acid solutions of alanine, cysteine, aspartic acid, glutaminic acid, and cystine have been studied from 650 to 200 $m\mu$ with a rotating sector photometer. Aspartic and glutaminic acids, whose molecules are nearly symmetrical about the bond between the α and β carbons, gave broad, structureless bands in the visible region with maxima at 526 and 495 $\text{m}\mu$, respectively, probably caused by vibration in this bond. Cystine showed a narrower band with maximum at 251 $\text{m}\mu$, which is ascribed to vibration in the S-S bond, about which it is symmetrical. Continuous absorption started in all the acids between 225 and 200 $\text{m}\mu$, due to dissociation in a common group, the least energy being required to dissociate the heaviest molecule. The energy of dissociation in volts is 5.46, 5.52, 5.62, 5.75, and 6.07 for cystine, glutaminic acid, aspartic acid, cysteine, and alanine, respectively. This dissociation probably occurs in the carboxyl group, for similar compounds, lacking the amino group, give continuous spectra in the same region, as was also found by Ley and Hünecke (Ber. Deut. Chem. Gesel. **59,** 510, 1926). Since the water solutions give like spectra except for a slight shift to shorter wave-lengths, the carboxyl group must be present in the same form in acid and water solutions, contrary to the zwitterion theory.

124. The fundamental vibration bands of CO_2. P. E. Martin and E. F. Barker, *University of Michigan.*—The absorption bands of CO_2 at 4.3μ and 14.9μ have been examined with a grating spectrometer of resolving power sufficient to separate the rotation lines. The 4.3μ band consists of positive and negative branches only, with rotation lines about 1.5 cm^{-1} apart, and shows considerable convergence. The spacing is the same as in the long wave band, and is about twice the value obtained when estimated in the usual way from the doublet separation. This indicates that the molecule is linear, with the carbon atom midway between the two oxygen atoms. In the low frequency band a strong zero branch appears at 14.9μ, with twenty or more rotation lines on either side, about equally spaced. The motion associated with this band is one in which the carbon-atom vibrates in a plane normal to the line adjoining the two oxygen atoms. A second harmonic band appears at 4.8μ, but there is no first harmonic. Superposed upon the fundamental are three other bands, considerably less intense, of which two correspond to absorption by molecules already excited to the first vibration state by thermal impacts, while the third is a difference band involving the inactive symmetrical vibration. The energy values for three of the vibration states associated with the lower frequency may thus be determined, and these yield precisely the Raman frequencies observed by Dickinson, Dillon and Rasetti, interpreted as transitions of two in the vibrational quantum number which are required by the selection rules for this isotropic vibration.

125. The vibration spectrum of the N_2O molecule. E. K. PLYLER AND E. F. BARKER, *University of Michigan.* Three very intense infrared bands which apparently correspond to the fundamental vibrations of the N_2O molecule have been observed at wave lengths of 16.9μ, 7.7μ and 4.5μ. All three have been resolved under high dispersion, the rotation lines in each case being spaced about 0.8 cm^{-1} apart. The band at 16.9μ has a strong zero branch, while the other two are of the doublet type. The three first harmonics have also been found, and the one at 8.6μ resolved. This latter is a doublet type band although its fundamental has a zero branch. In addition to these, five combination bands have been studied, all but one being of the doublet type. Several of the bands are complicated by the superposition of absorption due to molecules already excited to the first or second vibration state for the lowest frequency.

126. The band spectrum of germanium sulfide. C. V. SHAPIRO, R. C. GIBBS AND J. R. JOHNSON, *Cornell University.*—A band spectrum of germanous sulfide (GeS) has been observed in absorption at temperatures between 450 and 550°C, in the region $\lambda 3300$ to $\lambda 2400$. Two electronic transitions have been observed, originating from the same normal state of the molecule. The equations for the band heads are:

I. $\nu = \nu_e(\text{I}) + 378.2(v' + 1/2) - 1.55(v' + 1/2)^2 - 580.2(v'' + 1/2) + 3.2(v'' + 1/2)^2$

II. $\nu = \nu_e(\text{II}) + 309.6(v' + 1/2) - 1.3(v' + 1/2)^2 - 580.2(v'' + 1/2) + 3.2(v'' + 1/2)^2$

v' progressions of 13 and 9 members respectively have been followed in these systems, while v'' takes on values from 0 to 4. The intensity distribution is normal. There are indications of an isotope effect, as most of the heads are accompanied by two satellites, whose intensity is comparable to that of the main head, corresponding to the fact that germanium consists chiefly of three isotopes. These satellites are being investigated further. Extrapolation of the vibrational series of the two upper levels indicates that the products of dissociation are the same for the two. Assuming that normal atoms are produced by dissociation from the normal state, 3.7 volts are obtained as the upper limit for the energy of one or both of the atoms resulting from dissociation from the excited state of the molecule. This value is of the order of magnitude to be expected for the (still unknown) $^1S_0$ level of the basic configuration, $3s^23p^4$, of sulfur.

127. Zeeman effect in the $^2\Sigma - {}^2\Sigma$ cyanogen bands. E. L. HILL, *University of Minnesota.*—Interpreting the doublet separations in the lower state of these bands as due to a molecular magnetization by rotation, as suggested by Kemble, preliminary calculations have been made of the expected widths and intensity distributions of the Zeeman patterns of some of the doublets for various strengths of the magnetic field. The results indicate that for fields of about 8500 gauss a representative doublet such as $\lambda 3796.104 - 0.184$ should be unobservable as two lines, which seems at variance with the experiments of A. Bachem (Zeits. f. Physik **3**, 372 (1920)). For somewhat lower fields there may be complete or partial separation of the doublets. Further experiments are being conducted by Dr. Crawford at Harvard to determine with greater accuracy the form of the components of the doublets in the field. Assuming a suitable doublet separation in the upper $^2\Sigma$ state it seems possible that the rapid convergence of the predicted patterns might be checked, but there is at present no estimate of the magnitude of the no-field doubling for this state. If the experimental data seem to justify the effort, a more complete study of the Zeeman effect for Σ states will be undertaken.

128. Interpretation of the spectrum of BaF. A. HARVEY (*Commonwealth Fund Fellow*) AND F. A. JENKINS, *University of California.*—Observed in the first order of the 21-foot grating, the absorption spectrum of BaF presents some 200 bands heads in the region 3600–9000A. These represent all of the band systems previously known in emission, and two additional ones. The electronic levels, and the vibration frequencies, $\omega_{1/2}$, (in parentheses) are as follows: X, 0 (465.4); A, 11,630 (434.2); B, 12,260 (433.8); C, 14,040 (420.7); D, 19,990 (452.5); E, 20,190 (454.5); F, 24,170 (504.6); G, 26,240 (501.8). The systems $A \leftarrow X$ and $B \leftarrow X$, discovered in emission by Querbach, are evidently the components of the $^2\Pi \leftarrow {}^2\Sigma$ system analogous to that in

SrF and CaF, while the $C \leftarrow X$ system represents the $^2\Sigma \leftarrow {}^2\Sigma$ system also found for these molecules. $D \leftarrow X$ and $E \leftarrow X$ probably form a doublet system, which, by analogy with the Cs atom, would involve a more excited $^2\Pi$ level. The new systems $F \leftarrow X$ and $G \leftarrow X$ each consist of single-headed bands. New sequences in the $D \leftarrow X$ and $E \leftarrow X$ systems confirm Johnson's vibrational analysis, but Querbach's assignments in the infra-red system are corrected in important respects. All the bands resemble closely those of the isoelectronic molecule LaO, and here also the normal state must be the common lower level of all the known systems.

129. Boron hydride bands. R. F. Paton and G. M. Almy, *University of Illinois.*—Two bands due to boron hydride have been photographed in the spectrum of a 110-volt d.c. arc in hydrogen with amorphous boron contained in a nickel or copper cup as one of the electrodes. The bands obtained are those recently reported by W. Lochte-Holtgreven and E. S. van der Vleugel (Nature, Feb. 14, 1931) as the (0, 0) and (1, 1) bands of a $^1\Pi \rightarrow {}^1\Sigma$ transition in BH. They consist of P, Q, and R branches degraded to the red. The conspicuous Q heads are at λ4331 (0, 0) and λ4367 (1, 1). From the P and R branches the molecular constants obtained are $B_0' = 11.920$, $B_0'' = 11.808$, $B_1' = 11.21$, $B_1'' = 11.44$, $D_0' = -0.00143$, $D_0'' = -0.00118$, $D_1' = -0.0017$, $D_1'' = -0.00145$. These values indicate that the (0, 1) band should degrade rapidly to the violet. A careful search on our heaviest exposures failed to give definite evidence of such a band. The isotope band due to $B_{10}H$ was observed through the greater part of the P and R branches of the (0, 0) band and establishes the identity of the carrier. Microphotometer comparisons on three plates of the intensities of the 7 best lines in the R branch gave the abundance ratio of B_{11} to B_{10} as $4.86 \pm .15$, indicating an atomic weight of $10.841 \pm .005$, in good agreement with the chemical determination.

130. A further study of the emission spectrum of CO_2. H. D. Smyth and T. C. Chow, *Princeton University.*—The analysis of the CO_2 bands reported at the New York meeting has been considerably extended. We have now found combinations between the set of vibration terms previously reported ($\nu = \nu_0 + 1101.7v + 1.7v^2$) and eight or more levels of a different electronic state. This second set of levels seems to be made up of a double vibration set and seven of them can be fitted by a simple quadratic formula of the type

$$\nu = \nu_0 + a_1 b_1 + b_1 v_1^2 + a_2 v_2 + b_2 v_2^2 + b_{12} v_1 v_2$$

where the constants a_1 and a_2 are of the same order of magnitude as the Raman frequencies of CO_2. Though nearly a hundred bands have now been fitted into the scheme there remain numerous anomalies which we hope may be removed by further adjustment of the numerical constants. We are also endeavoring to get in emission the bands observed by Leifson in absorption and for this purpose are setting up a small fluorite vacuum spectrograph separated by a fluorite window from the excitation chamber previously described.

131. Band spectrum of bismuth chloride. Paul G. Saper, *University of Chicago. (Introduced by Robert S. Mulliken.)*—A band system of BiCl in the region from about 4300 to 5500A was excited by introducing vapor from heated $BiCl_3$ into active nitrogen. The bands are degrated toward longer wave-lengths. No other bands were found besides this system. The vibrational isotope effect showed that BiCl was the emitter. The isotope effect also served as a valuable aid in locating the origin of the system. The heads were measured and a vibrational analysis made. From the analysis an equation was obtained for the wave numbers of the $BiCl^{35}$ heads. Coefficients for an equation for the $BiCl^{37}$ heads were computed from theory from those of the $BiCl^{35}$ equation. These equations are given below.

$$BiCl^{35}:\ \nu = 21802.1 + [221.2(v' + \tfrac{1}{2}) - 308.6(v'' + \tfrac{1}{2})] - [2.65(v' + \tfrac{1}{2})^2 - 0.95(v'' + \tfrac{1}{2})^2]$$

$$BiCl^{37}:\ \nu = 21802.1 + [216.0(v' + \tfrac{1}{2}) - 301.4(v'' + \tfrac{1}{2})] - [2.53(v' + \tfrac{1}{2})^2 - 0.91(v'' + \tfrac{1}{2})^2]$$

The average difference between calculated and observed frequencies was ± 1.7 cm^{-1}. The isotopic displacement was calculated for the heads in the cases where the effect was evident, and a close agreement was found with corresponding observed values of the displacement.

132. Perturbations in the helium band spectrum. G. H. Dieke, *The Johns Hopkins University.*—A large number of electronic terms of the He_2 molecule is known, and therefore its spectrum is especially suited to test the theory of perturbations developed mainly by Kronig. Two levels which lie close together perturb each other if they have: 1. The same J, 2. The same inversion symmetry, 3. The same exchange symmetry, 4. Λ different by at most ± 1, 5. The same multiplicity, 6. Approximately the same internuclear distance. The $ns\Sigma$ and $nd\Sigma$ levels of the He_2 molecule satisfy conditions 1. to 6. Rotational levels having the same J lie close together for $J=17$ if $n=4$, for $J=9$ if $n=5$, for $J=5$ if $n=6$. [n, total quantum number.] All these levels show marked perturbations which show in the spectrum by a displacement of the lines in question and sometimes by abnormal intensities. The two levels involved are shifted in opposite directions as required by the theory. There are numerous cases in which levels of the He_2 molecule come close together which do not satisfy the above conditions. Then there is no trace of any perturbation.

133. The effect of temperature upon the ultraviolet band spectrum of ozone and the structure of this spectrum. OLIVER R. WULF AND EUGENE H. MELVIN, *Bureau of Chemistry and Soils, Washington, D. C.*—The ultraviolet absorption of ozone in the region 3400 – 2300A consists of a large number of bands appearing against a background of continuous absorption. The effect of temperature upon this spectrum has been studied over the range $-78°$ to 250°C. A definite though small effect has been observed. Grossly it manifests itself as an increase in contrast with decreasing temperature. Photometric results show this to be chiefly a decrease in absorption between the band edges, all of the bands appearing to come from normal vibrational levels of very low if not the lowest energy. Though somewhat diffuse, the bands tend to degrade to the red. The observed influence of temperature can be explained as the decrease of intensity in the higher rotational absorption of the bands, and possibly also in the continuous background, with decreasing temperature. Discontinuities in the intensity relations and the regular spacing of certain of the bands have led to a partial vibrational analysis indicating two active vibrational degrees of freedom in the excited electronic state. The observed change in the absorption with temperature may affect somewhat the estimates which have been made of the amount of ozone existing in the upper atmosphere.

134. Rotational analysis of the first negative group of oxygen (O_2^+) bands. DANIEL S. STEVENS, *University of Chicago.* (*Introduced by R. S. Mulliken.*)—The bands were produced by a hollow cathode discharge and photographed in the second order of 21-foot Rowland grating. The following bands were used in the analysis: 1–6; 0–6; 1–7; 0–7. As was expected these bands correspond to $^2\Pi \rightarrow {}^2\Pi$ transition like the double headed β bands of NO, the two molecules being alike in their electron configurations. The lower $^2\Pi$ is case a as in NO. Unlike the case of NO, however, the upper $^2\Pi$ is case b. The lower $^2\Pi$ is regular, with a doublet separation (corrected to zero rotation) of 195 cm^{-1}. Each band consists of eight branches (four P and four R) together with some indications of four weak Q branches. This is in agreement with theory. Alternate levels in each Λ-type rotational doublet are missing in both the upper and lower $^2\Pi$ states. This is as predicted by the quantum theory of homopolar molecules, since it is known that the nuclear spin of the oxygen atom is zero. The constants of the molecule in the two electronic states are given by: $B'=1.043-0.027v'$ cm^{-1}, $B''=1.583-0.009v''$ cm^{-1}, $r_e'=1.41 \times 10^{-8}$ cm, $r_e''=1.15\times 10^{-8}$ cm.

135. Electronic energy levels of neutral and ionized oxygen. ROBERT S. MULLIKEN, *University of Chicago.*—The normal state of O_2 is known to be a $^3\Sigma_g^-$, probably corresponding to an electron configuration $\cdots 3d\sigma^2 2p\pi^4 3d\pi^2$ hereafter called A. The upper state of the Schumann-Runge bands is a $^3\Sigma_u^-$ probably derived (Herzberg) from $\cdots 3d\sigma^2 2p\pi^3 3d\pi^3$, hereafter called B. Configuration A should also give two metastable levels $^1\Delta_g$ and $^1\Sigma_g^+$, and B a set of metastable levels $^3\Delta_u$, $^1\Delta_u$, $^3\Sigma_u^+$, $^1\Sigma_u^+$, and one non-metastable level $^1\Sigma_u^-$. The upper level of the atmospheric bands, previously identified as the metastable $^1\Sigma_g^+$, is more probably the $^1\Sigma_u^-$. If it were $^1\Sigma_g^+$, the bands would be an intersystem quadrupole transition and probably much weaker than they are. (That $^1\Sigma_u^-$ of B should be below $^3\Sigma_u^-$, as here assumed, is indicated by consideration of the wave-functions.) The numerous bands observed by McLennan and others in liquid oxygen probably represent transitions to various metastable levels mentioned above. Or possibly some of these and the $^1\Sigma_u^-$ may belong to some other configuration, e.g. $3d\sigma^2 2p\pi^4 3d\pi 3p\pi$.

The normal and excited $^2\Pi$ states of O_2^+ (cf. preceding abstract) probably result from the respective removal of a $3d\pi$ or a $2p\pi$ electron from A. Existing data on O_2 and O_2^+ bands indicate 11.7 volts as the most probable value of the minimum ionizing potential of O_2.

136. Magnetic rotation spectrum and heat of dissociation of Li_2. F. W. LOOMIS AND R. E. NUSBAUM, *University of Illinois.*—The green magnetic rotation spectrum has been obtained from lithium contained in a nickel tube which was heated to about 1200°C by a low voltage stepped-down current. The tube was mounted in a solenoid which produced a field of 1300 gauss. The phenomenon can be seen in greater detail than in the previously studied spectra of Na_2 and K_2. In addition to the strong line at the head of each band caused by the piling up of the R branch lines, one can see the first few lines of the P branches of the strongest bands. Bands due to the lighter isotope are also visible. The spectrum extends to much higher values of v' and v'' than Wurm or Harvey and Jenkins report in absorption. It has consequently been possible to deduce a much improved value for the heat of dissociation. The frequencies of the magnetic rotation lines are represented by the following formula:

$$\begin{aligned} = 20398.4 &+ (266.90v' - 2.840v'^2 - 0.0637v'^3) \\ &- (349.00v'' - 2.605v''^2 - 0.0097v''^3). \end{aligned}$$

The heat of dissociation deduced by extrapolation of the upper set of levels with a slight correction, due to the deviation of the highest observed levels from the formula, is 1.14 volts. Since the upper levels have been followed to within 0.1 volt of convergence this figure can hardly be in error by more than about 0.03 volt.

137. Valence forces in lithium and beryllium. J. H. BARTLETT, JR., AND W. H. FURRY, *University of Illinois.*—By methods similar to those used by Heitler and London, an investigation has been made of the interaction of two normal lithium atoms, and also of the interaction of two normal beryllium atoms. In the first case, two states, one attractive and the other repulsive, are possible for the molecule. The influence of the K shells has been neglected, and a nodeless wave function such as used by Guillemin and Zener (Zeits. f. Physik **61,** 199 (1930)) has been employed. The heat of dissociation of Li_2 is calculated to be 1.12 volts and the equilibrium internuclear distance to be 2.4A as against the experimental values of 1.14 volts (Loomis and Nusbaum, unpublished) and 2.67A, respectively (Harvey and Jenkins, Phys. Rev. **35,** 789 (1930)). No stable state is possible when two normal beryllium atoms interact with each other. A study is being made to ascertain under what conditions stable beryllium molecules will be formed.

138. Evidence against the existence of a chlorine isotope of mass 39. MURIEL ASHLEY AND F. A. JENKINS, *University of California.*—From results on the infrared spectrum of HCl, Becker (Zeits. f. Physik **59,** 601 (1930)) concluded that Cl^{39} exists in small amounts, in addition to Cl^{35} and Cl^{37}. A favorable opportunity for confirming this result is found in the ultraviolet absorption bands of AgCl analysed by Brice. The region adjacent to the $AgCl^{37}$ head of the 0.1 band is exceptionally free from structure, and the $AgCl^{39}$ head should appear at high vapor densities, if this isotope exists. The bands have been photographed with the 21-foot grating, using various vapor densities, from that at which the first appreciable absorption of the $AgCl^{37}$ head begins (550°C), to that for practically continuous absorption (850°). No trace of the predicted band was found. Using the vapor pressure data of Vartenberg and Bosse, the densities at the above temperatures are in the ratio 1/1000, and hence Cl^{39} cannot be present to a greater extent than 1/1000 of Cl^{37}, or 1/4200 of the whole. Similar investigations of the AgBr and AgI bands show that none of the elements involved possess heavier isotopes in quantities detectable by this method. For AgBr, the vapor pressure data of Jellinek and Rudat yield 1/2500 as the upper limit for a Br isotope of mass greater than 81.

139. The λ3360 band of NH. R. W. B. PEARSE, *Commonwealth Research Fellow, University of California.*—The band at λ3360 emitted by the molecule NH (so-called "ammonia" band) has been photographed in the second order of the twenty-one foot concave grating for the purpose of remeasurement. The source used was a water-cooled discharge tube of large current carrying capacity containing a mixture of hydrogen and nitrogen. With the dispersion of

1.3 A/mm which was obtained the closely crowded line structure of the central maximum of intensity could be to a large extent analysed into the three components of a triple Q-branch. The band shows the three P, three Q and three R branches appropriate to a $^3\Pi \rightarrow {}^3\Sigma$ transition where the $^3\Pi$ state is near Hund's case b. The rotational term differences are obtained from these branches and used to evaluate the molecular constants. The improved wave-length data giving rise to improved values of these constants.

140. On the resolving power of the concave grating. J. E. MACK AND J. R. STEHN, *University of Wisconsin.*—An expression for the resolving power of the concave grating has been obtained, taking into account the fourth order effect upon the phase, of the departure of the grating from the plane. The result is expressed in terms of the "effective width" of the grating; i.e., the width of plane grating which gives the same resolving power as the concave one under consideration. This effective width is equal to the actual width, for narrow gratings. It increases to a maximum as the width of the grating is increased, then it decreases again and oscillates about a constant value, so that there is an optimum width, depending on the radius of the grating ρ, the angle of incidence ϕ, the wave-length λ, and the order of the spectrum. Of special interest is the case of grazing incidence (which has recently become important in extreme ultraviolet spectroscopy), where the effective width can never be greater than $2.3[\rho^3\lambda \cos \phi]^{1/4}$, and approaches a value 20 per cent less, as the width of the grating is increased. In actual cases the optimum width may be as small as 1 cm.

141. Reflecting power and grating efficiency in the extreme ultraviolet. H. M. O'BRYAN, *The Johns Hopkins University.*—By using a lightly ruled concave glass grating with a water-cooled vacuum spark between tungsten electrodes, enough intensity has been obtained to make quantitative measurements of grating efficiencies and reflection coefficients for various angles of incidence between 1000A and 280A in a vacuum spectrograph. To obtain the reflection coefficients, a mirror of the substance to be examined was rotated about the axis of a cylindrical oil-coated film on which the reflected spectra was photographed. Small gratings were inserted in place of the mirror with their rulings perpendicular to those of the concave grating and the spectra of the crossed gratings examined. Lightly ruled glass gratings, which were good at normal incidence, gave only extremely faint spectra near grazing incidence. Glass gratings etched with hydrofluoric acid were of little value at normal incidence but surprisingly efficient near grazing incidence. A grating of the echelette type, with the angle between the incident light and reflecting face of the groove made small enough to utilize the increased reflecting power at small angles will be the most efficient grating for the extreme ultraviolet and soft x-ray regions. The etched glass gratings approximate an echelette with a wide V-shaped groove.

142. Three methods of studying capillary structure as applied to wood. ALFRED J. STAMM, *Chemist Forest Products Laboratory, U. S. Department of Agriculture.*—Three different physical methods for studying the capillary structure of porous materials are developed and applied to the study of the fine effective continuous capillary structure of wood. The three characteristic capillary properties measured are, (1) the ratio of effective capillary cross-section to the effective length, (2) the average effective capillary radius, and (3) the maximum effective capillary radius. Some of the important characteristics of the porous structure of wood are briefly presented in order to show that the major part of the void structure, the fiber cavities, have very little to do with the permeability of wood. The pores in the pit membranes which connect the adjacent fiber cavities are shown to be the structure effective in controlling permeability of wood. These pores in the pit membranes in general, are below microscopic visibility, thus necessitating other means of study.

The ratio of the effective capillary cross-section to the effective capillary length is determined from electrical resistance measurements of strong salt solutions filling the void structure and from the specific resistance of the salt solutions in bulk. Strong salt solutions are used in order to make the surface conductivity negligible as well as the conductivity of the swollen cell wall. The average effective capillary radius is determined by combining the results of the preceding measurements with results obtained from hydrostatic flow studies of a continuous water phase extending through the section. Poiseuille's law is used for the calculations. A differential pressure drop apparatus was devised for these measurements in which the flow of liquid through a standard capillary tube and the test specimen connected in series is determined by measuring the pressure drop through each. The maximum effective capillary radius is determined by measuring the gas pressure required to overcome the effect of the surface tension of water in the capillary systems. The data show the large differences between the fine capillary structure of heartwood and of sapwood.

143. The electric conductivity and dielectric constant of disperse systems. HUGO FRICKE, *The Biological Laboratory, Cold Spring Harbor, Long Island.*—This report refers in particular to suspensions of biological cells. The interior of a biological cell is a well conducting salt solution, but at its surface polarization or the presence of a non-conducting membrane obstructs the passage of an electric current with a resulting low conductivity and high dielectric constant of the suspension. The theory for the passage of an alternating current through a suspension of this type is dealt with and experimental work with various kinds of suspensions such as cream, wet sand, blood, and animal tissues, is described to show the applicability of the theory. The determination of the volume concentration of suspensions, of the form factor of the suspended particles, of the thickness of surface membranes, and of the interior conductivity of living cells are instances of practical applications.

144. Three component emulsions. P. G. NUTTING, *U. S. Geological Survey.*—A quartz sand grain, wet with water, tends to cling to oil but tends to remain on the water side of an interface. A glass plate, such as a microscope cover glass, may readily be floated on water if the water is first covered with gasoline. Muddy water, shaken with gasoline, is cleared, the particles of silt collecting in a tough skin at the interface. Muddy gasoline shaken with clear water gives the same result. Emulsions form whenever a dielectric fluid (air or an insulating oil), solid particles and a second fluid containing OH (water, alcohol, glycerine, linseed oil) are thoroughly mixed and allowed to stand. Two components give solutions and suspensions but never emulsions. The solid particles are supposed to adsorb OH ions on one side thereby acquiring an induced charge on the other which clings to the dielectric.

145. The electric mobility of proteins. HAROLD A. ABRAMSON, *Harvard University.*—I. The electric mobility of microscopic quartz particles covered with egg and serum albumins (crystallized 3×) is, between $pH=3.5$ to 5.5 (1) equal to the mobility of the dissolved protein molecules, and (2) proportional to the combining power of the proteins for acids and bases. This indicates that the amino and carboxyl groups of the adsorbed protein molecules are practically all oriented toward the aqueous phase. The method of mobilities, therefore, is a valuable means of studying the orientation of polar molecules at solid-liquid and liquid-liquid phase boundaries. This is further demonstrated by the behavior of crystals of tyrosine, cystine and aspartic acid. The electric mobilities of these particles indicate that the ampholytic nature of these substances is not simply responsible for the values of mobility. All these crystals are negatively charged at the isoelectric point calculated from the dissociation constants. All three have an isoelectric point at about $pH=2.4$, with reversal of sign in more acid solutions. The mobilities of the amino-acid crystals are, therefore, somewhat like those of inert surfaces, differing however in important respects. It seems likely that the amino and carboxyl groups at the surface of the crystal are not oriented toward the liquid.

II. The change in electric mobility of egg albumin with pH is proportional to the change in specific rotation. A method is available, therefore, for the comparison of change in potential with change in the rotation of the plane of polarized light.

146. The application of the ultracentrifuge to some colloid physical problems. J. B. NICHOLS, *E. I. duPont de Nemours & Company.*—Until recently there existed no very reliable method for determining particle-size distribution curves of colloidal material, especially lyophilic colloids. Accordingly a study was undertaken of the conditions required for undisturbed centrifugal sedimentation of fine-grained colloids and for the accurate determination of the sedimentation-velocity and diffusion relations. The present ultracentrifuge, as developed in Svedberg's laboratory, enables us to exert a centrifugal force 100,000 times that of gravity on a solution and thus to determine the particle size of a great variety of colloidal material and even molecular weights of complex dyes or proteins. Valuable information can be obtained on phenomena such as the interaction of particles in solution, the effect of the environment on the state of aggregation, and Donnan potential effects.

147. The limitations and adaptability of ultramicroscopes to the study of colloid systems. L. V. FOSTER, *Bausch and Lomb Optical Co.*—Ultramicroscopes are of two distinctly different types. The best known is the cardioid ultramicroscope in which the illuminating portion produces a hollow cone of large angular aperture with its apex at the object. The observing system is a microscope consisting of a high aperture objective of angular aperture slightly less than that of the hollow cone and a high power eyepiece. The other is the slit ultramicroscope. The illumination system in the slit ultramicroscope is perpendicular to the observing system. Both systems are of high numerical aperture, but no direct light can enter the observation system. Details of construction of both types of ultramicroscopes and their sensitiveness of adjustment will be discussed. Expressions for their limitations in colloid microscopy will be given.

148. Physics in the study of pigment dispersions. F. A. STEELE, *The New Jersey Zinc Co., Palmerton, Pennsylvania.*—The study of colloids has reached the point where many important contributions are coming from physicists. Even more attention from physicists will be required if this science is to progress as it should. A suitable dispersion of zinc oxide in kerosene has a high yield value and marked plastic properties. A few drops of a dispersing agent added to this mixture largely destroys its plastic properties and greatly increases its fluidity. It is well established that the dispersing agent accomplishes this result by decreasing the interfacial tension and thereby destroying the flocculation of the pigment. In certain cases in paints, however, there is reason to believe an entirely different phenomenon is responsible for yield value and plasticity. Much work with the tools of the physicist is indicated in the solution of this problem. There is much to be done in the study of solid-liquid interfacial tension, adsorption layers, interfacial potentials, and the di-electric properties of colloids before these problems are to be solved. The behavior of pigments in rubber is also discussed.

149. Some theoretical aspects of the biological applications of physics of disperse systems. N. RASHEVSKY, *Westinghouse Research Laboratories, East Pittsburgh.*—A review of the author's recent theoretical work on the properties of small liquid drops and more generally of systems with very large specific surface, is given. When such a system interacts chemically with the surrounding, in such a way, that the mass of the substances, of which the system is constituted, slowly increases, the system will possess, under very general conditions, properties remarkably similar to those found in living organisms. Thus it is found that such a system may possess a positive rate of growth, when its size exceeds a certain critical one. Below this critical size the rate of growth is negative. Such a system therefore can never be formed spontaneously, although all substances necessary for its formation may be present. Under certain very general conditions such a system will, under the influence of osmotic and other forces, divide into two halves, when reaching a certain size, each half again growing and dividing, and so forth. In many cases the system will possess a very definite geometrical form, which will tend to be restored, when the system is deformed by some external disturbance.

150. Some colloidal properties of bentonite suspensions. H. A. AMBROSE AND A. G. LOOMIS, *Mellon Institute of Industrial Research and Gulf Research Laboratory, Pittsburgh, Pa.*—A study of the swelling and gelling properties of bentonite dispersions has been made in connection with the increasing use of this mineral for drilling oil wells. It is shown that the emulsoid type of colloids present responds to changes in the *pH* of the dispersion medium with respect to rate of settling, viscosity and swelling, thus behaving as a typical hydrophilic colloid. The curve for per cent of solid matter settled in a definite time as ordinate against the *pH* shows a maximum at the isoelectric point, with minima on each side of this point, corresponding to the points of maximum adsorption. As the *pH* is further increased or decreased flocculation begins with increased rate of settling. The viscosity curve is closely related to the rate of settling curve, showing maxima and minima corresponding to the electro-viscous effect. Maximum swelling occurs at approximately the point of maximum viscosity. Methods are given for controlling the swelling of bentonites. Relaxation curves are given for bentonite suspensions and utilized to explain the suspension qualities of these sols for heavy mineral dispersions, such as barite or amorphous silica. A few applications of bentonite sols to the drilling of oil wells are given.

151. The theory of electrophoretic mobility. M. MOONEY, *United States Rubber Co., Passaic, New Jersey.*—The Helmholtz theory of electrophoresis is modified, in the case of a spherical particle, to take account of ionic diffusion, ionic mobility and the motion of the water. The effect of these factors on the charge distribution in the double-layer and on the electrophoretic mobility is calculated. The principal term in the resulting mobility formula applies to a sphere whose radius is infinitely greater than the mean thickness of the electric double-layer. It agrees with the Helmholtz mobility formula. A second term gives the first order correction for the curvature of the spherical surface. The Debye-Hückel theory of electrophoresis, the Helmholtz theory and the modified Helmholtz theory are compared; and it is shown that the different value for the numerical factor in the Debye-Hückel mobility formula results from a different assumption concerning the electric field in the immediate neighborhood of the particle when subjected to an external field. It is also argued, as a further consequence of this assumption, that the use of the Debye-Hückel formula is justified only at the other extreme in particle size, that is, for particles whose radii are small in comparison with the mean thickness of the double-layer. The experimental results of several investigators are considered in their connection with these theoretical deductions.

152. Wave motion and the equation of continuity. R. B. LINDSAY, *Brown University.*—The motion of a compressible fluid medium slightly disturbed from equilibrium is described by means of the two fundamental relations between ϕ, the velocity potential, and s, the condensation, viz., (A), the equation of *motion*: $\dot{\phi} = -c^2 s$, and (B), the equation of *continuity*-$\nabla^2\phi = -\dot{s}$. The elimination of either ϕ or s between (A) and (B) leads to the usual wave equation for propagation with velocity c. Now it is interesting that (A) focusses attention on the *motion* of a part of the medium which is considered to move as a whole (i.e., as a single particle), while (B) is the expression of the fact that a *continuous medium* is involved. Both ideas are thus implied in wave motion. The present paper studies several other cases where the combination of equations of type (A) and (B) leads to the wave equation. Such are, for example: (a) longitudinal waves in solid rods, (b) transverse waves along a flexible string (wherein, as in (a), the equation of continuity appears in the guise of Hooke's law), and (c), electromagnetic waves. As an allied matter of interest it is shown that equations of type (A) and (B) for a one dimensional continuum may be expressed in the form of generalized Hamiltonian canonical equations of motion where the Hamiltonian is replaced by a functional of ϕ representing the total energy in the medium. This further emphasizes the fundamental nature of equations of type (A) and (B).

153. Diffuse scattering of x-rays by simple cubic crystals. G. E. M. JAUNCEY AND G. G. HARVEY, *Washington University, St. Louis, Mo.*—The value of X in a previous paper by Jauncey (No. 68) has been determined for the case of a simple cubic crystal consisting of atoms of one kind and the formula obtained by Jauncey reduces to: $S = 1 + (Z-1)(f'^2/Z^2) - (F^2/Z)$. There are no experimental results for a crystal consisting of atoms of one kind, but Jauncey and May (Phys. Rev. **23,** 128 (1929)) have obtained values for the diffuse scattering of x-rays from a crystal of rocksalt. Assuming rocksalt to consist of atoms of atomic number $(11+17)/2$ or 14, we have calculated values of f' using values of F given by James and Firth (Proc. Roy. Soc. **A117,** 62 (1928)). These calculated values of f' are found to be only slightly greater than the values of F at absolute zero. Also Jauncey (Phys. Rev. **20,** 421 (1922)) has measured the effect of temperature on the diffuse scattering from crystals. From the above formula calculations of the ratio of the scattering at temperatures of 568° and 290°K have been made, using F values given by James and Firth. The theoretical and experimental values of this ratio in one case are 1.29 and 1.33 respectively, and in another case are 1.13 and 1.18, thus showing good agreement between theory and experiment.

154. An experimental test of the ionization chamber method of measuring relative intensities of x-ray spectrum lines. SAMUEL K. ALLISON AND VICTOR J. ANDREW, *University of Chicago.*—A two-compartment ionization chamber has been constructed with the following properties (1) The fraction of the x-ray energy in the direct beam absorbed in the front compartment could be directly measured, (2) The volume of gas from which the ionic saturation current was drawn was sharply defined, (3) Fluorescent radiation or photoelectrons produced in the chamber could not reach the walls (4) The direct beam entered and left the chamber through thin windows and encountered no other parts of the chamber. The relative ionization currents produced in methyl iodide, methyl bromide, argon, sulphur dioxide, and air by the α_1, β_1, γ_1, lines of the tungsten L-series were measured and the ratios obtained after correction for fraction absorbed were found to vary not more than 1 per cent in the first four gases. In air a correction (Compton, Phil. Mag. **8**, 961 (1929)) must be made for scattering; if this is done, ratios agreeing with the first four gases were obtained. The results give strong support to the following hypothesis: The saturation current obtained from a given volume of any gas is proportional to the power of the fraction of the x-ray beam transformed into β-rays within it, providing the β-rays come to the end of their ionising range within the volume. Similar experiments on the uranium L-series are being completed.

155. Effects of ground faults and ground connections of the Wheatstone bridge. FRANK WENNER, *Bureau of Standards, Washington, D. C.*—The insulation outside the bridge proper may not be perfect, and with an alternating test current there may also be displacement currents between the source and detector leads. Either results in ground faults and requires that a correction be applied to the usual bridge equation or that certain auxiliary adjustments be made, and usually these adjustments involve some type of ground connection. Ground faults in each of the source and each of the detector leads increase the number of arms of the bridge from 4 to 8. While the equation for the 8-arm bridge is easily determined, usually a part of the data required for its use are lacking. It is shown, however, that the correction to the usual bridge equation necessary to take account of the effect of these ground faults can in most cases be determined from two additional balances of the bridge. One of these is made with one terminal and the other with the opposite terminal of the bridge grounded. Effects of other types of ground faults, and the effectiveness of various adjustments and ground connections in reducing the magnitude of the error resulting from ground faults in case a correction is not applied, are considered.

156. A new principle of sound frequency analysis. THEODORE THEODORSEN, *National Advisory Committee for Aeronautics, Langley Field, Virginia. (Introduced by J. S. Ames.)*—A new method of sound frequency analysis has been developed by the National Advisory Committee for Aeronautics in connection with a study of aircraft noises. The method is based on the well known fact that the ohmic loss in an electrical resistance is equal to the sum of the losses of the harmonic components of a complex wave, except for the case in which any two components approach or attain vectorial identity, in which case the ohmic loss is increased by a definite amount, even though the total current remains the same. This fact has been utilized for the purpose of frequency analysis by applying the unknown complex voltage and a known voltage of pure sine form to a common resistance. By varying the frequency of the latter throughout the range in question, the individual components of the former will manifest themselves, both with respect to intensity as well as frequency, by changes in the temperature of the resistance. No difficulties exist as to distortions of any kind. The fidelity of operation depends solely on the quality of the associated vacuum-tube equipment. An automatic recording instrument embodying this principle is described in detail.

157. The blackening of photographic plates by positive ions of the alkali metals. K. T. BAINBRIDGE, *National Research Fellow, Bartol Research Foundation, Swarthmore, Pa.*—The blackening of Eastman x-ray plates has been measured as a function of the energy of the ions of Li, Na, K, Rb and Cs. The current density in the ion beam in the mass spectrograph was maintained at 1.32×10^{-8} amp/cm^2 for the most abundant isotope of each element. With exposures of one minute and for a density $D=0.3$ the energy of the ions ranged from 1440 electron-volts for Cs to 850 electron volts for Li^7. For a threshold density, $D=0.04$, the energy ranged from approximately 750 to 450 electron-volts for Cs and Li^7 respectively. A discussion is included of the probable mechanism of rendering a silver bromide grain developable, results with Schumann and Process plates, and blackening as a function of time and the intensity of the ion beams. The ion sources used, which are unsurpassed for steadiness, purity, and ease of manipulation, are described. The complete paper will appear in the Journal of the Franklin Institute.

158. The angular distribution of photoelectrons ejected by polarized ultraviolet light in potassium vapor. ERNEST O. LAWRENCE AND MILTON A. CHAFFEE, *University of California*—Light of wave-lengths in the region of 2400A selected by a monochromator and polarized by a pile of quartz plates illuminated a jet of potassium vapor. The lateral directions of emission of the photoelectrons relative to the electric vector were studied. Though the electrons were ejected with less than one equivalent volt velocity, the experiments were definite in establishing that the most probable direction of ejection is that of the electric vector and moreover that the angular distribution varies as the square of the cosine of the angle between the electric vector and the direction in question. This result is in accord with predictions of the wave mechanics for a spherically symmetrical atom and incidentally therefore constitutes additional evidence that molecules do not play an appreciable part in the observed photoionization of potassium vapor.

159. Λ-type doubling and electron configurations in diatomic molecules. ROBERT S. MULLIKEN AND ANDREW CHRISTY, *University of Chicago.*—Van Vleck's equations for the Λ-type doublet widths in ${}^2\Pi$ states, for all intermediate coupling cases between cases a and b, have been found to fit excellently the data on CH, OH, SiH, CaH, ZnH, CdH, HgH, etc. (Incidentally this had made possible a revision of the hitherto doubtful assignment of J values for the Q_2 lines in the ${}^2\Pi$, ${}^2\Sigma$ bands of CaH, and has permitted identification of the ${}^sR$ branch.) From the constants of these equations and similar constants for ${}^1\Pi$ and ${}^2\Sigma$ states, determined from empirical data, further confirmation of Van Vleck's theoretical results is obtained, also interesting information concerning electron configurations of molecules. In this way it is found that the n and l values previously assigned to outer electrons in hydrides have almost the same well-defined significance as they would in an atom formed by uniting the H nucleus with the heavier nucleus. For example, in the normal (${}^2\Sigma$) and first excited (${}^2\Pi$) state of CdH, with configurations $\cdots 5s\sigma^2 5p\sigma$ and $\cdots 5s\sigma^2 5p\pi$, the present evidence shows that the last electron really behaves like a $5p$ atomic electron, even though the normal (${}^2\Sigma$) state is formed with a small energy of formation from a normal Cd atom ($\cdots 5s^2$, ${}^1S$) and a normal H atom ($1s$, ${}^2S$).

160. Colloid physics in latex technology. ANDREW SZEGVARI, *American Anode Inc., Akron, Ohio.* Latex, a suspension of rubber hydrocarbon (latex particles) in an aqueous solution, flows from the rubber tree in an extremely unstable state. When stabilized by raising the *pH* with ammonia it may be stored and becomes available for commercial purposes. The concentration may then be increased by centrifuging, creaming, or evaporation until 60 percent or more is rubber. Rubber goods may be made directly from such stabilized latex by electrodeposition, coagulation, ultrafiltration, evaporation, etc. The controlling factors in the deposition processes are the colloid physical conditions of dispersed systems and most eminently, the electrokinetic characteristics. The electrodeposition of latex gives an interesting colloid physical analogy to electrodeposition of ionic dispersed metals. The most striking difference between these systems with particles of such widely varying size, is the rate of deposition. This is considerably larger in colloid dispersed than in ionic dispersed systems. For most technological purposes the liquid latex systems must be compounded with conditioning ingredients. In this compounding the physical properties of suspensoid-dispersed systems are again concerned.

161. Dirac's spinning electron and Barnett's gyromagnetic effect. Otto Halpern, *New York University.*—The paper contains a treatment of the influence of a constrained rotation of the Dirac electron which may be free or bound to a nucleus. The proper values in the rotating system are changed as in the old quantum theory, the sum of spin and orbital angular momentum entering instead of the orbital momentum alone. There appear small additional terms of the order of fine structure separation times angular velocity of rotation.

162. On the design of high-tension condenser leads. Harry Clark, *Stanford University.*—A condenser was built for use at 50 kv on direct current consisting of several large glass plates coated with tinfoil and stacked together almost in contact in air. The leads were tinfoil strips 1 inch wide. Although each plate withstood a long test at 80 kv, the assembly sparked over at 50 kv. The discharge occurred opposite a lead where the minimum spark-length was 9 inches and was caused by the inductive effect of the lead and proximity of the plates. The defect was remedied without separating the plates by using leads of thick wire so bent as to cross the margin of the plate at a 30-degree angle. This apparently causes the leakage along the glass opposite the lead to proceed as a very long narrow salient with a smaller potential-gradient.

163. Air-cooled electromagnet for Zeeman effect. I. Walerstein and A. I. May (*D. E. Ross Research Fellow*), *Purdue University.* (*Introduced by K. Lark-Horowitz*).—An air-cooled electromagnet for work in Zeeman effect has been constructed due to lack of a "soft" water supply for cooling. The pattern of the instrument follows the Boas type, but includes a number of improvements. The yoke is made of a wider cross section, thus eliminating the narrowing of the pole gap upon application of the field. The current is carried by 2000 turns of flat bare copper ribbon wound in 24 pancake coils which are cooled by a forced draft of air circulated between the coils by a fan. Temperature equilibrium is reached throughout the instrument in less than an hour, and in half an hour in the pole-gap where the temperature rise is about 5°C for an inducing current of 20 amps. Using ferro-cobalt pole caps with pole face of 8 mm diameter fields of 39500 gauss and 43500 gauss were obtained respectively for gaps of 4 mm and 2.4 mm with a current of 25 amps. For a gap of 1 mm and a current of 33 amps a field of 48500 gauss was reached. Zeeman patterns were produced corresponding to nearly full strength of the magnetic field with no loss in sharpness, due to thermal fluctuations even during the first hour of application of the field.

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