

**Proceedings
of the
American Physical Society**

MINUTES OF THE BOSTON MEETING, DECEMBER 28-30, 1933

THE 35th Annual Meeting (the 189th regular meeting) of the American Physical Society was held at Boston on Thursday, Friday and Saturday, December 28, 29 and 30, 1933, in affiliation with Section B—Physics—of the American Association for the Advancement of Science. The presiding officers were Dr. Paul D. Foote, President of the Society, Professor A. H. Compton, Vice-President, Dr. L. J. Briggs, Dr. K. K. Darrow, Dr. Thomas H. Johnson, Professor F. W. Loomis and Professor G. W. Pierce. There were more than five hundred physicists in attendance. Sessions were held at both Harvard University and the Massachusetts Institute of Technology.

On Thursday afternoon there was a symposium on *Nuclear Physics*. The speakers at this symposium were (1) Professor G. E. Uhlenbeck of the University of Michigan on *Introduction to the Theory of the Positron*; (2) Dr. Carl D. Anderson of the California Institute of Technology on *The Positron*; and (3) Professor J. R. Oppenheimer of the University of California on *The Theory of the Electron and Positive*. This proved to be a session of great interest and importance, and the attendance was about five hundred.

The annual joint session with Section B was held on Friday morning. The presiding officer was Dr. C. J. Davison, Vice-President of Section B. There was an address by Dr. Paul D. Foote, President of the American Physical Society, who delivered his presidential address on *Industrial Physics*. The Retiring Vice-President of Section B, Professor D. L. Webster, delivered an address on *Current Progress in X-Ray Physics*. An address was also given by Professor James Franck formerly of the University of Göttingen on *Hydrogen in Palladium*.

Annual Business Meeting: The regular annual business meeting of the American Physical

Society was held on Friday morning, December 29, 1933, in the New Lecture Hall of Harvard University. The meeting was presided over by President Foote. The President had appointed Messrs. G. Breit and I. I. Rabi to canvas the ballots for officers of the Society. They reported the following elections for the year 1934:

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| President | Arthur H. Compton |
| Vice-President | R. W. Wood |
| Secretary | W. L. Severinghaus |
| Treasurer | George B. Pegram |
| Members of the Council—four year term | E. O. Lawrence F. K. Richtmyer |
| Members of the Board of the Physical Review—three year term . . . | Alexander Ellett Louis A. Turner George E. Uhlenbeck |

The Secretary reported that during the year there had been 133 elections to membership. The deaths of 10 members had been reported during the year; 38 had resigned; and 4 had been dropped. The membership of the Society as of December 27, 1933 was as follows: Members: 2005; Fellows: 662; Honorary Members: 6; Total Membership: 2673.

The Treasurer presented a summary of the financial condition of the Society. It was impossible to present a final report for the year at the Annual Business Meeting because the fiscal year ends on December 31st. The Treasurer's financial report will be audited, printed and distributed.

The Managing Editor reported that it was no longer his duty to report the financial status of the various publications of the Society since this is now being done by the American Institute of Physics. He reported that during the first half of the past year the average length of papers was 6.93 pages and during the second half 6.19 pages. The advantages and disadvantages of attempting to shorten the papers were summarized. Among

other things it resulted in an acculumation of unprinted papers in the hands of the authors for correction.

On Friday noon Harvard University very kindly invited the members of the Physical Society to be its guests at luncheon in the Harvard Union.

The annual dinner of the Society was held on Friday evening at seven o'clock at the Parker House. There were 141 present. Dr. Paul D. Foote presided and introduced the new president, Professor Arthur H. Compton. The after-dinner speakers were Dr. K. K. Darrow, Professor Duane Roller, Editor of the American Physics Teacher, and Dr. W. F. G. Swann.

Meeting of the Council: At the meeting of the Council held on Thursday, December 28, 1933, one candidate was elected to fellowship, three candidates were transferred from membership

to fellowship, and twenty were elected to membership. *Elected to Fellowship:* Otto Stern. *Transferred from Membership to Fellowship:* Walter H. Brattain, Morris Muskat and Brian O'Brien. *Elected to Membership:* J. M. Benson, Jonathan Biscoe, T. W. Bonner, Carl A. Cinnamon, Byron E. Cohn, Paul M. Gross, Elmo E. Hanson, Clement L. Henshaw, Lawrence E. Kinsler, Esther U. Mintz, K. H. Moore, Daniel Norman, D. A. Quarles, William H. Ross, E. H. Schrieber, William L. Smith, S. Town Stephenson, D. A. Wilbur, Karl S. Woodcock, and W. W. Woodcock, Jr.

The regular scientific program of the Society consisted of sixty-four papers. Numbers 1, 3, 56, 57, 58, and 59 were read by title. The abstracts of these papers are given in the following pages. An *Author Index* will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. The Polarization of Light at Sea. E. O. HULBURT, *Naval Research Laboratory*.—Measurements have been made of the polarization of the light of the surface of the sea for a variety of weather conditions. From the experimental results and theory explanations emerge of the character of the sea reflection, the width of the sun path on the water and a number of familiar phenomena. A polarizing prism properly oriented darkens the sea relative to the sky, reduces the brilliancy of the sun path and renders the horizon more distinct. Attaching polarizing prisms to a sextant and to binoculars improved these instruments in certain cases.

2. The Rapid Derivation of Thermodynamical Relations for a Simple System. A. NORMAN SHAW, *McGill University*.—A procedure has been developed whereby relations involving first and second partial derivatives may be deduced with great rapidity. It has been possible to construct three compact tables which lead to the relations between derivatives chosen in any manner whatever. Previously available tables have been confined mainly to transformations involving only a few sets of those independent derivatives most commonly chosen for reference. The methods are based on the use of a Jacobian notation which leads to much simplification in transforming partial derivatives. The following equations are shown to be adequate for deriving rapidly the major portion of the myriad of possible thermodynamical relations for a simple system,—

$$J(x, y) \cdot J(z, w) + J(y, z) \cdot J(x, w) + J(z, x) \cdot J(y, w) = 0$$

$$J[J(x, y), z] + J[J(y, z), x] + J[J(z, x), y] = 0,$$

where x, y, z, w may be any thermodynamical variables considered under circumstances where any three of them determine the physical state of a system. These equations are combined with $J(p, v) = J(T, \phi)$; and in applications, the following is particularly useful,—

$$(\partial x / \partial y)_z = \partial(x, z) / \partial(y, z) = J(x, z) / J(y, z)$$

$$= (A_x B_z - A_z B_x) / (A_y B_z - A_z B_y),$$

where $A_r = (\partial r / \partial \alpha)_\beta$, and $B_r = (\partial r / \partial \beta)_\alpha$, in which α and β represent any two permissible independent variables, and r is any dependent variable.

3. A Note on the Ratio of the Thermal Coefficient of Expansion to the Specific Heat at Constant Pressure for Tungsten. WILFRID J. JACKSON, *Rutgers University, New Brunswick, New Jersey*.—The variation of the ratio α/C_p with temperature has been worked out for tungsten by using the recent careful measurements and the empirical relationship obtained from the data of Bronson, Chisholm and Dockerty. (*Canadian Journal of Research* **8**, 282–303 (1933)). The best available data on the thermal coefficient of expansion are used. It is found that the ratio is a constant for only a limited range of temperature for which the empirical relationships are applicable. Above 200°C the ratio increases continuously with temperature up to 500°C where the validity of the relationships ceases. A table is given showing the variation in the ratio.

4. The Science of Sealing Metals to Glass. ALBERT W. HULL, *General Electric Company, Schenectady, N. Y.*—The differential thermal expansion between glass and metal has

been measured with great care for all the common sealing materials and for a number of new alloys and glasses. Typical combinations have then been tested, after annealing at definite temperatures, for strength and strain, and the results compared with predictions based on the expansion measurements. A new alloy is described, whose expansion matches that of a particular glass over the entire range from zero to the softening point. With this combination of glass and metal it is possible to test the hypothesis, which is basic to a science of seal-making, that properly annealed seals will be strain-free to exactly the degree indicated by the expansion data. The results confirm this hypothesis.

5. Servo-mechanisms. H. L. HAZEN, *Massachusetts Institute of Technology*. (Invited paper.)—The paper has two parts, the first relating to the theory of servo-mechanisms in general, the second to the design and test of a particular high-performance servo-mechanism. In the first part, characteristics of three types, the relay type, the definite-correction type, and the continuous-control type, are examined quantitatively, considering such factors as inertia, the nature and amount of damping, time delay in the application of restoring forces, inactive zone, nature of control for the restoring forces, etc., and their effects on oscillation or hunting, and error of following. A figure of merit for the continuous-control type is developed as a guide for comparison and design. In the second part, the design of a non-oscillating, fast-following servo-mechanism is described, together with calculations and test results on its performance. This servo, which uses light from a photoelectric cell as input and delivers about 75 watts output in the form of mechanical rotation, substantially completes its response to a change in input variation within 0.05 second. Methods of improving the performance are suggested.

6. The Inherent Power Factor of Air Condensers and the Limits of Power-Factor Bridge Measurements. J. C. BALSBAUGH, *Department of Electric Engineering, Massachusetts Institute of Technology*. (Introduced by W. O. Severinghaus.)—In general, the use of a bridge for the power-factor measurement of a dielectric will not give an absolute power-factor measurement of the dielectric, but will indicate the difference in the power factors of the dielectric and of a reference condenser. Tests have shown that air condensers may have quite significant inherent power factors, the magnitude of which is determined principally by the kind of metal surfaces, the nature of the surfaces, the air pressure or degree of evacuation and the voltage gradient. A method has been developed which will permit the evaluation of the inherent power factors of air condensers from a series of test measurements. A bridge has been developed which will permit power-factor measurements, with an accuracy expressed in power factor of 10^{-6} , to be made on small oil samples. This bridge is a modified Schering type having a single shield circuit and with capacitance balancing between bridge and shield circuits so as to minimize the effect of a shield unbalance on the measured bridge values. The measured bridge

power factors may be expressed in terms of differences in absolute capacitances of the measuring capacitances.

7. Experiments Relating to the Study of the Electrical Resistivity of the Earth's Crust at Depth. L. B. SLICHTER, *Massachusetts Institute of Technology*.—It is known that knowledge of the surface potentials induced in a horizontally uniform flat earth by a direct-current flow from a point electrode uniquely determines the unknown variation of the electrical resistivity with depth. The present experiments were undertaken to obtain experience in the technique of mapping electrical potentials on a large scale on the surface of the earth. An earth current flow was established between a grounded electrode at Clinton, Massachusetts and a second electrode, about 50 km away, near Boston. A six kilowatt commutated d.c. source, and power line facilities kindly provided by the New England Power Association and the Edison Electric Illuminating Company of Boston were used. The ground potentials produced by this flow were systematically measured in an area about 80 km in diameter centering at Clinton, with the furthest point 140 km away, at Pittsfield, Massachusetts. The New England Telephone and Telegraph Company generously provided the circuit facilities for measuring these potentials. The resulting potential map is shown, and the experimental problem discussed.

8. Attempts to Produce Relief Patterns by the Direct Electrographic Effect. ELIZABETH WILCOX AND P. H. CARR, *Iowa State College, Ames, Iowa*.—The fact that the surface of many metals which has been exposed to cathode rays is rendered less active chemically toward corrosive vapors is termed the direct electrographic effect. Attempts to take advantage of this effect to produce a pattern in relief have been only partially successful. In these experiments a portion of the metal surface is protected by means of a stencil during the exposure in air to 100 kilovolt cathode rays. An attempt is then made to develop the image of the stencil on the metal by use of a suitable reagent and directly or indirectly build the image in relief. Results confirm previous reports that water vapor is helpful if not essential to satisfactory development. On silver, copper, tin, zinc, lead, brass and bismuth the inorganic materials investigated prove better developers than organic materials. The image was not rendered in relief by electroplating directly after exposure on any material except carbon. Attempts to produce the relief by first developing in the ordinary way and then electroplating failed except when anthraquinone was the developer. Cadmium vapor as a developer produces images of low relief directly.

9. The Effect of Low Speed Electrons on Silver and Bismuth. J. B. PHILIPSON AND P. H. CARR, *Iowa State College, Ames, Iowa*.—Silver and bismuth films sputtered on glass in a residual atmosphere of air have been exposed to beams of electrons having speeds of less than 100 equivalent volts. This produces a latent impression or image on the film which can be developed in vapors as described in R.S.I. 1, 711 (1930). Results show that bismuth films developed in the air of the laboratory

become very insensitive to electrons with speeds less than 25 equivalent volts, and records below this speed were not obtained. Silver films show a decrease in sensitivity with a decrease in speed of the electrons, but records have been obtained at speeds of 7 equivalent volts when iodine vapor was used as the developing agent. Records on silver films may be satisfactorily developed in a liquid developer consisting of iodine dissolved in ethyl alcohol. Experiments performed to discover the nature of the effect indicate that in the case of silver the action of the electrons is to render the metal less active chemically.

10. A Convenient Proton Source. E. S. LAMAR AND OVERTON LUHR, *Massachusetts Institute of Technology*.—In this investigation directed toward the development of a convenient proton source, a low voltage arc was employed of the type described by Langmuir and Jones (Phys. Rev. **31**, 357 (1928)). The arc was maintained in hydrogen at pressures ranging from 0.1 to 0.5 mm of Hg, between an axial filament and two anode end plates. Ions were drawn out through a slit in the side of a coaxial metal cylinder which was maintained negative with respect to the anode. The relative numbers of the different types of these ions were studied as a function of the negative voltage on the cylinder by means of a mass spectrograph. The proton percentage increased with increasing negative voltages reaching, at 100 volts, between 80 and 90 percent. The above proportions were unchanged when helium was mixed with the gas and no helium ions were observed. The arc current was always one ampere and the arc drop about 25 volts. Under these conditions the total ion current to the cylinder was 150 milliamperes or 3 milliamperes per square centimeter. It is believed that the hydrogen is dissociated by the neutralized positive ions which rebound from the surface of the cylinder with a large fraction of their initial kinetic energy.

11. Acceleration of Ions. J. W. BEAMS AND L. B. SNODDY, *University of Virginia*.—The method of accelerating electrons (Phys. Rev. **44**, 784 (1933)) has been applied to the acceleration of protons. Essentially the method consists in making the electric field move, in effect, with approximately the same speed as the ion. Hence, the ion acquires a final velocity corresponding to a voltage many times that originally applied. The accelerating field was applied, by means of an artificial transmission line, in succession between pairs of a series of short cylindrical electrodes mounted 10 cm apart in an evacuated glass tube. The velocity of the ions was measured by their deflection in a magnetic field. In a nine electrode tube the increase in velocity of the protons corresponded to six times the maximum applied potential of 15,000 volts. The ion "blast" may be accurately timed with the expansion of a Wilson cloud chamber. The method should also serve as an ion selector. It is believed that with a new tube now under construction ion velocities corresponding to several million volts can be obtained.

12. Negative Ion Formation by Electron Attachment. NORRIS E. BRADBURY (*National Research Fellow*), *Massa-*

chusetts Institute of Technology.—The formation of negative ions by electron attachment to neutral gas molecules has been studied by a direct method. This method permits the analysis of a mixed current stream of ions and electrons in such a manner that the rate of decrease of free electrons passing through the gas may be directly measured. A modification of the apparatus permits a simultaneous determination of the electronic mobility. The fraction of electronic impacts resulting in capture or the capture cross section may then be calculated as a function of the electronic energy. Measurements in hydrogen, nitrogen and carbon monoxide show these gases to have no electron affinity. Oxygen has a capture cross section which varies widely with electronic energy, the first excited state at 1.62 volts playing an important part. Ammonia shows no electron attachment below electronic energies of approximately three volts, but forms negative ions rapidly at higher electronic energies. The measurements are being continued for other gases, particularly nitric oxide.

13. An Investigation of an Alternating-Current Method of Determining Critical Potentials. R. W. HICKMAN, *Harvard University*.—An investigation of an alternating-current bridge method of measuring critical potentials in a vapor has been made. A tube containing mercury vapor and of similar structure to that used in the classical experiments of Franck and Hertz was used. It was placed in one arm of an impedance bridge and so arranged that a small alternating voltage in series with a small direct retarding voltage existed between the accelerating grid and collecting plate. Measurements of the equivalent variational plate resistance and reactance were made as the steady accelerating voltage was varied, the accelerating grid and the cathode being at the same alternating potential. Plots of the variational resistance or reactance, or the bridge balancing resistance or capacitance as a function of the accelerating voltage showed the typical irregularities usually found in the current-voltage plots to be enhanced. The positions of the irregularities were found to be dependent on the amplitude of the applied alternating voltage and independent of the frequency within the range investigated. Results indicated that the resolving power of the method varies inversely with the amplitude of applied alternating voltage. The effect of vapor pressure on the position and evolution of the irregularities were also studied.

14. Scattering of Molecular Rays in Gases. R. M. ZABEL (*National Research Fellow*), *Massachusetts Institute of Technology*.—The scattering of beams of hydrogen molecules and helium atoms in mercury vapor has been investigated in the region from 5° to 70° as measured from the original beam. The maximum found in the scattering curve of helium in mercury by Knauer (Zeits. f. Physik **80**, 80 (1933)) was not observed in spite of the higher intensity in the scattered beam. The results obtained for helium are satisfactorily explained on the basis of the quantum theory of scattering of rigid spheres as developed by Massey and Mohr (Proc. Roy. Soc. **141**, 435 (1933)). A simple approximation to this theory which predicts

large scattering at small angles and classical scattering at large angles (see Fig. 2 of their article) is sufficient to predict the results obtained. The scattering of hydrogen molecules shows some deviation from the results predicted by the same theory. In the case of both hydrogen and helium it is necessary to assume collision radii several times larger than the corresponding kinetic theory values in order to obtain the best agreement between the calculated and observed curves.

15. Electron Scattering in Mercury Vapor. A. P. GAGGE, *Yale University*.—The magnetic deflection method has been applied to the study of electron scattering in mercury vapor. In the large angle range (150° – 180°) for electrons of energy between 4 and 100 volts the elastic scattering curves reveal a new maximum which in each case studied precedes a minimum at 180° . As the electron energy is increased, this wide angle maximum moves toward the 180° region. At about 25 volts this maximum approaches the nearest to 180° and the backward scattering for 180° is the greatest for this voltage also. Below 25 volts the inelastic scattering curves for 6.7 volt loss have a maximum at about 90° , which increases in magnitude as the electron energy is decreased. Above 25 volts these inelastic curves develop with increasing energy into their corresponding elastic shapes as has been shown earlier by Mohr and Nicoll (Proc. Roy. Soc. A138, 229–244 (1931)).

16. Distintegration of Sputtered Deposits. E. A. JOHNSON* AND LOUIS HARRIS,** *Massachusetts Institute of Technology*.—If a slit or edge is interposed between a receiver and cathode, the sputtered deposit shows an anomalous pattern. The patterns are shown to be due to a disintegration of the sputtered deposit by electrons and by neutralized positive ions of the sputtering gas reflected from the cathode. The sputtered particles are scattered by the gas while the neutral gas atoms leave the cathode normally and are not scattered.

17. Evaporation Technique for Highly Refractory Substances. H. M. O'BRYAN, *Massachusetts Institute of Technology*.—Platinum, boron, quartz and other substances which cannot be readily evaporated by thermal contact with a hot filament have been evaporated by electron bombardment of a crucible. Substances which cannot be obtained in wire form or which alloy with a hot filament can be evaporated from a tantalum or graphite crucible. A tungsten filament, usually at less than 2000°C , surrounding the crucible supplies electrons at 4000 volts. Molybdenum has been evaporated at about 2600°C from a graphite crucible. Radiation losses necessitate a crucible of small dimensions. A disadvantage of this arrangement is that a pressure of 10^{-5} mm is required while the common method needs only a "black" vacuum of about 10^{-3} mm. Shields of sheet metal diminish radiation losses and prevent

deposition on the glass vacuum container. This method has been used in the preparation of surfaces for excitation potentials (Skinner, Proc. Roy. Soc. A140, 277 (1933)) and recently for x-ray targets and small mirrors.

18. Precise Measurements of Dispersion in Nitrogen. CLARENCE E. BENNETT, *Massachusetts Institute of Technology*.—A new and much improved displacement interferometer has been built after the general plan of the one previously described (Phys. Rev. 37, 263 (1931)), to measure simultaneously refractive index and dispersion constants for a gas over a range of pressures above atmospheric. It is constructed as a single unit on a steel I-beam framework 10 feet long and 2 feet wide. The whole apparatus is supported on automobile inner tubes which very effectively eliminate vibration. The features include a G.E. S-1 sunlamp light-source, aluminum mirrors, a carefully calibrated micrometer screw of high quality, and an improved temperature control. Observations made on nitrogen at four wave-lengths, 5780A, 5461A, 4359A, and 4047A, corresponding to pressure runs up to 14 atmospheres measured by a Keyes dead-weight gauge, at temperatures of 50°C , 30°C , and 0°C , give readings that are linear with pressure to such a degree that the Cauchy dispersion constants can be expressed to four significant figures. The results for N.T.P. conditions are: $A_0 - 1 = 0.0002932$, and $B_0 = 1.637 \times 10^{-14}$. Since $A_0 - 1$ is the extrapolated infinite wave-length refractive index, a dielectric constant $\epsilon = 1.0005864$ is thus predicted. This agrees with published determinations. The refractive index at any wave-length can be computed from these results, and values so calculated are found to agree with values found by other methods which are not suitable for direct extrapolation to infinite wave-length, and which are not likely to be so accurate.

19. Preliminary Results on the Analysis of the Arc Spectrum of Osmium. WALTER ALBERTSON, *Massachusetts Institute of Technology*.—1050 arc lines of osmium are found to result from combinations between 136 terms. The list includes most of the strong lines and nearly all the underwater spark lines. (Meggers and Laporte, Phys. Rev., Oct. 1926.) The classification was aided greatly by the mechanical interval recorder. (G. R. Harrison, R.S.I., Dec. 1932 and Nov. 1933.) The normal state of the osmium atom is $s^2d^6\ ^5D_4$; $\ ^5F_5$, the lowest term of the sd^7 configuration, is at $5144\ \text{cm}^{-1}$. Electron configurations and multiplets show such extreme overlapping that, except for a few cases, the configuration and multiplet assignments will be meaningless. The two low multiplets, $s^2d^6\ ^5D$ and $sd^7\ ^5F$, are partially inverted, the order of $J=2, 3$ being interchanged in each case. A feature of the array is the large number of combinations between terms. The selection rules for L and S are so completely broken down that nearly all the combinations allowed by the J selection rule have been found. New wave-length measurements are to be made using a grating having a dispersion of $0.4\ \text{\AA}/\text{mm}$ in the 2nd order.

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20. Arc and Spark Spectra of Cerium. GEORGE R. HARRISON AND WALTER ALBERTSON, *Massachusetts Institute of Technology*.—Application of the mechanical interval sorter (Harrison, R.S.I., Dec. 1932 and Nov. 1933) to King's lists of Ce I and Ce II lines reveals numerous coincidences which interrelate to form quadratic arrays. The profusion of lines makes guarding against accidental coincidences imperative, and trustworthy application of the combination principle requires more accurate wave-lengths than are available. Accordingly, we have photographed the cerium arc between 2000–5000Å with a 35 ft. grating, dispersion 0.4Å/mm, and are extending these measurements into the infrared. The accuracy of our wave-lengths appears limited only by the accuracy of the tertiary iron standards, results being consistent to 0.002Å, which renders highly probable the meaningfulness of quadratic arrays obtained with them. Theory indicates that the strongest Ce I lines lie in the infrared, explaining previous failures to get absorption lines in the underwater spark. The recent partial analysis of Ce I by Karlson (*Zeits. f. Physik* 85, 482 (1933)) shows internal deviations, which, considering the number of lines from which he made selections in forming an array, throws doubt on a number of his terms.

21. The Spectrum of Mo V. M. W. TRAWICK, *Cornell University*.—The vacuum spark spectrum of molybdenum has been photographed in the region below 2500Å. The transitions $4d5p^3(F^oD^oP^o)$ into $4d^2\ ^3(FP)$ and $4d5s\ ^3D$ in Mo V have been assigned to lines identified in part by extension of the Sr I-like isoelectronic sequence. Some of the transitions involving terms arising from the $4d5d$, $4d4f$, and $4d6s$ configurations have also been determined. This work has been facilitated by the use of unpublished data kindly supplied by Professor R. J. Lang on the spectrum of Cb IV.

22. Wave-Length Standards in the Extreme Ultraviolet. J. C. BOYCE, *Massachusetts Institute of Technology*.—With the two-meter focus normal incidence vacuum spectrograph previously described (Compton and Boyce, *Phys. Rev.* 40, 1038 (1932)), the spectra from electrodeless discharges in neon, argon, krypton, and xenon have been photographed. In the course of the measurement of the neon plates, which extend from about $\lambda 200$ to $\lambda 2530$, a number of impurity lines of carbon, nitrogen, and oxygen were measured in their higher orders against the first order of the iron arc lines in the region $\lambda 2250$ to $\lambda 2530$. These lines are among those previously established as standards by Bowen and Ingram (*Phys. Rev.* 28, 444 (1926); 29, 231 (1927)) and more recently remeasured by Edlen (*Zeits. f. Physik* 85, 85 (1933)). Present results from several exposures on each of two different plates show excellent agreement with the measurements of Edlen below $\lambda 800$ but definitely depart by small amounts from the results of the previous investigators for N I $\lambda 1134$ and $\lambda 1200$ and C III $\lambda 1175$. Suggested revised values for these wave-lengths will be published when more plates have been measured. Meanwhile for standards in this region it is suggested that use be made of second orders of Edlen's at

shorter wave-lengths and also of Paschen's calculated values for the Lyman series of hydrogen (*Preuss. Akad. Wiss. Berlin, Ber.* 1929, p. 662).

23. The Absorption Spectrum of the Iodine Atom. J. H. MCLEOD, *Harvard University*.—The absorption spectrum of atomic iodine has been investigated in the spectral range $\lambda 2100\text{Å}$ to $\lambda 1350\text{Å}$. The iodine was dissociated by heating to 1000°C. Light from a hydrogen discharge tube was passed through the heated iodine and recorded on the photographic plate of a vacuum grating spectrograph. Two spectral lines 1830Å and 1783Å were recorded as absorption lines. For the investigation of the spectral region below $\lambda 1650\text{Å}$ the hydrogen discharge tube was replaced by a discharge tube containing iodine. When the light from the discharge in iodine was passed through the heated iodine the following lines were found to be weakened by absorption: 1830, 1783, 1642, 1618, 1583 and 1515Å. In addition there was some indication that the lines 1507, 1459, 1453 and 1383Å were somewhat absorbed by the iodine atoms.

24. Hyperfine Structure of Fluorine. F. W. BROWN, *University of Illinois*. (Introduced by J. H. Bartlett, Jr.)—The theory of Breit and Doermann (*Phys. Rev.* 36, 1732 (1930)) has been extended and applied to the case of fluorine. The wave functions for the $2p^4\ 3s$ and $2p^4\ 3p$ configurations were found by the self-consistent field method. Assuming Russell-Saunders coupling, and with the experimental results of Campbell (*Zeits. f. Physik* 84, 393 (1933)), the magnetic moment of the fluorine nucleus has been calculated. Fairly consistent results are obtained, and the value of the nuclear magnetic moment is found to be about 3 nuclear magnetons.

25. A Modification of Levi-Civita's Wave Equation. BANESH HOFFMANN, *University of Rochester*.—Levi-Civita has recently proposed a modification of Schrödinger's relativistic wave equation in which the ψ -function is replaced by a four-vector ψ^α , and electron spin is introduced by the arbitrary inclusion of "coupling" terms of the form $C\epsilon^{abcd}g_{ae}F_{cd}\psi_b$, where F is the electromagnetic six-vector and C is a constant. The value of C is chosen as $(\pi e/\hbar)$ in order to give the correct magnitude for the spin. The author has considered ψ^α as being a degenerate projective vector having $\psi_0=0$; the simplest projective vector wave equation involving only four equations is

$$\gamma^{\alpha\beta}\psi_\gamma; \alpha\beta = \varphi_\gamma(\gamma^{\alpha\beta}\psi_\epsilon; \alpha\beta)\epsilon=0,$$

with the notation of the projective relativity theory. This equation automatically contains coupling terms equivalent to those introduced by Levi-Civita, and these terms automatically have the correct coefficients. A further set of terms contained in it is negligible unless $r\sim 10^{-12}$ cm or less. Apart from the advantages enumerated, the wave equation suffers from the same disadvantages as does that due to Levi-Civita.

26. Introduction to the Theory of the Positron.* G. E. UHLENBECK, *University of Michigan*.—First the considerations of Dirac will be shortly reviewed which led necessarily and almost uniquely to his relativistic wave equation for the electron. The great success of this theory is well known; it has explained the spin of the electron and from it follow the Sommerfeld fine structure formula and the Klein-Nishina formula for the scattering of free electrons which are both experimentally so well confirmed. But with the formalism of the theory were intimately related the difficulties connected with the states of negative kinetic energy. Transitions to these states are namely possible (most simply seen in an example given by Klein), in contrast with experience. Dirac has tried to overcome these difficulties by assuming that almost all negative states were “filled” in the sense of the Pauli principle. An unoccupied negative state or “hole” will behave like a particle of positive charge and positive mass which is, as one could show, the same as that of the electron. It could be destroyed by combination with an ordinary electron, whereby the energy connected with the masses ($=2mc^2=10^6$ volt) would be transformed into radiation. These ideas have now been beautifully supported by the discovery of the positron. And although this way of interpreting the Dirac equations is difficult to accept quite literally, it can be used already as Oppenheimer and Plesset have shown, to derive quantitative results for the probability of formation of an electron-positron pair by absorption of hard γ -rays near a heavy nucleus. In the same way one can calculate the probability of destruction of a positron by combination with an electron. Thus one can understand certain puzzling features in the absorption and scattering of γ -rays. One may hope therefore that further experimental and theoretical work will show the essential consistency of the Dirac theory with the experimental facts.

27. The Positron.* CARL D. ANDERSON, *California Institute of Technology*.—Positrons were first reported in September, 1932, to be present among the secondary particles of the cosmic radiation. During the present year the generation of them by hard gamma-rays, and by bombardment of various light elements by alpha-particles

has been reported. The various researches which have been carried out in this country and abroad on their production and properties will be discussed, including new experiments on both the cosmic-ray and Th C'' gamma-ray effects.

28. The Theory of the Electron and Positive.* J. R. OPPENHEIMER, *University of California, Berkeley, Calif.*—The most recent theoretical results on the production of positives by a beam of gamma-rays, by internal conversion of gamma-rays, and by electron impact are compared with experiment. In general the theory agrees well with observation for radioactive gamma-rays and those produced in nuclear disintegration, but fails entirely for gamma-rays of very high energy, and gives no understanding of the primary processes in cosmic-ray absorption. It also fails to explain the positives observed in disintegrating aluminum. The limitations of the theory which are indicated by these failures are formulated, and it is shown that within these limits it is possible to give a complete and consistent formalism for describing the state of a system containing electrons and positives, and computing the energy levels and transition probabilities of the system. Where the original Dirac theory gave results in agreement with experiment, the present formalism gives the same results; and the probabilities of pair production agree within wide limits with observation. The physical interpretation of the formalism is discussed, with particular reference to the question of the localizability of the electron, and it is shown that no complete spatiotemporal description of the system in terms of particles is possible. The effect of the pairs upon the electromagnetic field of particles is discussed, and it is shown in particular that the pairs contribute to the forces between two point charges. For large distances of separation between the particles the field is Coulomb; the difference between the “effective” charge which gives these forces and the “true” charge on the particles cannot be unambiguously computed, and is in our opinion not observable; but for smaller distances of approach of the particles, deviations from the Coulomb law of force appear, which are of the order of 1 percent for distances of the order of the Compton wave-length. These may be computed, and should ultimately be observable.

29. Industrial Physics.* PAUL D. FOOTE, *Gulf Research Laboratory*, Address of the President of The American Physical Society.

30. Current Progress in X-Ray Physics.* D. L. WEBSTER, *Stanford University*, Address of the Retiring Vice-President of Section B—A.A.A.S.

31. Hydrogen in Palladium.* JAMES FRANCK, *formerly of the University of Göttingen*.

32. Vibrational Analysis of the Green BaCl Bands. ALLAN E. PARKER, *Yale University and Columbia University*.—A study has been made of the green bands of BaCl by using as source an arc in a hydrogen atmosphere between a nickel anode and a copper cup containing BaCl₂. The vibrational analysis shows the existence of the

$\Delta v=0, \pm 1$ sequences, extending from $\lambda 5056$ to $\lambda 5322$. The bands are attributed, as are the green BaF bands, to a ${}^2\Pi-{}^2\Sigma$ transition, the four head-forming branches being the Q_1, R_1, Q_2 and R_2 branches. The major portion of the bands observed arise from the molecule Ba¹³⁸Cl³⁵ and the remainder can be ascribed to Ba¹³⁸Cl³⁷. The Q_1 and Q_2

* Invited paper.

heads are given by the following expressions:

$$\begin{aligned} \nu_h &= 19,062.9 + [280.2(\nu' + \frac{1}{2}) - 0.79(\nu' + \frac{1}{2})^2] \\ &\quad - [278.4(\nu'' + \frac{1}{2}) - 0.80(\nu'' + \frac{1}{2})^2], \\ \nu_h &= 19,450.1 + [285.0(\nu' + \frac{1}{2}) - 0.79(\nu' + \frac{1}{2})^2] \\ &\quad - [280.5(\nu'' + \frac{1}{2}) - 0.80(\nu'' + \frac{1}{2})^2]. \end{aligned}$$

The bands at low values of ν have sharp heads and degrade to the red. At high ν values they become somewhat diffuse due to B' becoming very approximately equal to B'' .

33. On Abnormal Rotational Temperature of Band Spectra. O. OLDENBERG, *Harvard University*.—(1) The abnormal intensity distribution of rotational quanta ("rotational temperature" of excited molecules much higher than the real temperature) has been interpreted in previous papers. It was pointed out that polyatomic molecules dissociating by excess vibration of certain modes might produce fragments with abnormal rotation, the energy of which is determined by the relation between potential curves and not by the temperature. This hypothetical statement is confirmed by the intensity distribution of the OH band in the discharge through water vapor. Absorption spectra of OH, taken in connection with another investigation, revealed a contrast with the emission spectra. In emission, lines of high rotation appear, although according to the temperature molecules with the corresponding energy ought to be present only with a relative concentration of 10^{-23} . For the discharge through water vapor it is known by independent arguments that the excited OH molecules are largely produced by the dissociation of excited water molecules. (2) The effect of foreign gases reducing the abnormal rotation by collisions is being studied. Helium shows a pronounced effect of this kind.

34. Pressure Coefficients of Acoustic Velocity for Nine Organic Liquids. J. CHESTER SWANSON, *Duke University*, with J. C. HUBBARD, *The Johns Hopkins University*.—From thermodynamic considerations it seemed desirable to study the change in velocity of a compressional wave in liquids at different pressures. For this purpose a supersonic interferometer was designed by Swanson (R.S.I. 4, 603 (1933)) the essential feature of which was the controlled movement of a reflector within a chamber containing the liquid under pressure, without introducing a change of pressure by the movement. Pressures up to about 300 kg/cm² were used and a quartz crystal was driven at about 200 kc by a Hartley oscillator as the source of the high frequency waves. The liquids examined show an increase of velocity with increasing pressure of the order predicted by thermodynamic theory. The liquids studied were: ethyl bromide, carbon tetrachloride, chloroform, carbon disulphide, benzene, toluene, aniline, ethyl ether and pentane. The temperature was that of the room which never varied over two degrees from 23°C for the whole series of readings and generally much less than one degree for any run of one liquid. The average variation in velocity (M/sec.) per 100 kg/cm² over the pressure range of 300 kg/cm² for each liquid is given below:

| | | |
|---|--|--|
| C ₂ H ₅ Br, 38.3; | CCl ₄ , 45.3; | CHCl ₃ , 33.0; |
| CS ₂ , 44.0; | C ₆ H ₆ , 42.0; | C ₇ H ₈ , 44.7; |
| C ₆ H ₅ NH ₂ , 35.0; | C ₂ H ₅ OC ₂ H ₅ , 87.3; | C ₅ H ₁₂ , 92.0. |

35. The Magnetostrictive Oscillation of Chladni Plates. R. C. COLWELL AND E. A. BRYANT, *West Virginia University*.—A rod of nickel placed in the grid coil of a vacuum tube circuit will be set in vibration at radiofrequencies. A Chladni plate balanced at the center on top of the nickel rod will also be set in vibration by mechanical impact. The radio vibrations measured upon a wave meter were 14,000 per second; the calculated vibrations of the plate were 3500, 2800, etc. At these very high frequencies many new sand patterns may be formed upon square or circular plates. A few of these will be shown.

36. A Magnetostrictive Phonograph Reproducer with Demonstrations. S. A. BUCKINGHAM, *Harvard University*. (Introduced by G. W. Pierce).—A phonograph reproducer has been constructed employing the principle of magnetostriction. The magnetostrictive element is a bimetallic strip of nickel and phosphorbronze. It is found that the length of the strip must be such that the lowest natural mode of transverse vibration is well above the highest frequency to be reproduced. When this condition is observed the fidelity of the reproducer compares favorably with that of the conventional magnetic type. In the present state of development, the output of the reproducer is approximately 30 decibels below that of the conventional reproducer and the stiffness exceeds that of the magnetic type. A working model of the instrument will be demonstrated.

37. Maintenance of the Earth's Electrical Charge by Electrical Rectification in the Earth's Lower Atmosphere. ROSS GUNN, *Naval Research Laboratory, Washington, D. C.*—The relation of the current density to the impressed electric field intensity is worked out for the earth's atmosphere, taking account of space charge. It is shown that the departures from Ohm's law are such that electricity is transferred outward from the earth with greater ease than inward. Thus the large random alternating electric fields of the type observed during storms will result in a net upward transfer of electricity which may leak off over a large area and contribute to, or account for the entire normal or fair weather electric field. The fair weather field is downward and hence, with given field intensities, the electrical discharge of the earth is more difficult than is the process of replenishment. The fundamental action of the atmosphere as an electrical rectifier is emphasized and it is noted that as a result of this property only *radially inward* atmospheric electric fields can be stable.

38. Progress Report on Kennelly-Heaviside Layer Measurements. HARRY R. MIMNO AND PAO H. WANG, *Harvard University*.—Automatic devices, which make continuous daily records of the equivalent heights of the Kennelly-Heaviside layers, have been described in a number of previous reports from this laboratory and from

other laboratories (Phys. Rev. **41**, 395 (1932); I.R.E. **21**, 529 (1933)). The present paper summarizes some of the results obtained during more than 6000 hours of operation in 1933. During a large portion of this period we recorded two frequencies simultaneously. We have plotted curves which indicate the degree of correlation between magnetic disturbances and layer heights at Cambridge. We have also examined the effect of magnetic disturbances in determining the hour at which penetration occurs. From the recorder measurements, it is possible to make quantitative estimates of the normal rates of ionization and recombination. Abnormal early-morning *E* layers, previously reported, were again noted on many occasions. Other observers have suggested that these may result from magnetic disturbances, or from local storm conditions. The examination of more than 20 cases does not yet provide experimental support for either view. A third recorder has been constructed. In the newest design, a revolving drum carries a roll of sensitized paper across the beam produced by a stationary glow lamp. The paper strip unrolls automatically as the drum rotates. Simultaneous recorder measurements have been made at different geographic points.

39. The Interpretation of X-Ray Diffraction Curves of a Fluid from a Gaseous to a Liquid State. N. S. GINGRICH AND B. E. WARREN, *Massachusetts Institute of Technology*.—An attempt has been made to find an expression for the intensity of scattering of x-rays in a monatomic fluid as a function of density, sufficiently general to hold continuously from the liquid to the rarefied gas. It is found that a very simple approximate model leads to scattering curves in good qualitative agreement with experiment. It is assumed that, surrounding any one molecule in the liquid, there is a continuous distribution of molecules beyond a distance *b*, roughly the intermolecular distance, and a concentration of molecules at a slightly smaller distance *a*. It is further assumed that in passing to the gaseous state, the relative density distribution remains the same, while the actual density decreases. The intensity of scattering from this model is calculated by the method of Zernicke and Prins, and a set of scattering curves obtained for several densities of fluid. In the limiting case of small density, the curves are typical of those for gas scattering, and for maximum density, typical of liquid scattering, with continuous transition between. Although the model used is only a rough approximation for ether, there is still a good qualitative agreement between the set of curves obtained, and the experimental curves of G. W. Stewart for ether at various specific volumes.

40. The Atomic Arrangement in Vitreous SiO₂ and GeO₂. B. E. WARREN, *Massachusetts Institute of Technology*.—X-ray scattering curves for vitreous SiO₂ and GeO₂ have been made with considerably improved experimental conditions. The radiation Cu *K*α is monochromatized by reflection from a NaCl crystal, and passed through a thin sample of the glass in a cylindrical camera. The camera is evacuated to eliminate air scattering. By these precautions the troublesome background is largely

eliminated. SiO₂ shows a single strong peak at $(\sin \theta)/\lambda = 0.118$ and GeO₂ a strong peak at $(\sin \theta)/\lambda = 0.118$ and a weaker peak at 0.194. The atomic arrangement in the two glasses is the same; each cation is tetrahedrally surrounded by 4 oxygens and each oxygen is shared between two tetrahedral groups. The orientation about the direction of bonding is random, and the resulting network non-repeating. It is this feature which distinguishes the glass state from the crystalline state. Scattering curves for SiO₂ and GeO₂ calculated for such an atomic arrangement are in very good agreement with the experimental curves. Within the experimental error the interatomic distances in the glass are found to be the same as in the crystalline modifications.

41. Rotation of the Plane of Polarization of Beam of X-Rays. RONALD LYMAN MCFARLAN, *Harvard University*.—The question, as to whether or not the plane of polarization of a plane polarized beam of x-rays is rotated on passing through a quartz crystal in a direction parallel to the optic axis, is investigated experimentally. Quartz crystals 0.75 mm thick are observed to rotate the plane of polarization through an angle of about 2° 30'. The investigation of thicker crystals indicates that the angle of rotation is not proportional to the thickness of the crystal. This is ascribed to the effects of double scattering and to the linear absorption of the beam. Arguments are advanced to show that the rotation is almost entirely due to the x-rays scattered according to the Bragg law in the crystal.

42. The Measurement of Absolute X-Ray Intensities and Absolute Sensitivity of X-Ray Film with a Geiger-Mueller Counter. GORDON L. LOCHER, *National Research Fellow, Bartol Research Foundation of the Franklin Institute*, and DONALD P. LEGALLEY, *The Pennsylvania State College*.—A special G-M counter of small dimensions has been constructed for measuring absolute intensities of x-rays of known wave-lengths. The rays pass through the counter in such a way that only electrons set free in the *gas* are counted. The absorbing gas column is krypton at 6 cm pressure, 1 cm thick, and 0.0062 cm² in cross section. For fluorescent ZrK x-rays, the absorption is 3.84 percent of the beam, as calculated for an energy distribution of the Zr radiation $K\alpha_1 : K\alpha_2 : K\beta = 0.562 : 0.281 : 0.157$, by using absorption coefficients as computed from Richtmyer and Warburton's formula. A "standard beam" of fluorescent Zr rays from a special x-ray tube has been calibrated with the counter; its intensity is 1.66×10^4 quanta cm⁻² sec.⁻¹, 57.3 cm from the fluorescer, of which 0.75 cm² area is exposed. With this beam, the minimum exposure of x-ray film for detectable blackening is found to be 0.75×10^6 quanta cm⁻², incident on the film; or 6.35×10^4 quanta cm⁻², absorbed in the emulsion of the film (Eastman Ultra-Speed Duplitized X-Ray Film). The mass absorption coefficients of the film, celluloid, and emulsion, for the Zr rays are found, respectively, to be 8.81 cm⁻¹, 1.88 cm⁻¹ and 18.4 cm⁻¹. A time-blackening densitometer curve has been obtained for the same film and radiation, for exposures between 2.5 min. and 60 min.; after 10 minutes (10^7 quanta cm⁻²), the blackening (*B*) and the time (*t*) are

related by the equation: $\log B = 0.54 \log t + \log 3.5$. The average number of quanta required to blacken a grain is found by means of photomicrographs of the blackening of a spot exposed for 15 minutes (1.5×10^7 quanta cm^{-2}).

43. Soft X-Rays and Energy States of the Conduction Electron. H. W. B. SKINNER AND H. M. O'BRYAN, *Massachusetts Institute of Technology*.—The emission spectra of a number of the light metallic elements have been photographed in the region from 40Å to 600Å. The target surfaces were prepared by distillation of the metal in vacuo and the results are believed to be characteristic of the pure polycrystalline solid. The widths of the lines observed are due to the initial state of the transition and agree with those computed from the Sommerfeld electron gas theory. The shape of the beryllium line agrees in general with the transition probabilities computed by Houston. All elements having two or more conducting electrons per atom show departures from the simplest electron gas theory. Beryllium, magnesium and aluminum indicate that certain velocities of the conduction electron are forbidden within the lattice. The de Broglie wave-lengths associated with these forbidden velocities are given by Bragg's law. Silicon shows a distinctly different type of distribution for the energy levels, resembling more what is expected with bound electrons. Ordinary x-ray selection rules do not hold for these transitions. A dirty beryllium target gave a spectrum consisting of the *K* line superimposed on a background of continuous radiation.

44. Electron Diffraction and the Imperfection of Crystal Surfaces. L. H. GERMER, *Bell Telephone Laboratories, Inc., New York*.—Bragg reflections are obtained by scattering fast electrons (0.05Å) from etched surfaces of metallic single crystals. The surfaces studied are an iron (100) face, a nickel (111) face and a tungsten (110) face. Each reflection occurs accurately at the calculated position, with no displacement due to refraction. A reflection occurs, however, even when the glancing angle of the primary beam differs considerably from the Bragg value—by over 1° in some cases. The accuracy with which a glancing angle must be adjusted is a measure of the degree of perfection of a crystal surface. Estimates are made of widths at half maximum of electron rocking curves. These estimates are 0.8° for the iron crystal, 1.5° for the nickel crystal and somewhat over 1° for the tungsten crystal. X-ray rocking curves for these same crystals are much narrower, although the observed widths vary considerably with surface conditions. It is concluded that the values obtained from the electron measurements apply to projecting surface metal only, and that *the degree of misalignment is much greater at the surfaces than within the crystals*. Furthermore, even the x-rays [Mo *K* α radiation—0.71Å] are not sufficiently penetrating to yield values characteristic of these crystals.

45. Electron Diffraction by the Oxides of Nitrogen. LOUIS R. MAXWELL, V. M. MOSLEY AND LOLA S. DEMING, *Bureau of Chemistry and Soils*.—Electron diffraction has been obtained by the transmission of electrons (20–35 kv) through molecular beams of N_2O , NO_2 , and N_2O_4 . The

molecular structures were obtained in the usual manner by utilizing the Debye interference theory for single molecules with the proper atomic scattering amplitudes, together with the inclusion of the incoherent electron scattering as formulated by Morse (Phys. Zeits. **33**, 443 (1932)) and Bewilogua (Phys. Zeits. **33**, 688 (1932)). The results can be summarized as follows: (1) Nitrous oxide; for a linear model the separation of the end atoms was found to be $2.38 \pm 0.05\text{Å}$ in exact agreement with Wierl's measurements on this structure (Ann. d. Physik **8**, 521 (1931)). Unfortunately it is impracticable to distinguish between models of the form N-O-N and N-N-O. (2) Nitrogen dioxide and nitrogen tetroxide; photographs obtained from a mixture of N_2O_4 and NO_2 showed only one diffraction ring at $(\sin \theta/2)/\lambda = 0.455 \pm 0.01$ which disappeared when the gas was completely decomposed to NO_2 . These results are compatible with a triangular NO_2 structure as definitely distinguishable from a linear model and with a $\text{O}_2\text{N-NO}_2$ form with an N-N distance of approximately 1.6Å. This is within the range of the N-N distance considered possible by Hendricks from an analysis of Vegard's x-ray diffraction photographs of solid N_2O_4 (Zeits. f. Physik **70**, 699 (1931)).

46. Group Phenomena in Metal Crystals. A. GOETZ, *California Institute of Technology*.—Discussion of experimental results concerning properties of metal crystals which depend on the magnitude of the crystal. Most properties typical for a solid metal seem to be caused by large but limited groups of molecules. The "critical" size above which a property of a crystal becomes size-independent lies for the metals investigated between 10^7 and 10^9 atoms. Evidence indicating the existence and size of such groups have been obtained by the study of the magnetic properties of microscopic crystals of graphite, Bi and Sb and by the determination of the effects of foreign atoms inserted in small concentrations into macroscopic crystals. The magnitude of the groups derived for different properties but for the same crystal comes out to be the same.—There seems to be a close analogy between these group phenomena and the "swarm" effects observed in anisotropic liquids.

47. The Recrystallization of the Metallic Layers. A. B. C. ANDERSON AND A. GOETZ, *California Institute of Technology*.—Discussion of resistivity measurements of thin layers of Ag deposited on amorphous and crystalline surfaces (calcite) by evaporation in vacuo. The change of conductivity after deposit under controlled conditions is used as a measure of recrystallization. It is found that the tendency of the isolated atoms of forming aggregates is independent of the number of atoms present and that the resistance per layer decreases suddenly when a definite statistical thickness is reached. (300 atoms.) This indicates the formation of crystalline groups of definite size, 10^{-5} to 10^{-4} cm in diameter and are commensurable to the size of the primitive etch figure. The results are in agreement with certain findings of electron spectroscopy about the state of thin layers and support the hypothesis of the formation of large atomic groups in a crystal.

48. Vacuum Tube Characteristics in Relation to the Selection of Coincident Pulses. LEWIS FUSSELL, JR., *Massachusetts Institute of Technology* and THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute*.—The characteristics of various vacuum tubes have been analyzed in relation to their use in the Rossi type of circuit for selecting coincident G. M. counter pulses. The ability of the circuit to discriminate between partial and total coincidences is found to depend upon the ratio of the tube impedance under normal conditions to the impedance when cut off by a pulse and the best discrimination is realized from the superamplifier pentodes such as the '57. In a test circuit containing ten '57 tubes in parallel, according to the Rossi scheme, when pulses of one volt were simultaneously applied to the grids of all tubes the added output pulse was more than one hundred times that resulting from pulses on but nine of the grids. A one stage coincidence selecting circuit with these tubes has most of the advantages of the three stage Johnson-Street circuit. However, the three-stage circuit has the ability, not possessed by a one-stage circuit, of reducing the pulse time below the actual duration of the counter discharge so that the number of "accidentals" may be reduced.

49. Directional Measurements of the Cosmic Radiation and Their Significance. THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute*.—The west-east asymmetry of the cosmic radiation increases from two or three percent at 50° geomagnetic latitude to thirteen percent at the magnetic equator. This effect, as well as the latitude intensity variations found by J. Clay and A. H. Compton, are described by the Lemaitre-Vallarta theory in terms of the action of the earth's magnetic field on an electrically charged corpuscular radiation. Since the latitude effect depends upon the sum of the intensities of the positive and negative radiations whereas the asymmetry depends upon their difference, a comparison of the two effects gives a measure of the relative proportions of the two signs of charge. In the energy range from 5×10^9 to 2×10^{10} volts the corpuscular radiation is principally positive and within the present experimental accuracy it may be entirely positive though a negative component of lower intensity cannot be definitely excluded. The azimuthal asymmetry at the equator establishes the existence of corpuscular rays of higher energy than had been predicted by the latitude effect and the theory shows that the observed asymmetry is consistent with the small magnitude of the intensity variations between the equator and the 20° parallel.

50. A Possible Explanation of the Frequency Distribution of Size of Hoffmann Stösse. C. G. MONTGOMERY, *Bartol Research Foundation of the Franklin Institute*.—The cloud-chamber experiments of Blackett and Occhialini, and Locher lend weight to the idea that Hoffmann Stösse are the result of the cooperation of several atoms in the formation of groups of rays rather than a burst of rays produced by a single atom. If one assumes that every group of rays formed contains entities capable of producing

other groups, then the total number of rays which will be produced in a block of material will depend upon where the first group is produced. This results in a frequency distribution of Stoss sizes which falls off hyperbolically as the size increases and has a sharp lower limit which is the size of the first group produced. Such computed distribution curves are compared with observations of Messerschmidt, and W. F. G. Swann and the author. The upper limit to the average distance between the formation of successive groups of rays is determined to be 0.3 cm in iron and 0.6 cm in lead. The production of secondaries all along the path of a primary does not enable a distribution curve of the observed type to be obtained. The mechanism here suggested contains, of course, a consequence already under experimental investigation by W. F. G. Swann and the writer, that the size of a Stoss depends upon the thickness of the material in which it originates. The theory also predicts that certain "transition" effects are to be expected.

51. Comparison of Absorption Coefficients of Different Elements for Cosmic Rays. J. C. STEARNS AND CARL HEDBERG, *University of Denver*.—The cosmic-ray energy absorbed by 6 inches of aluminum, zinc, copper and lead respectively, was determined by a double coincident Geiger-Müller counter. With the counters in a vertical plane, the number of coincidences during a twenty-four hour period was determined with the respective elements above mentioned between the counters. These tests were alternated with runs of the same type with only air between the counters. The zero of the instrument was determined by placing the counters in a horizontal plane with the same absorbing material above or below each counter as was used in the actual test and determining the number of coincidences as the distance between the counters was increased. From these data the number of accidental coincidences were estimated by extrapolation. The data indicate that the ratio of linear absorption coefficient to density decreases with increase in density. By placing the same absorbing material above and between the counters it was possible to estimate the secondaries or tertiaries produced in and penetrating the absorbing blocks. At 11,000 feet the ratio of the number of coincidences with 6 inch lead above to those with the same lead between was 1.12 while at 8000 feet it was 1.10. This ratio for 4 and 2 inches of lead was 1.20 and 1.36 respectively.

52. Further Geographic Studies of Cosmic Rays. A. H. COMPTON,¹ J. M. BENADE² AND P. G. LEDIG.³—Since our last communication, we have measured the intensity of the cosmic rays, using the standard ionization chamber method previously described, in Singapore, the Chinese coast, Japan, and Chicago, also at various points along both coasts of South America, including the Straits of Magellan. All of the observations confirm the minimum previously

¹ University of Chicago.

² Forman Christian College, Lahore.

³ Carnegie Institution of Washington.

reported by Clay and ourselves near the equator. The data confirm also our earlier conclusion that this latitude effect depends upon the location relative to the magnetic rather than geographic pole. The South American data suggest, however, that a large region whose magnetic field differs from the average for that latitude, has its cosmic-ray intensity appreciably affected by the local magnetic field. Such an effect would mean that the cosmic-ray particles are appreciably bent by the magnetic field within a distance above the earth comparable with the linear dimensions of the area concerned, in this case of the order of 1000 miles. New checks on the data got by Allen Carpe on Mt. McKinley in 1932 show that at high altitudes the latitude effect continues to latitudes considerably higher than at sea-level. This shows the existence of electrically charged cosmic rays which have insufficient energy to penetrate the atmosphere.

53. Secondary Photons in Cosmic-Ray Showers. CARL D. ANDERSON AND SETH H. NEDDERMEYER, *California Institute of Technology*.—Stereoscopic observation of cloud-chamber tracks in a magnetic field of 17,000 gauss (in some cases 800 gauss) has shown the presence in positron-electron showers of *large numbers* of non-ionizing rays. A comparison between low energy positron-electron pairs and small showers produced in plates of lead by these secondary rays, and those produced by Th C'' γ -rays has shown a striking similarity in the effects of the two radiations. It is concluded therefore, that the bulk of the non-ionizing secondary rays in cosmic-ray showers are photons. To test for the presence of the ordinary neutrons, a search was made for projected carbon nuclei and nuclear disintegration products from a plate of graphite, and none were observed. The conclusion is reached that ordinary neutrons are not present in considerable numbers, at least in the energy-range where their presence would be indicated by the usual tests. In several cases a large number of positrons and electrons (in one example more than 80 distinct tracks) with energies of the order of several million electron volts occurred which could not possibly have originated except from a considerable number of separate centers, thus indicating large numbers of secondary photons. Pair production by high speed positrons or electrons does not occur frequently since in only two cases out of more than five hundred where the particles penetrated a plate of lead, were secondary positron-electron pairs observed.

54. Neutron Emission. J. R. DUNNING AND G. B. PEGRAM, *Columbia University*.—The spectrum of the neutrons emitted from a radon-Be source has been analyzed by the ranges of recoil protons. The presence of three groups of alpha particles causes the energy distribution to be more complicated than the RaF-Be disintegration studied by Chadwick (Proc. Roy. Soc. **A142**, 1). There are a large number of neutrons in the group having a maximum energy of about 4.8×10^6 e.v., and smaller groups of about 6.5×10^6 and 8.0×10^6 are also prominent, while low energy groups of the order of 0.5 to 1.5×10^6 e.v. appear to be present. A small number of neutrons have

energies ending at around 12.5×10^6 e.v. and there appear to be a few neutrons having energies up to approximately 14.2×10^6 e.v. Assuming the reaction: $\text{Be}^9 + \text{He}^4 \rightarrow \text{C}^{12} + n$, this energy indicates a neutron mass of approximately 1.0066. Careful search for higher energy neutrons shows no evidence for their presence. From the energy distribution, two resonance levels are probably present, but a large part of the neutron emission appears to be due to penetration over the potential barrier, with accompanying gamma-ray transitions. We have failed to find the large neutron emission from a radon-zinc source, about 50 times that from RaF-Be, reported by Kirsch and Matzner (Naturwiss. **35**, 640). Our measurements indicate that the number of neutrons of energy greater than 0.5×10^6 e.v. from radon-Zn, if any, is less than 1/50 the number from radon-Be. Fruitless search for neutrons from the possible disintegration of deuterium by alpha-particle bombardment of "heavy water" has indicated that the probability of such disintegration is less than 1 to 10^7 alpha-particles.

55. Cosmical Electric Fields. W. F. G. SWANN, *Bartol Research Foundation of the Franklin Institute*.—Some time ago the writer proposed a modification of electrodynamics designed to secure a slow death of positive electricity in the earth, with the result that the corresponding negative electricity passed off to infinity as the atmospheric electric current. It is now pointed out that the space charge of this distribution creates a potential in the body from which it comes. The detailed working out of the situation leads to a potential which would become logarithmically infinite in infinite time. However, with times of such an order of magnitude as to have significant meaning in our universe, a logarithmic infinity is not a complete barrier to the attainment of a reasonably definite meaning to the story of what actually may happen. In application of the idea to stars it is possible to see how on a basis of the fundamental assumption concerned, potentials of the order of those encountered in cosmic-ray phenomena may arise.

56. An Analysis of the Double Crystal Spectrometer and the Determination of X-Ray Line Shapes. LLOYD P. SMITH, *Cornell University*.—A somewhat finer grained mathematical analysis of the action of a double crystal spectrometer has been carried out, as a result of which a method of using the instrument has been devised which makes it possible to determine the diffraction patterns of the crystals experimentally and to resolve the problem of determining the spectral energy distribution of x-ray lines.

57. The Distribution of Initial Velocities of Positive Ions from Tungsten. GEORGE J. MUELLER, *Cornell University*. (Introduced by Lloyd P. Smith).—The distribution of initial velocities of positive ions emitted from a hot tungsten filament in vacuum has been investigated by measuring the positive ion current from a short length (0.05 cm) of filament to a coaxial cylindrical electrode against various retarding potentials. Measurements were made for eighteen different temperatures ranging from 1300°K to 3000°K. The ion current consisted of not only

tungsten ions but also those of impurities in the metal, chiefly potassium. Within experimental error, it was found that the ions were emitted with velocities distributed in accordance with Maxwell's law.

58. Precipitation Hardening and Secondary Structure. K. H. MOORE, *Rensselaer Polytechnic Institute, Troy, N. Y.* (Introduced by R. A. Patterson.)—This is a preliminary report upon the use of polarized light in the investigation of the possible connection between the phenomenon of precipitation hardening and the secondary or mosaic structure of metallic crystals. The structure of an age-hardened alloy of copper-beryllium, (2.5 percent Be), was studied by means of an improvised polarization microscope in an effort to connect the favored planes upon which the first precipitation takes place with the hypothetical net of planes making up the secondary structure of crystals. Precipitation, and coalescence of the precipitated particles, were found to take place at the grain boundaries first, as expected. After a light etch to remove polishing flow, etc., the polarization microscope, with crossed nicols, and in some cases a retarding plate, revealed nets of lines, indicating the surface traces of favored planes; these being invisible under normal or conical non-polarized illumination. The question of whether these are due to internal strain or actual presence of precipitate has not been answered as yet. The usual period of etching with the customary concentration of etchant reveals a diffuse form of the same type of structure, because of preferential etching. With crossed nicols, the nets of lines, observed after light etching, were resolved. The spacing of two rectangular nets, apparently a pattern of squares, was measured as slightly less than 10,000 Angstroms, indicating a possible connection between the planes favored in precipitation and the secondary net of planes whose spacing has been estimated as being of that order of magnitude in metals. It may be significant that, among a series of samples aged for various times at the optimum temperature, the first reasonably complete and measureable nets were found in grains of the sample aged for the time found by other investigators to be the optimum time of treatment for producing hardness in this alloy.

59. A Grating Interferometer. BERTRAND P. RAMSAY, *University of Kentucky.* (Introduced by O. T. Koppfus.)—Discussions of the Michelson interferometer indicate that fringes are formed by the superposition of two approximately parallel wave fronts. Wave fronts having the necessary characteristics can be obtained by mounting gratings on the arms of the interferometer in the places of the customary reflecting mirrors. The instrument becomes its own monochromator when the gratings are rotated to positions of minimum deviation for some particular wavelength. The characteristics of the intensity patterns when the constants of the interfering beams are different have been studied. The customary form of the Michelson interferometer may be considered as the special case of the grating interferometer for which the grating space is infinite and the spectrum order is zero.

60. The Branching of Lightning and the Polarity of Thunderclouds. J. C. JENSEN, *Nebraska Wesleyan Uni-*

versity.—This is a continuation of investigations previously reported. In thundercloud observations extending over a period of four years 77 photographs have been obtained which show downward branching of lightning discharges from a negative cloud to ground while only 13 discharges to ground with downward branching came from positive clouds. Discharges from a positive cloud to ground are characterized by many more finely branched streamers than those from a negative cloud. This is in agreement with Allibone, and with Peek, whose laboratory experiments show branching from a negative to a positive, grounded plane as well as in the opposite direction, and with engineering reports that power-line outages due to lightning are almost always caused by discharges of negative electricity to ground. The meteorological and electrical data obtained in the storms studied show general agreement with the type of cloud described by Banerji in which there is a concentration of negative charge in the front portion.

61. An Experiment to Detect Photon Spin. RICHARD A. BETH, *Worcester Polytechnic Institute.* (Introduced by A. Wilmer Duff.)—There is a possibility that the angular momentum of circularly polarized light (photon spin) can be detected and measured directly by mechanical means. The following apparatus and procedure are being used for a preliminary test in our laboratory. A circular half-wave plate of mica, 3 cm in diameter, is suspended in a vacuum from a Wollaston wire 0.0005 cm in diameter and one meter long. A photon of right circularly polarized light passing vertically up through the half-wave disk emerges as left circularly polarized light and, according to theory should deliver an angular impulse of $2h/2\pi = h/\pi$ to the disk. Besides doubling the effect, this use of a half-wave plate has the very important advantage of nearly eliminating heating and radiometer effects on the disk. Assuming that the equivalent of 40 lumens of circularly polarized sodium light could be concentrated on the disk, and that a resonance method be used, it is shown that an amplitude of torsional oscillation of 1/100 radian could be built up. A much stronger beam of white light could be concentrated on the disk, and, even though only partially circularly polarized, would give a much stronger effect. This amplitude could easily be detected by the usual mirror and scale method.

62. Measurement of the X-Ray Absorption Coefficient of Xenon. T. N. WHITE, *Office of Cancer Investigations, U. S. Public Health Service, Harvard Medical School.* (Introduced by B. E. Warren.)—The absorption coefficient of xenon was measured through a wave-length range from 0.18 to 1.47A, with Soller slits allowing of an inhomogeneity of 0.04A. The results of two series of measurements under different conditions were quite consistent, and the values of $\log(\mu/\rho - 0.70)$ lie on straight lines well within the errors of measurement both above and below the absorption limit. The values lie below those calculated from Jönsson's universal absorption curve, and in general the discrepancy is somewhat larger than would be expected.

63. Neutrons of High Energy from Cosmic-Ray Bursts in Aluminum, GORDON L. LOCHER, *National Research*

Fellow, Bartol Research Foundation of the Franklin Institute.—Cloud photographs in argon of the disintegration products of cosmic-ray Stösse, or ionization bursts, arising from aluminum, show recoil atom tracks similar to those of argon atoms recoiling from collisions with neutrons, but of very much larger *volume*. These are attributed to argon atoms that have been stripped of their extra-nuclear electrons by the sudden impact of *neutrons of very high energy*. W. F. G. Swann has pointed out that since the specific ionization of a charged particle is proportional to N^2 , where N is the number of charges, such stripped recoil atoms would dissipate a large amount of kinetic energy in a very short path; also, that the *broadness* of the tracks is to be expected on the basis of the momentum transmitted to the electrons by collision with the highly-charged recoil nucleus. Thus the energy communicated by a particle of charge Ne is N^2 times that given by a particle of the same mass, and charge e . Hence all electrons ejected by a stripped argon nucleus may make tracks of appreciable lengths (similar to fast delta-rays), adding subsidiary ionization that extends to appreciable distances from the primary path. The ranges of these electron tracks are calculated, approximately, for a charge of $18e$, and are found to be in approximate agreement with the radius of the largest

ionization cluster photographed, namely about 1.5 cm. The energies of the recoil atoms so far photographed in Al-Stösse are uniformly larger than those of the Pb-Stösse previously reported (Locher, *Phys. Rev.* **44**, 779 (1933)), which suggests that *characteristic differences exist between the processes giving rise to cosmic-ray neutrons from Stösse in different substances*. The paucity of electron tracks in photographs of Al-Stösse, as compared with those from lead, is also of interest.

64. The Raman Spectrum of Heavy Water. R. W. WOOD, *Johns Hopkins University.*—The Raman spectrum of 18.5 percent heavy water has been obtained with excitation by the 2536 mercury line. A quartz tube 35 cm long with a capacity of 7.5 cu. cm was clamped to a Hannoveria Hg vacuum tube of quartz and the whole surrounded by a cylinder of polished aluminum. The band of frequency difference 3420 due to ordinary water was photographed in twenty minutes with a density equal to that of the new band due to HOH² obtained with an exposure of 80 minutes. The frequency difference for this band was 2549 in good agreement with theory. The water was prepared by John W. Murray of the Chemistry Department.

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