strahlung, while the positrons annihilate and produce photons. If the multiplication or the cascade of very low energy photons compensates more than the decrease in photon-efficiency of counters, the transition curve rises again and reaches a maximum after about 5 cm Pb (twice the mean free path of the photons of minimum absorption). The counters are triggered essentially by the production of photoelectrons or Compton electrons on their metallic walls. Counters of thin glass walls covered with metal increase the maximum appreciably. The small angle arrangements of Bothe constitute another factor favorable to the maximum. Owing to Compton and coulomb scattering, low energy photons and electrons deviate widely from their origin. The concurrent particles of the shower proper may easily miss the detector, but scattering increases the chance to detect its residual rays. All the difficulties, such as the large magnitude of the maximum, the differences in the behavior of ionizing and non-ionizing primaries, the independence of angle and multiplicity,[3] the associated *Zusatzstrahlung*, etc., can be understood very well. The irregularity between 5 and 10 cm probably arises from the discontinuity in the energy spectrum of soft components; near sea level low energy electrons, and particularly photons, are more abundant below 200 Mev.[17] To avoid the nuclear phenomena and to eliminate the softer primaries, underground measurements should give better results. Whether this hypothesis is good or not can be decided by experiments.

[1] W. Bothe, Revs. Modern Phys. **11, 82 (1939)**, and the references contained in this article.
[2] W. Bothe and H. Thurin, Phys. Rev. **79**, 544 (1950).
[3] J. Clay, Revs. Modern Phys. **11**, 287 (1939); **21**, 82 (1949).
[4] T. Kameda and I. Miura, Prog. Theor. Phys. **5**, 323 (1950).
[5] E. Fenyves and O. Haiman, Nature **165**, 244 (1950).
[6] P. K. Sen Chaudhary, Phys. Rev. **81**, 274 (1951).
[7] K. Schmeiser and W. Bothe, Ann. Physik **32**, 161 (1938).
[8] K. Schmeiser, Z. Physik **110**, 443 (1938); **112**, 501 (1939).
[9] R. P. Shutt, Phys. Rev. **69**, 261 (1946).
[10] L. Jánossy, Proc. Roy. Soc. (London) **A179**, 361 (1941); Phys. Rev. **64**, 345 (1943); L. Jánossy and G. D. Rochester, Proc. Roc. Soc. (London) **A183**, 181 (1944).
[11] Brown, McKay, and Palmatier, Phys. Rev. **76**, 506 (1949).
[12] Up to the present time the only exception seems to be the experiment of Kameda and Miura. Their transition curves for narrow and wide angle penetrating showers are at complete variance with other workers. It is not clear that they are really contributed entirely by penetrating particles. One does not know whether their first and second maxima at 5 and 17 cm are really the second and third maxima (total thicknesses of lead equal to 15 and 27 cm) or not.
[13] W. D. Walker, Phys. Rev. **77**, 687 (1950).
[14] Cocconi, Cocconi Tongiorgi, and Greisen, Phys. Rev. **75**, 1063 (1949); K. Greisen, Phys. Rev. **75**, 1071 (1949).
[15] R. Maze and Tsai-Chü, Compt. rend. **232**, 224 (1951).
[16] Altmann, Walker, and Hess, Phys. Rev. **58**, 1011 (1940).
[17] D. J. X. Montgomery, *Cosmic Ray Physics* (Princeton University Press, Princeton, New Jersey, 1949), p. 263.

PHYSICAL REVIEW VOLUME 83, NUMBER 4 AUGUST 15, 1951

Proceedings of the American Physical Society

MINUTES OF THE MEETING AT SCHENECTADY, NEW YORK, JUNE 14–16, 1951

THE 307th meeting of the American Physical Society, being the 1951 Summer Meeting in the East, was one of the delightful small meetings which more or less alternate with those that are huge and congested; and it was particularly delightful because of the excellent planning of our hosts, who were the General Electric Company and Union College. It was held at Schenectady, New York, on Thursday, Friday, and Saturday, June 14, 15, and 16, 1951. The attendance was over 400; this is believed to have made it the largest summer meeting which we have ever held, apart from the Semi-Centennial Meeting of 1949. The programme comprised sixty-four contributed papers and seventeen invited papers, their topics distributed widely over the field of physics: it is reproduced *in toto* on the following pages. Cool rain fell throughout the Thursday and the Friday, distressing to those who did not remember that sunny June days in the Northeast are likely to be hot, distressing also to our hosts of General Electric who had hoped to offer us the hospitality of their gardens as well as that of their laboratory "The Knolls." Mention should be made that General Electric provided a fleet of buses to take our members to and fro between their living-quarters and the Knolls, and gave us a reception on the Thursday afternoon; and that Union College extended to our members the privilege of living in its new dormitory, and put three of its buildings at our disposal for the scientific sessions. The heads of the very efficient Local Committee were L. R. Apker and M. H. Hebb of General Electric, and H. E. Way of Union College.

The banquet of the Society was held in the Van Curler Hotel on the Friday evening with an attendance of 170. Messrs. Hebb and V. Rojansky made brief and witty remarks, and V. J. Schaefer gave the principal after-dinner speech under the title "Cloud Physics."

The Council met on the Friday afternoon, and elected three candidates to Fellowship and one hundred and forty-seven to Membership: their names are appended. It was decided that beginning in 1952, *Journal of Chemical Physics* shall be offered to our members on membership subscription as an "option" alternative to *Physical Review*—without payment beyond regular dues. Also beginning in 1952, as stated in the Minutes of the Washington meeting, an extra payment of $2.00 (in addition to dues) will be required from each member who subscribes to either section of Science Abstracts and an extra payment of $7.50 from any member who subscribes to both. The Society will also make an annual grant or subsidy to the management of "Science Abstracts" as a contribution to the fixed charges of that journal, and the Council approved a specific proposition, in line with the report of the Committee on Science Abstracts at the Washington meeting.

Reports reaching the office of the Society indicate that we have lost through death Arnold Sommerfeld

(Honorary Member) and Edward Bennett, A. Wilmer Duff, C. F. Eyring, H. E. Marsh, Hantaro Nagaoka, Yoshio Nishina, Tokiharu Okaya, R. T. Ratliff, and A. H. Rollefson.

Elected to Fellowship at the Schenectady meeting: W. W. Beeman, Claude Cherrier, and Erich Regener.

Elected to Membership at the Schenectady meeting: Robert P. Abrahams, Ralph M. Adams, Denis Aliaga-Kelly, Harold W. Anderson, James K. Anderson, LeRoy E. Anger, Edwin L. Armstrong, Frank G. AtLee, Jr., Alfred E. Attard, Paul Avignon, Herman W. Bandel, Emanuel Baskir, Zoltan Bay, Ralph E. Beatty, Jr., John F. Bedinger, Emanuel Belmont, George Bemski, Róger J. Blin-Stoyle, Clyde M. Bliven, Theodore Bowen, Malcolm K. Brachman, Lee C. Bradley III, Chancellor Bramblett, John C. Cacheris, Joseph E. Cahill, Piero C. Caldirola, Nazzareno P. Cedrone, Te-Ning Chin, William Chinowsky, Edward L. Chupp, Armand Cioccio, Stanley J. Ciosek, David Cohen, Kenneth M. Crowe, Paul H. Cutler, Richard W. Damon, Lucien A. D'Asaro, William J. Davis, Jr., Peter T. Demos, George Derderian, Leon M. Dorfman, James B. Dozier, Jr., Richard M. Drisko, Ralph D. Drosd, Thomas A. Green, Daniel H. Greenberg, Alford J. Greenwald, Ernest M. Grunwald, George L. Guthrie, Sister M. Bernarda Handrup, Charles W. Durieux, Seymour Edelberg, Walter G. Elwell, Harald A. Enge, Ismael V. Escobar, Bill W. Fain, Craig S. Fenn, Robert J. Friauf, George C. Fullmer, Harvey L. Garner, John H. Gibbons, Howard B. Glenn, Samuel Globe, Joseph M. Green, Lloyd H. Groth, Daniel W. Healy, Jr., Hans Heil, Robert B. Heller, Rudolf Hermann, Bernard Herzog, Abraham Hirschman, Erik V. Hulthen, Andrew R. Hutson, Thomas O. Jeffries, David W. Juenker, C. C. Jonker, Adolph S. Jursa, Quentin C. Kaiser, Bernard Kaplan, Thomas A. Kaplan, Robert J. Kerr, Alvin E. Kiel, Raymond A. Kinmonth, Jr., Joseph M. Krafft, Albert L. Latter, Michael Leichter, William H. Lupton, Leo Mandelkern, Raymond F. McCartney, Clyde L. McCrary, Clayton J. McDole, Bruce J. McDonald, Edgar A. McLean, William H. McMaster, John W. Michener, Robert H. Mills, Jean A. Minken, James O. Montague, June O. Montgomery, Marion M. M. Morgan, Thomas A. Morgan, Edward L. Murphey, Irving Nadelhaft, James R. Novotny, M. Thomas O'Shaughnessy, Edward D. Padgett, DeWitt R. Petterson, Sanborn F. Philp, Vernon C. Plane, David G. Proctor, David Reiner, Michel C. Renardier, Stanley E. Rittenburg, James P. Rodman, Herbert Rabin, David C. Rahm, Eugene C. Raka, Marc H. Ross, Bernard Roth, Jean L. Ryan, George Saphir, Norman M. Schaeffer, Morris F. Scharff, Curtis L. Scoville, Aaron J. Seriff, John D. Servis, Frank H. Shelton, Edwin Shotland, Robert H. Silsbee, A. Lee Smith, Anne Smith, Harold D. Smith, Helmut Sommer, David E. Soule, B. Frank Sterling, Jr., Yoshio Tanaka, Fred W. Thalgott, John M. Tinker, Robert A. Uphaus, Jack Uretsky, Warren P. Waters, Christopher B. Walker, Dean A. Watkins, Arthur E. Williamson, Jr., Edward J. Winhold, Albert M. Wittenberg, and Max Wolfsberg.

KARL K. DARROW, *Secretary*,
American Physical Society
Columbia University
New York 27, New York

Errata Pertaining to Papers C4, F3, F7, H9, and J2

C4, by J. E. Goldman. In lines 13 and 14, "too close for a strong exchange interaction" should read "too close for a strong positive exchange interaction." In line 17, "face-centered cubic" should read "simple cubic."

F3, by H. W. Boehmer and J. E. Coolidge. The by-line should read, "H. W. Boehmer, University of Colorado, and J. E. Coolidge, Pennsylvania State College." In line 15, "$I(\theta)=I(0)\cos\lambda\theta$" should read "$I(\theta)=I(0)\cos^{\lambda}\theta$."

F7, by J. E. MacDonald and D. L. Falkoff. In line 14, "it is" should read "it is not." In line 15, "all" should read "these." In line 16, "provided" should read "even when."

H9, by F. A. Grant. The by-line should read, "F. A. Grant, University of Maryland (Introduced by Raymond Morgan). Footnote* should read "Supported by Bureau of Ships Contract."

J2, by K. W. DeSorbo and W. C. Dunlap, Jr. In line 12, "0.12 ev" should read "0.03 ev."

PROGRAMME

THURSDAY MORNING AT 10:00

Knolls Auditorium

(J. H. VAN VLECK presiding)

A1. Opening Address. C. G. SUITS, *General Electric Company.*

A2. Nuclear Research with X-rays up to 100 Mev. GEORGE BALDWIN, *General Electric Company.* (35 min.)

A3. Report on the McGill University Radiation Laboratory J. S. FOSTER, *McGill University.* (35 min.)

A4. The Research Programme of the Berkeley Linear Accelerator. W. K. PANOFSKY, *University of California, Berkeley.* (35 min.)

THURSDAY AFTERNOON AT 2:00

Knolls Auditorium

(C. G. SUITS presiding)

B1. Lightning. K. B. MCEACHRON, *General Electric Company. Pittsfield.* (40 min.)

B2. Periodic Deviations of Thermionic Emission from the Schottky Law: Experiments. W. B. NOTTINGHAM, *M.I.T.* (30 min.)

B3. Periodic Deviations of Thermionic Emission from the Schottky Law: Theory. N. H. FRANK, *M.I.T.* (30 min.)

THURSDAY AFTERNOON AT 2:45

Knolls 441

(J. H. HOLLOMON presiding)

Magnetism; Physics of Metals

C1. The Magnetic Susceptibility of Metallic Uranium in the Range −195°C to 1060°C.* C. J. KRIESSMAN, JR.,† AND T. R. MCGUIRE, *U. S. Naval Ordnance Laboratory.*—The magnetic susceptibility of uranium was found to increase uniformly from $1.65\pm0.02\times10^{-6}$ at −195°C up to $1.98\pm0.02\times10^{-6}$ at 800°C. These results are in agreement with those of Bates,[1] who made measurements in the range 20 to 350°C. An abrupt increase of about 6 percent in the susceptibility was found at 800°C with a second but smaller sudden increase at 940°C. The susceptibility discontinuity at 800°C is probably associated with the crystallographic transition[2,3] tetragonal (β) to cubic (γ) structure, occurring at about this temperature. When the temperature was lowered from 1060°C, a temperature hysteresis loop was developed in the region of 760–800°C; but the susceptibility seemed to be reversible at all other temperatures. Uranium is also known to have a crystal structure transition,[2] orthorhombic (α) to tetragonal (β) at 600°C. However, in the neighborhood of 600°C, only a small increase in susceptibility (within the range of experimental error) was observed.

* This work was supported in part by the ONR.
† Also at Catholic University of America.
[1] L. F. Bates and J. R. Mallard, Proc. Phys. Soc. (London) **63**, 520 (1950).
[2] A. S. Wilson and R. E. Rundle, Acta Cryst. **2**, 126 (1949).
[3] C. W. Tucker, Jr., Knolls Atomic Power Laboratory, Schenectady, New York, unpublished work referred to by Kasper, Decker, and Belanger, J. Appl. Phys. **22**, 361 (1951).

C2. Intensity of Magnetization of Thin Nickel Layers.* E. C. CRITTENDEN, JR., L. O. OLSEN, AND R. W. HOFFMAN, *Case Institute of Technology.*—The intensity of magnetization of nickel as a function of thickness is being investigated. The nickel is evaporated under a pressure of 1×10^{-5} mm or less at a constant rate of 70 angstroms per second onto fire-polished glass held at constant temperature. The change in electrical conductivity of a second monitor specimen is used to control the rate of deposition and to determine the thickness deposited on the specimen. A set of shutters exposes the specimen for a short period. The thicker monitor specimen avoids difficulty with the variation of resistivity with thickness. The magnetic data is obtained with an instrument previously described.[1] The specimens saturate at low fields as a result of the single domain structure. A decrease of intensity of magnetization to zero at a finite thickness is observed, as predicted by Klein and Smith.[2] For samples deposited at 75°C, ferromagnetic behavior ceases at about 20 angstroms. Work is continuing in an effort to minimize the effects of surface non-uniformities.

* Work is supported by the ONR.
[1] E. C. Crittenden, Jr., and R. I. Strough, Phys. Rev. **75**, 1630 (1949).
[2] M. J. Klein and R. S. Smith, Phys. Rev. **81**, 378 (1951).

C3. Atomic Moment and Magnetostriction in Ordered Iron-Aluminum Alloys. J. K. STANLEY, J. E. GOLDMAN, AND W. HASSEL,* *Westinghouse Research Laboratories.*—The atomic moment and saturation magnetostriction of polycrystalline iron-aluminum alloys in the range of 13 to 31 atomic percent aluminum have been measured in both the quenched and annealed condition. The quenched alloys were given a prolonged soak at a temperature above the critical ordering temperature before quenching; the annealed alloys were slowly cooled therefrom. Magnetization measurements were made

ballistically with the double balanced coil method in a field of 15,000 oersteds. Magnetostriction was measured using the resistance strain gauge technique with gauges mounted on the 15×3×0.035-cm samples in two directions in order to eliminate volume effects and increase the accuracy of the measurements of the longitudinal magnetostriction in the neighborhood of saturation. The atomic moment of the ordered samples as a function of composition can be represented by two straight lines with the break occurring at the Fe_3Al composition. The quenched samples do not show this sharp discontinuity and resemble more closely the curve of Fallot.[1] The magnetostriction is large and positive over the entire range and is a maximum at the composition Fe_3Al in both cases, but is greater for the ordered samples.

* Now at Carnegie Institute of Technology, Standard Oil of Indiana, and Naval Ordnance Test Station, Inyokern, respectively.
[1] M. Fallot, Ann. phys. **6**, 361 (1936).

C4. Theory of the Magnetic Properties of Fe–Si and Fe–Al Alloys. J. E. GOLDMAN, *Carnegie Institute of Technology.*—The magnetic, metallurgical, and lattice properties of the Fe–Al and Fe–Si systems are very similar. Both have identical ordered structures at the composition Fe_3X, and in both cases the magnetic crystalline anisotropy changes sign at about 22 atomic percent Si and Al. However, in Fe–Al the magnetostriction increases,[1] whereas in Fe–Si it decreases and becomes negative at about 13 atomic percent silicon.[2] The behavior of the Fe–Si can be understood on the basis of Neel's theory in which the only ferromagnetic interaction in an iron lattice is the next-nearest neighbor interaction, since the nearest neighbors are too close for a strong exchange interaction. In ordered Fe_3Si, one-third of the iron atoms have only silicon atoms as next-nearest neighbors and will not be magnetic on an atomic dipole representation. The "magnetic" iron atoms now form a face-centered cubic "magnetic superlattice" which can be shown on the basis of the dipole interaction theory[3] to give a negative magnetrostriction of the proper order of magnitude. That the situation is different in the case of Fe_3Al will be discussed from the point of view of an exchange interaction through the $3p$ electrons in aluminum as is suspected to be the case in Heusler alloy.

[1] Stanley, Goldman, and Hassel, previous abstract.
[2] W. J. Carr, Dissertation, Carnegie Institute of Technology, 1950; W. J. Carr and R. Smoluchowski (to be published); J. E. Goldman, Proceedings of the International Conference on Magnetism, Grenoble, 1950.
[3] R. Becker, Z. Physik **62**, 253 (1930); J. E. Goldman and R. Smoluchowski, Phys. Rev. **75**, 140 (1949).

C5. Effect of Ordering on the Magnetic Anisotropy of Iron-Nickel Alloys. R. M. BOZORTH AND J. G. WALKER, *Bell Telephone Laboratories.*—Single crystals[1] of iron nickel alloys containing from 35 to 100 percent nickel were cut in the form of disks parallel to (100) planes. Measurements of the anisotropy constant, K, were made using the torsion magnetometer previously described.[2] Specimens (about 1 cm diameter, 1 mm thick) were cooled from above 600° to below 300°C at about 2°C/hr to promote atomic ordering, or were quenched from 600°C onto copper to maintain disorder. Anisotropy is dependent on heat treatment from about 50 to 85 percent Ni, the quenched alloys having the higher positive (or less negative) values of K, as observed by Grabbe.[3] Zero anisotropy occurs at 62 percent Ni for the ordered alloys, 71 percent Ni for the disordered alloys. The effect of ordering is greatest when the nickel content is somewhat below that corresponding to $FeNi_3$; at 73 atomic percent K is -3000 after quenching, -23000 after slow cooling.

[1] Walker, Williams, and Bozorth, Rev. Sci. Instr. **20**, 947 (1949).
[2] H. J. Williams and R. M. Bozorth, Phys. Rev. **55**, 673 (1939).
[3] E. M. Grabbe, Phys. Rev. **57**, 728 (1940).

C6. Magnetic Anisotropy and Physical Structure of Alnico 5. Part I. R. D. HEIDENREICH AND E. A. NESBITT, *Bell Telephone Laboratories.*—It is concluded from electron metallographic results that the high coercive force and anisotropy of Alnico 5 are due to a very finely divided precipitate produced by the permanent magnet heat treatment. This precitate is a transition structure rich in cobalt and is face centered cubic with $a_0 = 10$A and appears as rods growing along the [100] directions of the matrix crystal when no magnetic field is applied during heat treatment. The size of the precipitate rods at optimum properties is approximately 75–100A by 400A long. The spacing between rows of rods is about 200A. The rods are not distinctly resolved in the electron images unless they are grown by aging at 800°C. Their orientation and structure is clearly evident in the electron diffraction patterns at all stages of growth. The precipitate responds to a magnetic field applied during heat treatment both by suppression of nuclei making an angle greater than about 70° with the field and by the forcing of the rods off the [100] direction into that of the field. The precipitate rods tend to scatter in direction about the field vector when the field is off the [100] but are aligned accurately when the field is along [100].

C7. Magnetic Anistotropy and Physical Structure of Alnico 5. Part II. E. A. NESBITT AND R. D. HEIDENREICH, *Bell Telephone Laboratories.*—As a result of measurements of magnetic anisotropy and coercive force on single crystals of Alnico 5 and the electron metallography of Part I, the following conclusions were obtained. When the alloy is heat-treated in a field, directional precipitation takes place largely in the field direction. The easy direction of magnetization is always the field direction; and magnetically the crystal has the twofold symmetry of the magnetic field. However, there is a strong tendency due to crystal forces for the precipitate to grow in [100] directions; and, therefore, the crystal has the highest anisotropy when the field and the [100] direction are parallel. The large increase in residual induction of Alnico 5 which results from the magnetic field heat-treatment is caused by the easy directions of the crystal changing from the [111] directions to a single easy direction parallel to the field. Domain rotations rather than boundary movements account for the coercive force of the alloy, since the dimensions of the individual particles are approximately 200 angstroms. The final physical picture of the alloy is one of single domains of precipitate material in parallel with single domains of matrix material, the observed coercive force being the resultant of this combination.

C8. Ultimate Strength Levels in Copper Wire. RICHARD LATORRE AND WALLER GEORGE, *Naval Research Laboratory.*—The resistance of OFHC wire to plastic extension at constant true strain rates has been measured using an extension of a technique previously described by the authors.[1] The results indicate the ultimate true stress to be essentially independent of strain rate over selected intervals and to rise rapidly from level to level over narrow strain-rate intervals. Three successively increasing levels of strength are observed at room temperature, at rates of straining from approximately 10^{-7} sec^{-1} to 1 sec^{-1}. The observed level differences are considered to be significant with respect to the magnitudes of experimental uncertainties, about ±3 percent. The position of the ultimate strength transition from the lowest level to the next higher can be shifted to higher strain rates by increasing the temperature of the specimen. In the region of this transition, the magnitude of the shift in strain rate with a 10°C temperature increase appears to be fitted by a relation between strain rate and temperature of the Ahrenious type.

[1] R. LaTorre and W. George, Phys. Rev. **75**, 1309A (1949); **76**, 470A (1949).

C9. Diffusion along Grain Boundaries. GLENN M. ROE, *Knolls Atomic Power Laboratory.*—Fisher[1] has presented a numerical calculation on the effect of a relatively high grain boundary diffusivity on the average concentration at a dis-

tance μ from an initial concentration discontinuity normal to the grain boundaries. He concludes that the log of the average concentration varies as the first power of μ. An analytical solution of the same problem shows that the log of the average concentration varies as (1) μ times a slowly varying function of μ for small distances, (2) $\mu^{4/3}$ for intermediate distances, and (3) eventually as μ^2 for large distances. The calculated curves will be compared with the measurements of Hoffman and Turnbull[2] on self-diffusion in silver.

[1] C. Fisher, J. Appl. Phys. **22**, 74 (1951).
[2] R. E. Hoffman and D. Turnbull (to be published in J. Appl. Phys.).

C10. Temperature Dependence of Internal Friction of Single Crystals. J. PITTENGER, *Carnegie Institute of Technology** (Introduced by J. E. Goldman).—The internal friction has been measured as a function of temperature for single crystals of Cu, Mg, and Al in the temperature range of 20 to 400°C and in frequency range of 4 to 30 kc and at various values of strain amplitude. Resonant rods were excited with a magnetic drive, and the decrement was measured by counting electronically the number of cycles after the drive is switched off. The Cu and Mg crystals both show a pronounced minimum in the decrement *vs* $1/T$ curve. In Mg this minimum occurs at about 60°C; in copper it is found at about 180°C and is considerably sharper. In Mg the minimum is broadened by the ability of this metal to anneal or "age" at room temperatures. In the case of the Al crystals the data indicates a slight rise in decrement near room temperature although the existence of a minimum in that region has not been established with certainty. The apparatus will be described, and an attempt made to interpret the data.

* Supported by the ONR.

C11. Rupture of Plastic Sheets as a Function of Size and Shape. H. L. SMITH, J. A. KIES, AND G. R. IRWIN, *Naval Research Laboratory.*—The role of stored elastic energy in the propagation of brittle fracture was investigated. Fracture strength was found to be a function of the dimensions of the test piece as well as of the material. This is in accordance with the predications of the modified Griffith theory as proposed by G. R. Irwin. Fractures were initiated in Plexiglas and cellulose acetate sheets by a bullet perforation while the specimen was under a tensile load. It was found that the initial stress required to cause complete fracture increased as the size of specimen decreased and as the ratio of width to length increased. As the initial stress was further increased, the specimen shattered or the crack split into branches. The crack length at which branching occurred was a linear function of an energy equivalent to that initially contained within an expanding geometrical figure in which similitude was maintained during the growth of the crack.

THURSDAY AFTERNOON AT 2:45

Knolls 585

(GEORGE BALDWIN presiding)

Nuclear Physics

D1. Initial Performance of the Purdue University Synchrotron.* R. O. HAXBY, H. J. HEIM, C. S. SPRAGUE, R. M. WHALEY, R. S. MATHEWS, P. C. MURRAY, C. A. TATRO, AND R. F. DONOVAN, *Purdue University.*—The Purdue synchrotron uses a ring-shaped magnet with a nominal vacuum tube radius of one meter. The machine is designed for pulsed operation with pulse rates up to 12 per second. The betatron principle is used to accelerate electrons up to 4 Mev. The betatron flux bars are designed so that injection of electrons and vacuum pumping may be done from inside the ring magnet. For synchrotron operation, a master oscillator-power amplifier system feeds a quarter-wave cavity which forms one section of the vacuum tube. This section is made of a low-loss ceramic, coated with silver, and striated to reduce eddy currents. The rest of the vacuum tube is made of ordinary porcelain. Successful operation as a betatron was achieved early this year while final tests were being made on the rf system. When the rf equipment was installed, a weak synchrotron beam was detected. The maximum energy attained so far is about 100 Mev.

* This work was supported in part by the ONR and AEC.

D2. Absorption and Scattering of γ-Rays in Water.* M. A. VAN DILLA AND G. J. HINE, *Massachusetts Institute of Technology.*—The transmission of the radium, Co^{60}, Au^{198}, and Hg^{203} γ-rays through water has been investigated under conditions which allow the separation of absorption and scattering effects. A point source and a small liquid-filled ionization chamber were placed in a steel water tank (3 feet diameter and $3\frac{1}{2}$ feet high). When the water level in the tank was raised, an increase in ion current due to scattered γ-rays became apparent as the water level approached the source-chamber plane closer than 3 inches. A sharp drop in intensity was observed when the water entered the region between source and chamber (good geometry absorption), followed by an increase due to scattering as the water level rose further. Further experiments show the manner in which the relative intensity of primary and scattered γ-rays varies with the distance between source and chamber. A build-up factor is defined as the observed ion current with the water divided by the ion current in air times $\exp(-\sigma_a r)$. Close to the source ($r<30$ cm) this function is slightly greater than unity owing to backscattered γ-rays. For larger distances it approaches zero, indicating multiple scattering processes and eventual photoelectric absorption of of the scattered γ-rays. There is no indication of an equilibrium between the primary and secondary photons.

* Assisted by the joint program of the ONR and AEC.

D3. Measurements on the Relative Transmission of Beta-Particles through Geiger-Müller Counter Windows.* CHIA-HUA CHANG AND C. SHARP COOK, *Washington University.*—A method utilizing the electrostatic acceleration of beta-particles from the source of a thin lens spectrometer has been reported[1] at a previous meeting of the American Physical Society. A report of progress since that time will be made, and results obtained will be compared with results recently reported by Saxon.[2]

* Assisted by the joint program of the ONR and AEC.
[1] C. S. Cook and C. H. Chang, Phys. Rev. **79**, 244 (1950).
[2] D. Saxon, Phys. Rev. **81**, 639 (1951).

D4. The Relative Transmission of Electrons through Thin Zapon Foils.* PAUL H. OWEN AND C. SHARP COOK, *Washington University.*—Electrostatic acceleration of beta-par-

ticles[1] in a thin-lens spectrometer for the determination of their relative transmission through a G-M counter window has not been perfected for beta-particle kinetic energies below 25 kev. For studies of this low energy range, electrons have been accelerated from an electron gun, focused by a semicircular, uniform field, magnetic spectrometer and detected by a Faraday cage. A movable window assembly, placed immediately in front of the Faraday cage, has been constructed in such a way as to allow rapid insertion into or removal from the electron beam of a zapon foil. Such an arrangement has not been completely satisfactory, because of the collection of charge on the foil under certain conditions. The results will be discussed.

* Assisted by the joint program of the ONR and AEC.
[1] C. H. Chang and C. S. Cook, preceding abstract.

D5. Space-Charge-Limited and Space-Charge-Free Behavior of Diamond Crystal Counters. A. G. CHYNOWETH, *University of London, King's College.*—Applying alternate light flashes and electric field pulses to the crystal has enabled its behavior under a large variety of conditions to be investigated. The effect of field strength and illumination intensity on the growth and decay of the space charge field is described. From a simple picture of the electron trapping and releasing processes involved, it is predicted how the technique can be used to study the space-charge-free behavior of the counter. These predictions are verified experimentally. Preliminary studies of the effect of temperature on the counter suggest the possibility of permanently preventing the formation of space charge by keeping the temperature of the counter sufficiently high and also how information concerning the distribution of trap depths in the crystal and the lifetimes of trapped electrons could be obtained. For solid-state studies the technique has the advantage over luminescence methods in that radiationless transitions of electrons from trapping levels to ground states can be studied. Proportional response is obtained for beta-rays of energy 0.66 to 1.0 Mev, and the average energy required to liberate an electron from the lattice by the beta-rays is found to be approximately 7 ev.

D6. Response of Anthracene Scintillation Counters to High Energy Protons.* G. GUERNSEY, G. MOTT, AND B. K. NELSON, *University of Rochester.*—The resolution and pulse height variation with energy loss in anthracene have been studied for protons of energy 100–200 Mev. Protons of 200 Mev and less have been obtained by $N-P$ scattering in the external neutron beam of the U. and R. 130″ synchrocyclotron. Recoil protons have been detected by a scintillation counter telescope, the pulse height being analyzed in the last counter. The upper limit of the proton spectrum has been established as a reference point by range determinations. The lower energies have been obtained by either increasing the recoil angle or interposing copper absorbers. Preliminary results indicate that the resolution of the order of 10 percent width at half-maximum can be obtained. Data thus far obtained are consistent with proportionality between pulse height and the energy loss of protons in this range. The response to high energy protons is also being compared with that to deuterons and alpha-particles in approximately the same energy region.

* Supported by the AEC.

D7. Absolute Counting of Fast Neutrons with Anthracene Counters. W. G. CROSS, *Chalk River Laboratory.*—High efficiency absolute counting of fast monoenergetic neutrons, possible with organic scintillation detectors, is complicated by the fact that the differential pulse height distribution is not rectangular (as the recoil proton energy spectrum is) but rises steeply at low energies. The pulse spectrum observed for 14-Mev neutrons (from the $T(d, n)$ α-reaction) has been explained quantitatively on the basis of (a) nonproportionality of anthracene's light output with proton energy, (b) alpha-particles from the $C^{12}(n, n)3\alpha$ and $C^{12}(n, \alpha)Be^{9}$ reactions, (c) wall losses in the crystal, and (d) small corrections for the statistical spread at the photomultiplier cathode. For crystals of various sizes, the neutron flux calculated from the part of the pulse distribution due to protons above 4 Mev, and hence above alpha-particle pulses, agrees within 5 percent with that derived from counting alpha-particles from the tritium target and assuming that they are emitted isotropically. For $D-D$ neutrons only (a) and (d) are appreciable, and the whole pulse spectrum is used to get the flux.

D8. Total Cross Sections of Light Nuclei for p, T Neutrons.* C. K. BOCKELMAN,† H. H. BARSCHALL, AND D. W. MILLER† *University of Wisconsin.*—Measurements of the energy dependence of total neutron cross sections of light nuclei were extended to higher energies by the use of the $T(p, n)$ reaction as a source of monoenergetic fast neutrons. Tritium was absorbed in a Zr film evaporated on a tungsten disk,[1] and was bombarded with protons from the electrostatic generator. Neutrons of energies up to 3.5 Mev were produced with a 20-kev energy spread. Narrow cross section peaks were observed for Be, C, and O. For Li, only a gradual rise in cross section was found. A comparison of measurements on normal B with those on enriched B^{10} gave the cross sections of B^{10} and B^{11}. For B^{10} only two broad maxima were observed, while the cross section of B^{11} shows five sharp peaks. In addition to these relatively narrow resonances, evidence was found for very broad levels in all the nuclei studied.

* Work supported by the AEC and the Wisconsin Alumni Research Foundation.
† AEC Predoctoral Fellow.
[1] A. B. Lillie and J. P. Conner, Rev. Sci. Instr. **22**, 210 (1951).

D9. Angular Distribution of Neutrons Scattered by Helium.* R. K. ADAIR, *University of Wisconsin.*—A proportional counter filled with helium was irradiated with monoenergetic fast neutrons produced by bombarding thin lithium targets and tritium-filled zirconium targets with protons from the electrostatic generator. Angular distributions of the neutrons scattered by helium were determined by measuring the distribution in energy of the pulses from the recoiling alpha-particles with a differential discriminator. Measurements were made for eleven different neutron energies from 400 kev to 2730 kev. The scattering of neutrons and protons from alpha-particles has been described[1] in terms of a potential leading to a $P_{3/2}-P_{1/2}$ doublet in He^{5}, split by about 5 Mev, a description which is consistent with the neutron-alpha total cross section and the proton-alpha differential cross sections. Using the same assumptions, the differential cross sections for the scattering of neutrons by alpha-particles was calculated and was found to be in qualitative agreement with the measured angular distributions.

* Work supported by the AEC and the Wisconsin Alumni Research Foundation.
[1] R. K. Adair, Phys. Rev. **82**, June 1, (1951).

D10. Recoils from High Energy Neutrons. C. E. SWARTZ, *University of Rochester.*—A helium-filled cloud chamber has been exposed to a collimated neutron beam from the Rochester 130″ cyclotron. Details of shielding and beam synchronization will be described. The helium recoils and disintegrations can be distinguished from background and oxygen events. The 2700 recoils are divided into three groups depending on the energy of the bombarding neutron. Angular distribution of each group shows that recoils from high energy neutrons are concentrated in angles nearly perpendicular to the beam.

FRIDAY MORNING AT 10:00

Knolls Auditorium

(M. H. HEBB presiding)

E1. The Behavior of Crystal Imperfections at High Temperatures. A. W. LAWSON, *University of Chicago.* (40 min.)

E2. Computing Metallic Cohesive Energy without the Use of Potential Functions. THOMAS KUHN, *Harvard University.* (30 min.)

E3. Crystal Growth. F. C. FRANK, *University of Bristol, England.* (40. min.)

FRIDAY MORNING AT 10:00

Knolls 441

(ARTHUR ROBERTS presiding)

Cosmic Rays and Nuclear Physics

F1. Distribution in "Size" of Cosmic-Ray Stars as a Function of Altitude and Surrounding Material. M. BIRNBAUM, F. W. O'DELL, M. M. SHAPIRO, AND B. STILLER, *Naval Research Laboratory.*—The frequency *versus* magnitude of nuclear explosions in emulsions exposed in the stratosphere was studied, using the multiplicity of "heavy" prongs (grain density >1.4 times minimum) as an index of star "size." From such distributions, together with data on hard-shower multiplicities, energy spectra are deduced. Ilford G.5 emulsions, 400μ thick, were flown at $\lambda = 57°$N at average atmospheric depths of 14 and 22 g/cm^2, surrounded by air and Pb. When the frequency of stars with prong number $\geq n$ is plotted against n, the results, like those at mountain altitudes,[1] can be represented by two straight lines which intersect at $n \simeq 7$. These lines decrease in steepness with rising altitude, as expected from the increasing mean energy of the star-producing particles. The stratosphere distribution in Pb differs inappreciably from that in air. Our "free air" curves are compared with Lord's,[2] at 15 g/cm^2, and with Bristol[2] data at 49 g/cm^2. The interpretation and application of such curves is discussed.

[1] E. P. George and A. C. Jason, Proc. Phys. Soc. (London) A, **62**, 243 (1949); N. Page, **63**, 250 (1950); G. Bernardini *et al.*, Phys. Rev. **79**, 952 (1950).
[2] J. J. Lord, Phys. Rev. **81**, 901 (1951); U. Camerini, *et al.*, Phil. Mag. **40**, 1073 (1949).

F2. Behavior in Pb Absorbers of the Nucleonic Component in the Stratosphere. MAURICE M. SHAPIRO, *Naval Research Laboratory,* AND ANDREW F. GABRYSH, *The Catholic University of America.*—The air-to-lead transition effect of the star-generating radiation in the stratosphere has been further studied with two[1] experimental arrangements, to investigate the effects of absorber geometry. In one flight (at mean pressure-altitude 2.3 cm Hg), ultrasensitive emulsions were placed vertically in a narrow aperture in Pb. The small-star frequency shows a maximum at $\simeq$28 g/cm^2. Stars with >6 prongs have a less pronounced effect. The slight initial drop previously reported for small stars is confirmed and explained. In another flight, at mean depth 2.5 cm Hg, rates of star production were measured above and below a massive Pb slab$\simeq$1 ft^2, and 2.15 cm thick.[2] The following ratios (below/above) were observed: for *all* stars, 1.74$\pm$0.16; for *small* ($\leq$6-fold) stars, 1.86$\pm$0.22; for *large* stars, 1.55$\pm$0.22. Our results showed no significant difference between vertical and horizontal plates above the lead. Dallaporta's secondary-neutron theory[3] is discussed, and an alternative hypothesis, i.e., that the transition effect at shallow depths is mainly due to *charged* secondaries (protons and/or pions) is tentatively proposed.

[1] In both the geometries differed from that in a parallel investigation by Shapiro, Birnbaum, O'Dell, and Stiller, Bull. Am. Phys. Soc. Vol. 26 No. 3, 10 (1951).
[2] Courtesy of Dr. G. Perlow, who sent this slab aloft for another experiment.
[3] Dallaporta, Merlin, and Puppi, Nuovo cimento **7**, 99 (1950).

F3. Directional Intensities of Cosmic Rays. H. W. BOEHMER AND J. E. COOLIDGE, *Pennsylvania State College.*—Measurements have been made of the directional intensities of cosmic radiation at Boulder, Colorado (lat. 40°N; long. 105° 16'W; alt. 5440 ft) using the dual counter telescope described in a previous publication.[1] The initial results presented here represent 20 days of observation in September and October of 1948. A total counting rate of 0.0135$\pm$0.00003 count/sec/steradian/cm^2 was observed for the vertical intensity; a hard component (>180 g/cm^2 of lead) of 0.00835$\pm$0.00004; a soft component (<90 g/cm^2 of lead) of 0.00429$\pm$0.00007. The variation of intensity with zenith angle was observed at 0°, 15°, 30°, 45°, 60°, and 75° and the total, soft, and hard components conformed to a simple cosine power function $I(\theta) = I(0)\cos\lambda\theta$ down to 60°. The 75° indications showed no such simple relation. The values of λ are 2.4$\pm$0.1, 1.77$\pm$0.01, and 1.90$\pm$0.04 for the soft, hard, and total components, respectively.

[1] H. W. Boehmer and J. E. Coolidge, Rev. Sci. Instr. **21**, 633–638 (1950).

F4. The Interaction of π-Mesons with Carbon Nuclei.* ANATOLE M. SHAPIRO. *Cornell University.*—π-mesons produced in targets placed in the Cornell synchrotron beam are focused by a double magnet system into a 12-in. cloud chamber. The mesons incident on the cloud chamber have an initial energy of 65$\pm$10 Mev. In an earlier experiment performed with this apparatus,[1] plates of several materials were placed in the chamber and the resulting interactions were studied. In the present experiment several improvements have been made and a more thorough investigation using carbon plates is in progress. To date 6180 traversals of $\frac{1}{8}$-in. carbon plates have been observed, and 28 stars of 0–3 prongs, 11 scatterings with angles greater than 75°, and 19 scatterings with angles between 20° and 75° have been found. After suitable corrections[1] this corresponds to 44 nuclear events and 13 diffraction scatterings between 20° and 75°. If the carbon nucleus were opaque to π-mesons with energy between 30 and 60 Mev, we would expect 57 nuclear events and 42 diffraction scatterings. These results indicate that carbon is only about (75$\pm$15) percent opaque. The cross sections for π^+ and π^- mesons are

equal within the present statistics. Further results will be presented.

* This work was performed under contract with the ONR.
[1] Camac, Corson, Littauer, Shapiro, Silverman, Wilson, and Woodward, Phys. Rev. **82**, 335 (1951).

F5. A New System of Autoradiography. H. J. GOMBERG, *University of Michigan.*—A new system of autoradiography, suitable for highly accurate location of radioactive tracers in organic and inorganic materials, has been developed. To detect beta-particles from radioactive inclusions within the specimens, a one micron thick layer of sulfur sensitized silver bromide crystals is grown in a collodion film directly on the surface to be studied. The point at which the beta-particles leave the surface and enter the crystal layer can be located to within one micron. The formed layer of crystals is dense so that no particle can pass through it without interacting with the layer. From a statistical study of autoradiographs produced by calibrated iodine 131 sources, two beta-particle hits are necessary to render a grain developable. However, some beta-tracks have been observed, indicating higher sensitivity for specific beta-particle energies. Background fog has been kept low by temperature control during the formation of the crystals and chemical control of the constituents. Physical development rather than chemical development is used. Where direct chemical interactions between the surface being studied and the sensitized layer occurs, a thin inert protective layer must be used. Autoradiographs of tissue specimens and of metal alloys which can be enlarged 1500 diameters have been produced.

F6. Radio-Isotope Br^{76}. S. C. FULTZ* AND M. L. POOL, *Ohio State University.*—Selenium metal was bombarded with protons of 8.3-Mev energy. Besides established activities, an activity with half-life of 17.2 hr also was present. Decay curves for electromagnetically separated particles showed strong positron activity but no negatrons with this half-life. X-rays with this half-life were observed, and the ratio of x-rays to positrons is approximately 0.7. Absorption methods reveal that the positron spectrum appears to be complex, having end points at 1.096 and 1.645 g/cm^2 or 2.25 and 3.23 Mev, and the gamma-rays have averaged energies of 1.4 Mev and possibly another around 0.6 Mev. Comparison of the induced activities with isotopic percentages, using natural Se and Se enriched with Se^{76}, showed the 17.2-hr activity to be due to Br^{76}. The reaction is (p, n). Chemical separation confirmed that the activity is due to a Br isotope. It agrees somewhat with a 15-hr activity previously reported. An activity with a 76-day half-life also was observed. It was attributed to As^{73} obtained from Se^{76} by (p, α) reaction.

* Fellow, National Cancer Institute.

F7. On the $\gamma-\gamma$-Polarization-Polarization Correlation. J. E. MACDONALD AND D. L. FALKOFF, *University of Notre Dame.*—The theory[1] of the polarization-polarization $(P-P)$ correlation of successive nuclear γ-rays showed that, unlike the directional correlation, this type of experiment could distinguish between the electric and magnetic multipole character of the γ-radiations. Later it was shown[2] that for many cases the simpler direction-polarization $(D-P)$ experiment could yield the same information. However, there remained classes of $\gamma-\gamma$-sequences as e.g. magnetic dipole–electric quadrupole, electric quadrupole–magnetic dipole, magnetic dipole –magnetic dipole, for which the $D-P$ experiment could not distinguish between the several alternative schemes. We have further developed the $P-P$ theory and shown that it is possible in *all* cases to uniquely identify the electric or magnetic character of the γ-radiations provided the over-all counting efficiencies are different and known for the respective γ-rays. We have also shown that all the numerical coefficients occurring in the $P-P$ correlation function may be expressed in terms of the coefficients (calculated or observed) for the directional correlation, thus providing an internal consistency criterion for both experiments. This simplification also makes unnecessary the explicit calculation of any new combinations of matrix elements for the $P-P$ correlation.

[1] D. L. Falkoff, Phys. Rev. **73**, 518 (1948).
[2] D. R. Hamilton, Phys. Rev. **74**, 782 (1948).

F8. A Method of Measuring Conversion Coefficients.* THOMAS B. COOK, JR., AND S. K. HAYNES, *Vanderbilt University.*—The problem of determining conversion coefficients of isomeric transitions which are not accompanied by continuous beta-spectra involves numerous uncertainties because electron and gamma-intensities must be compared. The use of scintillation spectrometers makes possible the determination of conversion coefficients by measurements involving only electron-electron and gamma-gamma-intensity comparisons. An isotope is used for which α is known from comparison of conversion and beta-spectra and whose gamma-ray energy differs little from the energy of the gamma-ray whose conversion coefficient is being measured. By duplicating the geometry, absorbers used to remove the beta-rays, and source conditions for the two isotopes, one may assume that the distortions in the two sets of data are similar and may therefore be neglected in comparing the two sets of data. If the above conditions are satisfied, the calculation of the unknown conversion coefficient essentially involves a comparison of the areas under the two conversion lines, the heights of the Compton distributions produced by the two gamma-rays, and the known conversion coefficient. The measurement of α for the 390-kev transition in In^{113} by this method will be discussed.

* Supported by the Research Corporation and the AEC.

F9. Deuteron-Induced Reactions with a LiF Target.* FRANKLIN B. SHULL, *Washington University.*—Incomplete preliminary results have been obtained from magnetic analysis of charged particles from 10.3-Mev deuteron bombardment of LiF targets. Particles are observed at 90° from the incident beam and detected with photographic emulsions. Proton group from the $F^{19}(d, p)F^{20}$ reaction give tentative Q-values (in Mev) of 4.55, 3.86, 3.57, 2.35, 1.85, 1.43, 0.81, and 0.14. Two or more poorly-resolved groups give additional Q-values in the range 2.8 to 3.3 Mev. Four pronounced deuteron peaks correspond to Q-values of 0 and -0.48 Mev for $Li^7(d, d')Li^7$ and Q-values of 0 and -1.52 Mev for $F^{19}(d, d')F^{19}$. Additional unresolved deuteron groups seem to be present. At the time of writing this abstract, respectable numbers of tritons are being found which have approximately the energy expected if they are attributed to the $Li^7(d, t)Li^6$ and $F^{19}(d, t)F^{18}$ reactions. The triton analysis is slow and tedious, but it is hoped that definite results can be presented at the meeting.

* Supported by the joint program of the ONR and AEC.

F10. Neutrons from the Deuteron Bombardment of O^{16}.* FAY AJZENBERG, *University of Wisconsin.*—A thin tungsten oxide target was bombarded by 3.083-Mev deuterons from the Wisconsin electrostatic generator. The neutron spectrum was observed by means of Eastman NTA nuclear emulsions, 100 microns thick, mounted at 10 cm from the target, and at angles of 0°, 10°, 20°, 30°, and 90° to the beam. A total of 800 proton recoil tracks have been measured so far. These preliminary measurements indicate a level at 0.55 ± 0.02 Mev above the ground state of F^{17}. The intensities of the neutron groups as a function of angle, if interpreted on a stripping hypothesis,[1] favor $L=0$ deuterons producing the first excited state (and hence an $S_{1/2}$ state), but do not distinguish clearly between $L=1$ and $L=2$ deuterons for the ground-state transition. Mirror nuclei arguments predict that the ground state of

F^{17} should be the same as the ground state[2] of O^{17} and hence $D_{5/2}$. The present data are consistent with such an assignment.

* Supported by the AEC and the Wisconsin Alumni Research Foundation.
[1] S. T. Butler, Phys. Rev. **80**, 1095 (1950).
[2] F. Alder and F. C. Yu, Phys. Rev. **81**, 1067 (1951).

F11. Classification of Levels in N^{13}.* H. L. JACKSON† AND A. I. GALONSKY, *University of Wisconsin.*—Goldhaber and Williamson's data[1] for elastic proton scattering from C^{12} has been investigated by partial wave analysis, using Laubenstein's[2] technique. The analysis indicates that the first resonance (0.484-Mev bombarding energy) is due to an $S_{1/2}$ level in N^{13} with excitation energy $E_r=2.373$ Mev. The second resonance (1.73-Mev bombarding energy) results from a $P_{3/2}$ and a $D_{5/2}$ level with 3.503 and 3.550 Mev, respectively. The reduced widths of the $S_{1/2}$ and $D_{5/2}$ levels are comparable to the Wigner limit, but that of the $P_{3/2}$ level is much less. It is fairly certain that no other reasonable assignment explains the experimental data. Since the absolute cross section is in doubt to about ±30 percent, the interaction radius is somewhat arbitrary. Consequently, the numerical values of E_r and γ^2 may be slightly in error. However, to obtain a reasonable fit of the data, the interaction radius must be approximately $1.45(A^{\frac{1}{3}}+1^{\frac{1}{3}})\times10^{-13}$ cm. Below 1.0 Mev the experimental cross section is progressively less than that calculated. The discrepancy may result from a loss of detector efficiency at low energies.

* Work supported by AEC and Wisconsing Alumni Research Foundation.
† Kimberly-Clark Predoctoral Fellow.
[1] Goldhaber and Williamson, Phys. Rev. (to be published).
[2] R. A. Laubenstein, Ph.D. thesis, University of Wisconsin, 1950.

F12. The Systematics of Nuclear *Q*-Values. ALEX E. S. GREEN AND ROBERT B. MINOGUE, *The University of Cincinnati.*—The nuclear *Q*-values derived from nuclear energy surface may be computed simply and systematically if certain key functions of the mass number are known. The key functions associated with the semi-empirical nuclear energy surface and a far simpler modified set of key functions will be presented. A survey of experimental and computed neutron binding energies and alpha-decay energies will be presented. This survey reveals a serious breakdown of the semi-empirical surface for heavy elements. The significance of the breakdown and the nature of the true surface will be discussed.

FRIDAY AFTERNOON AT 2:00

Knolls Auditorium

(V. ROJANSKY presiding)

G1. Odd-Even Variations in Nuclear Resonances. H. HURWITZ, *Knolls Atomic Power Laboratory.* (20 min.)

G2. Photoelectric Disintegration of Nuclei. J. S. LEVINGER, *Cornell University.* (30 min.)

G3. Renormalization of Theories of Spin-Zero Particles. ABDUS SALAM AND P. T. MATTHEWS, *Institute for Advanced Study.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Knolls 441

(L. APKER presiding)

Optical Properties of Solids; Thin Films; Electron Physics

H1. Infrared Properties of Tellurium.* J. J. LOFERSKI AND P. H. MILLER, JR., *University of Pennsylvania.*—The transmission of tellurium crystals (about 99.9 percent pure) in the infrared was observed, and the absorption edge was found to lie at 4.2 microns. A polished sample, 0.067 cm thick, transmits 25 percent of the incident energy in the range from 4.5 to 10 microns, in which range the transmission remains fairly constant. The same material exhibited a small photoconductivity at room temperature. For an incident energy of 10^{-4} watt and a wavelength of 2.0 microns, ΔI was $\sim3\times10^{-8}$ amp with a dark current of 15×10^{-3} amp. A signal which was three times the rms noise was still detectable at 4.0 microns. The effect of dilating the lattice by subjecting the samples to pressure and by doping them with considerable amounts of selenium will be discussed.

* Assisted by ONR.

H2. Energy Level Relationships in the Thallium Activated Potassium Chloride Phosphor. PETER D. JOHNSON AND FERD E. WILLIAMS, *General Electric Research Laboratory.*—Thallium activated potassium chloride exhibits[1] absorption bands at 1960A, 2060A, and 2460A and emission bands at 3050A and 4750A. Measurements of the intensities of the emission bands as a function of excitation wavelength and temperature elucidate the configurational relationships among the unexcited and excited states of the activator. The 4750A emission is favored by 1960A and 2060A excitation. The 3050A emission and 2460A excitation are similarly related, as indicated theoretically.[2] In addition, however, there is a tendency toward thermal equilibrium between the two emitting states which differ in energy by 0.02 ev. This effect results in the 4750A emission increasing at the expense of the 3050A emission at low temperatures. At high temperatures the decrease in efficiency of 3050A emission indicates an activation energy of 0.6 ev for radiationless de-excitation, in satisfactory agreement with 0.69 ev obtained from the intersection of the theoretical potential energy contours for the emitting and ground states. The quantitative analysis of these data, including the

identification of the excited states and the evaluation of the rate constants and transition probabilities, will be presented.

[1] R. Hilsch, Z. Physik **44**, 860 (1927); P. D. Johnson and F. E. Williams, J. Chem. Phys. **18**, 1477 (1950).
[2] F. E. Williams, Phys. Rev. **80**, 306 L (1950); J. Chem. Phys. **19**, 457 (1951).

H3. Theoretical Low Temperature Spectra of Luminescent Solids. FERD E. WILLIAMS, *General Electric Research Laboratory.*—A fundamental calculation of the absorption and emission spectra of thallium activated potassium chloride has been reported.[1] The quantum-mechanical zero point energies responsible for the broad spectral bands at low temperatures have been computed recognizing that the interaction with the lattice of the unexcited or excited activator is accurately in accord with the characteristics of a hormonic oscillator. The theoretical absorption spectrum,[2] evaluated from exact Hermite polynomial wave functions for the ground state and classical treatment of the excited state, has been confirmed experimentally.[3] The classical treatment is equivalent to the use of delta-functions. The use of Hermite polynomial wave functions for the final state is not feasible because vibrational quantum numbers between 35 and 65 are involved. Approximate wave functions have been investigated, and the importance to the spectrum determination of oscillations in extended wave functions has been demonstrated. The interpretation of the properties of luminescent centers from experimental low temperature absorption and emission spectra will be discussed in terms of principles derived from these calculations.

[1] F. E. Williams, Phys. Rev. **80**, 306 L (1950); J. Chem. Phys. **19**, 457 (1951).
[2] F. E. Williams, Phys. Rev. **82**, 281 L (1951).
[3] P. D. Johnson and F. J. Studer, Phys. Rev., to be published.

H4. Transparent Luminescent Films. F. J. STUDER, D. A. CUSANO, AND L. R. KOLLER, *General Electric Research Laboratory.*—A method has been found for depositing transparent luminescent coatings of various materials on glass, by means of vapor phase reactions at the heated glass surface. The best of these so far studied is manganese activated zinc sulfide which gives a yellow-orange luminescence. These coatings are produced by allowing a stream of zinc vapor, with a small amount of manganese chloride, to pass over a heated glass surface in an atmosphere of hydrogen sulfide. The thickness of the coatings is determined by the time the reaction is allowed to continue. These films respond to cathode rays only or to both cathode rays and ultraviolet, according to the conditions of preparation. The emission spectrum and the optical absorption coefficients of these films will be discussed. The penetration of electrons into these films has been studied by means of measurements of the voltage brightness relation under cathode-ray excitation at voltages up to 40 kv. The maximum depth of penetration is in fair agreement with the theoretical value. The shape of the curves indicates that the scattering of electrons in the films is large.

H5. Oxide Films on Sodium Surfaces. JAMES W. MOYER, *Knolls Atomic Power Laboratory.*—The rate of oxidation at a surface of sodium at room temperature has been found to depend markedly on the presence of small amounts of inert gas mixed with the oxygen. Using very pure oxygen, the rate is very low and a white layer of Na_2O is formed. With a small amount of nitrogen present, the rate is very high and colored films of oxide appear. The rate may be suddenly lowered in the latter case, however, by raising the oxygen pressure. Warming the sodium to about 90°C will restore the fast reaction rate. Some properties of the oxide films will be discussed as well as the mechanism for the oxidation.

H6. The Absorption of N_2 on W as a Function of Pressure, Temperature, and Time. J. A. BECKER AND C. D. HARTMAN, *Bell Telephone Laboratories.*—The amount of N_2 adsorbed on a clean 100 W surface held at a fixed temperature in N_2 gas for variable time, is determined by measuring the pressure rise when the W ribbon is flashed at 2300°K. The number of layers adsorbed, θ, is plotted *versus* time. For 600°K, and gas pressures less than 10^{-7} mm: θ increases linearly with time up to $\theta=0.6$; then $d\theta/dt$ decreases and approaches zero beyond $\theta=1$. The initial value of $d\theta/dt$ is proportional to the pressure. For pressures near 10^{-6} mm: θ reaches 1 in 8 seconds; then $d\theta/dt$ decreases rapidly and approaches zero when $\theta=1.7$. For pressures near 10^{-5} mm: $\theta=1$ in 4 seconds, $\theta=2$ in 60 seconds; then $d\theta/dt$ decreases rapidly toward zero. For 300°K, 3 to 4 layers can be adsorbed. From these data one can compute the probability, s, that a molecule which strikes the surface sticks to it. For $\theta<0.6$, s is about 0.3; then it decreases linearly to 0.02 near $\theta=1$; beyond this, s decreases to 0.0004 at $\theta=2$.

H7. A Mass Spectrometric Study of the Activation of Barium Oxide Cathodes.* PAUL M. STIER,† *Cornell University.*—A study of the activation of cathodes, prepared by decomposition of pure barium carbonate on platinum, has been carried out using a mass spectrometer whose ion source was similar to those of Dart[1] and Plumlee.[2] As the cathode temperature was raised, the intensity of ion peaks sensitive to cathode conditions were monitored cyclicly. The resulting CO^+ and CO_2^+ ion peaks were plotted as functions of time during cathode heating. Corrections were made for CO_2 dissociation by the ionizing electron beam, as determined by admitting CO_2 under the same operating conditions. Just prior (temperaturewise) to the carbonate breakdown and also during the rise of emission, significant quantities of CO were evolved by the cathodes. The lower temperature release is believed to be the result of outgassing from the porous $BaCO_3$ as well as partial oxidation of the binder residue. The CO evolved as the emission commences may be the result of reduction of BaO by residue carbon and amounts to nearly 10^{20} molecules/cc of BaO. Possible interpretation will be discussed.

* This paper is based on a thesis submitted in partial fulfillment of the requirements for the degree of Ph.D. in Physics at Cornell University, Ithaca, New York. It was supported in part by ONR.
† Now at the Oak Ridge National Laboratory, Oak Ridge, Tennessee.
[1] F. E. Dart, Phys. Rev. **78**, 761 (1950).
[2] R. N. Plumlee and L. P. Smith, J. Appl. Phys. **21**, 811 (1950).

H8. An Analysis of the Bioelectric Action Potentials Produced in the Lobes of Venus' Flytrap by Mechanical Stimulation. OTTO STUHLMAN, JR., *University of North Carolina.*—The slow electrical transients were subjected to dc amplification and photographically recorded from a Dumont oscillograph. Electrical contact with the epidermis of the leaf was established with nonpolarizable Ag−AgCl electrodes which terminated in microcontacts of asbestos fibers saturated with 0.7 percent KCl solution. Closure of the trap-like structure normally followed when any one or all of the spike-like trigger hairs on the inner surface of the trap were bent. This mechanical external stimulus was found to set up an electrical transient that traveled across the surface of the leaf at about 3.0 cm per second, depending on temperature and age of the leaf. The evidence tends to support the hypothesis that the complex negative action potential, about 0.05 volt at 25°C, originates at the point of mechanical stimulation and spreads as an electrical wave front over the surface of the leaf. The contour of the pulse was separable into two components: one attributed to the progressive depolarization of the cell structure, and the other to an accompanying electrolytic displacement causing the mechanical closure of the trap. The latter lagged or lead the former, depending on the relative positions of the electrodes on the surface of the leaf.

H9. Decay of Metastable Neon Atoms in the Afterglow of a Helium-Neon Discharge.* F. A. GRANT, *University of*

Maryland (Introduced by Raymond Makgan).—Using previously described techniques,[1] the decay of the population of $^3P_2$ metastable neon atoms has been measured in the afterglow of a helium-neon discharge. After the interruption of the electrical discharge, a beam of monochromatic radiation of wavelength 5945A was passed through the discharge tube, and the intensity of the transmitted radiation was measured with a photomultiplier tube. The absorption of the radiation is a measure of the population of $^3P_2$ neon atoms. Measurements have been made in the pressure range 0.1 to 2 mm of Hg using mixtures containing 5 percent to 100 percent neon.

* Supported by contract.
[1] F. A. Grant, Can. J. Research **A**, **28**, 339–358 (1950).

H10. The Use of Probes to Study a Pulsed Mercury Arc Plasma.* B. T. McCLURE AND R. B. HOLT, *Harvard University.*—The short time response of conventional probes in mercury arc plasmas has been investigated. All evidence indicates that the probe response to plasma conditions attains an equilibrium value in less than a microsecond. Such probes have been used in order to observe changes in electron density, plasma potential, electron temperature, etc., in a plasma of an arc which is maintained at a low value of current and pulsed to a much higher value for 30 microseconds. Complete probe characteristics are taken by applying to the probe a 2-microsecond pulse which is adjustable in height and in phase relative to the arc pulse. The electron temperature increases gradually during the arc pulse and decreases abruptly following it. The electron density begins increasing toward the end of the 30-microsecond arc disturbance and returns to its equilibrium value some time later. Various other properties of the pulsed plasma have been noted and will be reported.

* Assisted by the ONR.

H11. Quantum Effects in the Interaction between Free Electrons and Radiofrequency Fields. CARL SHULMAN, *RCA Laboratories and Princeton University.*—The quantum nature of the exchange of energy between free electrons and electromagnetic fields implies a dispersion in energy exchange which the classical theory cannot predict. L. P. Smith[1] has shown that the standard deviation in the number of photons exchanged is proportional to the square root of the number of photons handled by an interacting electron, while the mean expected, or classical exchange, is proportional to the total number handled. This quantum dispersion was detected by observing the increase in the apparent temperature T of a high velocity beam which was allowed to interact with a strong longitudinal oscillating electric field at $\lambda = 1.25$ cm, such that the standard deviation arising from quantum processes was at least of order kT, while the mean exchange was held small by adjusting the exchange time to an integral number of cycles.

[1] L. P. Smith, Phys. Rev. **69**, 195 (1946).

FRIDAY EVENING AT 7:00

Hotel Van Curler

(J. H. VAN VLECK presiding)

Banquet of the American Physical Society

Cloud Physics. VINCENT J. SCHAEFER, *General Electric Company.*

SATURDAY MORNING AT 9:30

Union College, Chemistry Lecture Hall

(V. C. WILSON presiding)

I1. Principles of Optical Detection of Radiofrequency Resonance in Excited States and Ground States of Atoms and Ions. A. KASTLER, *Ecole Normale Superieure.* (20 min.)

I2. Optical and Radiofrequency Double Resonance. F. BITTER, *M.I.T.* (20 min.)

I3. Survey of Experimental Data on π-Mesons. ARTHUR ROBERTS, *University of Rochester.* (40 min.)

I4. Production of Neutral Mesons by Gamma-Rays. K. A. BRUECKNER, *Institute for Advanced Study.* (30 min.)

SATURDAY MORNING AT 10:00

Union College, Physics Lecture Hall

(R. N. HALL presiding)

Semi-Conductors Mostly

J1. The Specific Heat of Graphite from 13°K to 300°K. W. W. TYLER AND W. DESORBO, *Knolls Atomic Power Laboratory and General Electric Research Laboratory.*—The specific heat of high purity Acheson type graphite prepared by the National Carbon Company has been measured from 13°K to 300°K. Curves showing temperature dependence of C_p will be presented and compared with data of Nernst[1] (25.8–92.6°K), Magnus[2] (44.1–1100°K), and Jacobs and Parks[3] (93.3–

293.5°K). In the region 13–40°K the C_p data follows a $(T/\theta)^2$ dependence quite accurately in agreement with Gurney's theory.[4] The value of θ obtained is 608°K. The derived thermodynamic functions have been determined by graphical integration and tabulated at integral values of the temperature up to 300°K. $S^0_{298.16}=1.371\pm0.005$ E.U. of which 0.004 E.U. is extrapolated from 13°K to 0°K assuming the third law and the T^2 dependence. Jacobs and Parks' value of 1.36 E.U. at 298.1°K had been obtained using graphical integration of their data from 90°K to 298.1°K and a T^3 extrapolation from 90°K to 0°K with the aid of Nernst's data.

[1] W. Nernst, Ann. Physik **36**, 395 (1911).
[2] A. Magnus, Ann. Physik **70**, 303 (1923).
[3] C. J. Jacobs and G. S. Parks, J. Am. Chem. Soc. **56**, 1513 (1934).
[4] R. W. Gurney, unpublished work.

J2. Resistivity of Heat-Treated Germanium between 11°K and 298°K. W. DESORBO AND W. C. DUNLAP, JR., *General Electric Research Laboratory.*—Two single crystals of germanium that had been made *P*-type by heat treatment have been studied in the temperature range between 11°K and 298°K. The samples were originally 5.3 and 5.8 ohm cm *N*-type, and were quenched in oil after having been heated in vacuum for one-half hour at 850°C. The resistivity reached a minimum at about 78°K, then rose by a factor of 1000 as the temperature was lowered to 11°K. The rise in resistivity between 78°K and 30°K was approximately exponential. An activation energy $\Delta\epsilon$ of about 0.12 ev was found from the relation $\rho=\rho_0 e^{\Delta\epsilon/kT}$. Below 30°K the resistivity change was equivalent to an activation energy of the order 0.003 ev. The activation energy 0.12 ev is considerably larger than values (~0.01) found by several authors[1,2] for impurity acceptors in germanium. We conclude that heat treatment introduces a different type of acceptor state into germanium, probably a lattice defect.

[1] G. L. Pearson and W. Shockley, Phys. Rev. **71**, 142 (1947).
[2] C. S. Hung and J. R. Gliessman, Phys. Rev. **79**, 726 (1950).

J3. Scattering by Ionized Impurities in Semiconductors. HARVEY BROOKS, *Harvard University.*—The fourier coefficients of the potential fluctuations in a semiconductor arising from a random distribution of ionized impurities have been obtained by two methods. The first is a modification of the Fermi-Thomas method for finite temperatures, introduced by Slater and James. The second is a Hartree self-consistent field method similar to that used by Bardeen in discussing the conductivity of the alkali metals. The two methods give the same results provided the density of impurities is substantially less than 10^{18} per cm^3 and the fluctuations are not larger than kT. The results were used to compute the electrical resistivity arising from impurity scattering. The formula agrees with that of Cornwell and Weisskopf except for the argument of the logarithmic factor, which is multiplied by $\gamma=(e^2/12\pi Kd)/(K^2/2md^2)$, where d is the mean distance between impurities. This factor is of order unity for practical cases but may be larger with both donors and acceptors present.

J4. Ionic and Electronic Conduction in Silver Sulfide. M. H. HEBB, *General Electric Research Laboratory.*—The mixed electronic and ionic conduction in silver sulfide is examined from the standpoint of Wagner's theory.[1] It is shown that the electric field in the experiments by Tubandt[2] is zero and that the ionic current there arises entirely from the gradient in chemical potential ζ. Published conductivity data together with free energies of formation are used to show that the electronic conductivity varies as $\exp B\zeta$. The coefficient B changes abruptly from e/kT for β-silver sulfide below 177°C to $e/2kT$ for the α-form above. This is attributed to the sudden freeing at the phase transition of electrons from excess silver atoms. Experiments in which ionic conduction was suppressed give potential distributions in excellent agreement with the theory.

[1] C. Wagner, Z. physik. Chem (B) **21**, 25 (1933).
[2] C. Tubandt, Handb. exp. Phys. XII/1 (1932).

J5. Electrical Conductivity of Compressed Semiconducting Powders, in Particular of Zinc Oxide. J. C. M. BRENTANO AND COLMAN GOLDBERG,* *Northwestern University.*—The relation between conductance, time, and pressure was examined for compressed Al_2O_3 and ZnO powders. To determine the effect of moisture powders were heated in a desiccator to 130°C and handled under protective coatings. They gave the current-time dependencies previously observed.[1] After heating in high vacuum the current-time dependency disappeared, indicating removal of an otherwise stable surface film. For low pressures the conductance of ZnO increases with increased pressure. Above 2000 psi to 38000 psi it decreases, its logarithm decreasing approximately linearly with increasing pressure. The proportionality constant depends on the maximum pressure previously applied. This pressure effect is reversible. A slow time decay of conductance, extending over several hours, occurs after each sudden pressure change. This conductance behavior is determined by the contact areas of the particles increasing rapidly for small and slowly for large pressures, by the pressure dependency of activation energy (Bardeen) and by the lifting of electrons into the conduction band when lattice breaks occur. The theoretical treatment is given more fully by one of us (Goldberg) in his Doctoral dissertation (Northwestern, 1951).

* Milwaukee Gas Specialty Company Fellow.
[1] J. C. M. Brentano and D. H. Davis, Phys. Rev. **79**, 216 (1950).

J6. Effect of the Probe Metal in Locating a $p-n$ Barrier in Germanium. FRIEDA A. STAHL, *Sylvania Electric Products, Inc.*—In studying $p-n$ barriers in germanium, the inversion line determined by exploring with a narrow beam of light does not coincide with lines determined by probing with metal whiskers. Furthermore, the apparent location of the inversion depends upon the metal using in probing. Referred to the junction location found by a 0.1-mm light spot, all inversion locations determined by metals fall in a fixed order on the p-type side. The series thus far established, proceeding outward from this reference, is as follows: Al, phosphor bronze, W, Cu, Mo; other metals, including Ni, Pt, and Ta, are being studied. The distance between the reference junction location and the inversion location determined by a given metal appears to be proportional to the barrier width, within the limits of experimental error.

J7. The Effects of Pressure and Temperature on the Resistance of $p-n$ Junctions in Germanium.* HARRY H. HALL, *University of New Hampshire*, J. BARDEEN AND G. L. PEARSON, *Bell Telephone Laboratories.*—According to Shockley's theory,[1] the low voltage resistance, R_0 of a $p-n$ junction is proportional to $\exp(E_G/kT)$, where E_G is the energy gap. Measurements of the change with pressure of the characteristics of a junction in a single crystal of germanium indicate a change $\Delta R_0/R_0$ of 12.5 percent, corresponding to a change ΔE_G of about 3.1×10^{-3} ev, for a pressure change of 10,000 lb/in.[2] Analysis of measurements made at temperatures between 16.5°C and 20.5°C give values of E_G averaging about 0.72 ev. These values are in agreement with those obtained from the change in intrinsic resistivity with temperature and pressure.[2]

* Supported in part by the Bureau of Ordnance of the Navy.
[1] W. Shockley, Bell System Tech. J. **28**, 435 (1949).
[2] P. H. Miller and J. Taylor, Phys. Rev. **76**, 179 (1949) and Julius H. Taylor, Phys. Rev. **80**, 919 (1950).

J8. The Crystal Structure of Tetragonal Barium Titanate. HOWARD T. EVANS, JR., AND REINA A. HUTNER, *Philips Laboratories, Inc.*—A detailed crystal structure study of

tetragonal barium titanate has been carried out with diffraction intensities measured at room temperature. Integrated intensities have been measured on a single crystal $0.16\times0.19\times0.07$ mm using a Weissenberg camera on which has been mounted a Geiger counter. 99 reflections ($h0l$) have been measured using MoKα radiation. The best fit of calculated and observed intensities is obtained with the atoms located in the space group $P4$ mm as follows: Ba(0, 0, 0); Ti($\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$ +0.015); O_I($\frac{1}{2}$, $\frac{1}{2}$, −0.024); $2O_{II}$($\frac{1}{2}$, 0, $\frac{1}{2}$, −0.020), (0, $\frac{1}{2}$, $\frac{1}{2}$, −0.020). The Ti−O_I distances are 1.860 and 2.174A. A good approximation to the true structure consists of assuming the cubic oxygen lattice undistorted, and considering the barium and titanium ions displaced in the same direction along the z axis, the former by 0.10A, and the latter by 0.16A. Using this model, equations have been set up involving the spontaneous polarization, the local fields on each atom, the electronic polarizabilities of each atom, and the ionic polarization of the barium and titanium ions. From experimental and estimated values of these, the ionic charge of the titanium ion is determined to be about +0.4, if the barium charge is assumed to be +1.8.

J9. Kinetics of Solidification of Mercury Droplet Aggregates. DAVID TURNBULL, *General Electric Research Laboratory.*—Previous experiments[1] showed that the temperature coefficient of the solidification of stearate coated mercury droplets is in reasonable agreement with nucleation theory. However the isothermal rate constants for solidification could not be described satisfactorily in terms of the measured distribution of particle sizes. We have found that mercury droplets, ranging in diameter from 2 to 7 microns, when coated with a laurate film solidify at a conveniently measurable rate in the temperature range −117° to −120°C. Rates of solidification of the droplet aggregates were measured at various constant temperatures in the range −117 to −120°. The rates were described precisely in terms of the measured particle size distribution on the basis that the nucleation frequency, I, is proportional to the volume of the droplets. I is related to temperature, T, and the supercooling ΔT by the equation: $I=10^{42.1}\exp[-8.0\times10^{7}/T(\Delta T)^2]$ cm^{-3} sec^{-1}. The measured factor $10^{42.1}$ is in fair agreement with the value 10^{36} predicted by nucleation theory.

[1] D. Turnbull, J. Chem. Phys. **18**, 768 (1950).

J10. A Direct Experimental Verification of Kelvin's Relation between Vapor Pressure and Droplet Curvature. VICTOR K. LA MER AND RUTH GRUEN, *Columbia University.*—Although Kelvin's relation (1871) predicting the increase in vapor pressure with increasing curvature is basic to colloid science; e.g. phenomena of capillarity, kinetics of phase transitions, production and stability of colloidal systems, etc., no unambiguous direct experimental confirmation has ever been obtained. Indirect tests on rate of evaporation in falling drop experiments (Woodland and Mack, J. Am. Chem. Soc. **55**, 3149 (1933)), are open to question due to the effect of surface film impurities. The quantitative acceptance of this fundamental law rests upon the thermodynamic cogency of the Gibbs-Poynting type of derivation, and the success of theories based upon it. Recently, we have extended the growth method of determining the radii of droplets in the sub-Tyndall region (see La Mer, Inn, and Wilson, J. Colloid Sci. **5**, 471 (1950), where 99 percent H_2SO_4 droplets are grown under controlled conditions over $H_2SO_4-H_2O$ master solutions) to D. O. P. (dioctyl phthalate) aerosols using toluene as the volatile growth producing component as well as oleic acid aerosols with chloroform as the volatile component. The large molecular volume of these solvents magnifies the Kelvin effect as compared to water. Excellent quantitative confirmation of the equation has been obtained by equilibrium methods.

SATURDAY MORNING AT 10:20

Union College, Electrical Engineering Lecture Hall

(J. H. VAN VLECK presiding)

Microwave Spectroscopy; Theoretical Physics

K1. A New Type of Hyperfine Structure in the NH_3 Microwave Spectrum. W. E. GOOD* AND D. K. COLES, *Westinghouse Research Laboratory*, G. R. GUNTHER-MOHR, A. L. SCHAWLOW, AND C. H. TOWNES, *Columbia University.*†—The $K=1$, $J=2$, 3, 4 and 5 lines of the inversion spectrum of $N^{14}H_3$ have been found to split into two slightly unequal components. The amount of splitting increases as J increases, representative values being 100 to 200 kc/sec. Satellites of these lines due to effects of the N^{14} quadrupole moment also split in approximately the same way. This new type of splitting is not primarily dependent on the nitrogen nucleus, since a similar splitting is observed in $N^{15}H_3$. In the cases examined closely, the weaker component of the double lines is on the low frequency side for odd J and on the high frequency side for even J, becoming more nearly equal to the stronger component for the larger values of J. No splitting of this type has been found for $K\neq1$. These observations are apparently satisfactorily explained as a new type of effect due to magnetic coupling between the protons and the molecular fields (see following abstract).

* Now at General Electric Research Laboratory.
† Work supported by the AEC.

K2. Theory of the Hyperfine Splitting of the Levels $K=1$ in NH_3. J. H. VAN VLECK, *Harvard University.*—A theoretical basis is developed for the doubling of the levels $K=1$ of ammonia observed experimentally as described in the preceding paper. The mechanism is one proposed to the writer by Professor Townes, and consists in the interaction of the spins of the protons with the off-diagonal elements of the orbital angular momentum, along with perturbations caused by molecular rotation. The K-degeneracy is lifted because the local fields at the various H nuclei differ from each other by 120° in orientation, and so do not have as much isotropy as the symmetrical top. The calculation is made by the Dirac vector model, and requires no group theory. Expressions for the splitting are complicated by the coupling of N^{14} or N^{15} to the NH_3 molecule. For large J, the splitting is approximate proportional to $2J+1$.

K3. Measurement of the Microwave Inverstion Spectrum of ND_3. R. G. NUCKOLLS, L. J. RUEGER, AND H. LYONS, *National Bureau of Standards.*—Measurement of the inversion spectrum of ND_3, previously reported[1] between 2094 and 2533 Mc, has been extended to below 1600 Mc. The main $K=J$ series of absorption lines has been identified and has its low

frequency limit at approximately 1600 Mc. This frequency is to be compared with the figure 2000 estimated by Weiss and Strandberg,[2] and 1600 estimated by Townes.[3] The apparent intensity distribution is shifted to higher J, K, values than for NH_3, as expected.

A newly designed Stark-modulation 10-ft coaxial absorption cell ($\frac{3}{4}$-in$\times\frac{5}{16}$-in. radii) was used with special wave guide transformer sections. Frequencies were read to 0.01 Mc, using a frequency multiplier system based upon the NBS 100-kc primary frequency standard, and are believed accurate to better than 0.1 Mc.

[1] Lyons, Rueger, Nuckolls, and Kessler, Phys. Rev. **81**, 630 (1951).
[2] M. T. Weiss and M. W. P. Strandberg, Phys. Rev. **81**, 286 (1951).
[3] C. H. Townes, private communication.

K4. Far Wing Absorption of Atmospheric Spectrum Lines. T. F. ROGERS, *Air Force Cambridge Research Laboratories.**—Certain measurements of microwave absorption lines during and immediately after the last war implied that the Van Vleck-Weisskopf equation predicts too low an absorption value, by a factor of about 5, in the line far wings. In consequence, the recent literature tends to conceive of a statistical rather than an impact, model for absorption in frequency regions remote from resonance, inasmuch as it predicts absorption values which decrease less rapidly away from resonance. Detailed consideration of recent experimental work, however, allows a reassessment of both the accuracy of the earlier measurement details and certain assumptions underlying parameter values then used in the impact equation. Absolute intensity measurement errors, multiple-line fine-structure influence, dipole moment value, and line-to-line variation in half-width values are possible sources of error. These, coupled with recent measurements over extremely wide frequency ranges, indicate that the assumed experimental-theoretical discrepancies are inconclusive, and that the Van Vleck-Weisskopf impact equation has not been shown to be invalid for atmospheric gases at pressures equal to or less than one atmosphere.

* Now at the Massachusetts Institute of Technology.

K5. Microwave Collision Diameters. J. WEBER, *U. S. Naval Ordnance Laboratory and University of Maryland.**—In the course of a microwave spectroscopy investigation of the isotopic exchange reaction betweeen ammonia and deuterium[1] the microwave collision diameters of several molecules were measured and compared with the microwave collision diameters of the corresponding isotopically substituted molecules. Results are presented and compared with what one might expect on the basis of collision broadening theory. The previously reported variation of collision diameter with mix ratio was not observed.

* Department of Electrical Engineering.
[1] J. Chem. Phys. (to be published).

K6. Radiation from Hyperfine Levels of Interstellar Hydrogen.* H. I. EWEN AND E. M. PURCELL, *Harvard University.*—The hyperfine transition in the ground state of atomic hydrogen ($\nu_H = 1420.405$ Mc/sec)[1] has been detected in galactic radiation. The hydrogen is apparently an extended source concentrated in the plane of the local galaxy. Measurements were made at a declination of $-5°$ with an antenna beam width of approximately 30°. The line as measured in the vicinity of the galactic center appears in emission with a temperature difference of $40°\pm5°$C with respect to the radiation field and with a width of approximately 80 kc. The line shows a doppler shift which can be explained by the earth's orbital motion and the motion of the solar system. Evidence that the source is extended is provided by the variation of doppler shift during the time of observation.

The apparatus, consisting essentially of a superheterodyne receiver and large horn type antenna, differs from a conventional radiometer by comparing the radiation temperature of the line with the background temperature in the same spectral region.

* Assisted by a grant from the Rumford Fund, American Academy of Arts and Sciences.
[1] A. G. Prodell and P. Kusch, Phys. Rev. **79**, 1009 (1950).

K7. Interaction of Electronic States with the Rotation Spectrum.* B. V. GOKHALE, H. R. JOHNSON, M. W. P. STRANDBERG, *M.I.T.*—The rigid rotor idealization is used as a first approximation in the analysis of rotational spectra, but high resolution microwave spectroscopy has forced consideration of the interaction of vibration with rotation. In this paper, we treat the remaining interaction, that of the electronic states with rotation, theoretically, but with the result in terms of experimentally measurable quantities. The main results are two: A useful first approximation to the interaction for molecules made up of heavy nuclei is rigorously shown to be accomplished by replacing nuclear with atomic masses; the remaining fractional correction in the reciprocal moment of inertia tensor is the magnetic g gactor tensor in molecule fixed axes expressed in Bohr magneton units, $e/2mc$. As an example of the order of magnitude of this correction, we consider the molecule O=C=S. Changing from nuclear to atomic masses causes a decrease in the calculated O=C distance of 0.000158A and in the C=S of 0.000212A. Introduction of the measured $g_{bb}=g_{cc}=-0.025\pm0.002$ gives a further decrease in O=C of 0.000008A and in C=S of 0.000011A. These small quantities are frequently an order of magnitude larger than the estimated, experimental error due to the frequency measurement, although small compared to vibration interaction terms.

* This work has been supported in part by the Signal Corps, Air Materiel Command, and ONR.

K8. Diatomic Homonuclear Molecules in Magnetic Fields. NORMAN F. RAMSEY, *Harvard University.*—The hamiltonian of a $^1\Sigma$ diatomic homonuclear molecule in a magnetic field is discussed. Included in the hamiltonian are the effects of the nuclear and rotational magnetic moments interacting with the external magnetic field, magnetic shielding, molecular diamagnetism, the spin-spin magnetic interaction of the two nuclei, the interaction of the nuclear magnetic moments with the field due to the rotation of the molecule, the interaction of nuclear electric quadrupole moments, and nuclear polarizability. Perturbation theory expressions for the energy of H_2 and D_2 in the first rotational state are obtained in both strong and weak field limits. The secular equation is numerically solved for intermediate fields. Curves are given showing the theoretical dependence of the energy and the transition frequencies upon the field.

K9. A New Electric Field Design for the Molecular Beam Electric Resonance Method.* J. W. TRISCHKA, J. SWARTZ, AND R. LUCE, *Syracuse University.*—In the electric resonance method of molecular beam spectroscopy transitions are observed at radiofrequencies between the Stark levels of a single rotational state of a diatomic molecule.[1] One of the important factors contributing to broadening of the lines observed by this method is the inhomogeneity in the electric field used to produce the Stark splitting. Formerly fields uniform to 1 part in 2000 have been obtained between two condenser plates made of brass. In the present design two glass plates are coated with an almost opaque thickness of Al and separated by glass spacers. Optimum parallelism of the plates is obtained by observation of the Haidinger fringes produced when Na light is transmitted through the structure normal to the surfaces. With $\frac{1}{4}$-in. spacers and selected pieces of plate glass a field uniform to 1 part in 3500 was obtained. By making use of optical flats it should be possible to improve the uniformity by a factor of ten. Measurements on the spectra of CsF will be presented to show the effectiveness of the design.

* Supported in part by the ONR.
[1] H. K. Hughes, Phys. Rev. **72**, 614 (1947).

K10. New Solutions for the Field Due to a Point Charge Moving with Uniform Velocity in a Straight Line. J. J. SMITH, *General Electric Company.*—The usual solution gives a field symmetrical with respect to the point charge. When u the velocity of the point charge equals c there should be no change in the field ahead of the charge for retarded solutions. New solutions found are given by

$$v=\frac{q}{\pi^2}\int dt_1\int_0^\infty \lambda d\lambda J_0(\lambda R)\int_0^\infty \cos\gamma[z-z_0+u(t_1-t_0)] \times\frac{\sin[c(t-t_1)(\lambda^2+\gamma^2)^{\frac{1}{2}}]d\gamma}{c(\lambda^2+\gamma^2)^{\frac{1}{2}}}.$$

If the limits for t_1 are from t_0 to t the retarded solutions for a point charge created at time $t_0<t$ is obtained. The advanced solution is obtained by a slight modification. In both cases the usual solution is obtained plus other terms. These new results do not become infinite except at the point charge itself even at the velocity of light. In the retarded case the field ahead of the charge is unchanged and a physical picture of the motion confirms the mathematics. In deriving the usual solution the limits with respect to t_1 are taken as $-\infty$ and $+\infty$ and this improper integral does not converge uniformly giving an incorrect result.

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Roe, Glenn M.—C9
Rogers, T. F.—K4
Salam, Abdus and P. T. Matthews—G3
Schaefer, V. J.—Friday evening
Shapiro, Anatole M.—F4
Shapiro, Maurice M. and Andrew F. Gabrysh—F2
Shull, Franklin B.—F9
Shulman, Carl—H11
Smith, H. L., J. A. Kies, and G. R. Irwin—C11
Smith, J. J.—K10
Stahl, Frieda A.—J6
Stanley, J. K., J. E. Goldman, and W. Hassel—C3
Stier, Paul M.—H7
Studer, F. J., D. A. Cusano, and L. R. Koller—H4
Stuhlman, Otto, Jr.—H8
Suits, C. G.—A1
Swartz, C. E.—D10
Trischka, J. W., J. Swartz, and R. Luce—K9
Turnbull, David—J9
Tyler, W. W. and W. DeSorbo—J1
Van Dilla, M. A. and G. J. Hine—D2
Van Vleck, J. H.—K2
Weber, J.—K5
Williams, Ferd E.—H3