Proceedings of the American Physical Society

MINUTES OF THE WASHINGTON, D. C. MEETING, APRIL 28–30, 1938

THE 220th regular meeting of the American Physical Society was held in Washington, D.C. at the National Bureau of Standards on Thursday and Friday, April 28 and 29, 1938, and at the National Academy of Sciences on Saturday, April 30, 1938. There were three parallel sessions for the reading of ten-minute contributed papers on Thursday morning and afternoon, and on Friday morning and afternoon. At the National Academy of Sciences on Saturday there were two parallel sessions morning and afternoon. The presiding officers were Dr. Lyman J. Briggs, president of the Society, Professor John T. Tate, vice president, Dr. H. C. Dickinson, Dr. H. L. Dryden, Dr. W. E. Forsythe, Dr. Ross Gunn, Dr. A. W. Hull, Dr. F. L. Mohler, Dr. L. B. Tuckerman, and Professor P. I. Wold. The attendance at the meeting was over six hundred.

At the beginning of the Thursday afternoon session through the kindness of the General Electric Company a short talking motion-picture film of Lord Rutherford was shown. At the end of this session an invited paper by Dr. M. Goldhaber of the Cavendish Laboratory on *Experiments on Nuclear Isomerism* was also given. At the close of the Friday afternoon session Professor R. W. Wood of the Johns Hopkins University demonstrated his latest grating.

On Friday evening the Society held its dinner at the Raleigh Hotel. President Briggs presided and called upon Professor Meissner, Dr. Szilard and Dr. Goldhaber, guests of the Society, to speak. After the dinner Professor F. K. Richtmyer gave an address with slides showing the results achieved at the eclipse of 1937 on the Canary Islands.

Meeting of the Council. At its meeting held on Thursday, April 28, 1938 the deaths of two fellows (D. W. Hering and P. A. Ross) and of one member (E. R. Stoekle) were reported. One candidate was reinstated to fellowship, one candidate was transferred from membership to fellowship, and twenty-seven candidates were elected to membership. *Reinstated to fellowship:* Gordon S. Fulcher. *Transferred from membership to fellowship:* Hermon W. Farwell. *Elected to membership:* Raymond L. Alty, Waldemar Ayres, Sanborn C. Brown, Robert E. Burroughs, Ernest E. Charlton, Elliott W. Cheney, E. P. Clancy, Dale R. Corson, L. A. Delsasso, G. B. Estabrook, Andrew Gemant, J. Halpern, Morton Hamermesh, Leopold Infeld, Martin D. Kamen, Lucien J. B. LaCoste, Geo. W. Maxwell, Russell A. Nielsen, J. Monroe Schmidt, Games Slayter, S. Sugden, John Sweer, Chas. H. Townes, Jr., W. R. Van Wijk, E. H. Vestine, E. Russell Wightman, and Thomas C. Wilson.

The regular scientific program of the Society consisted of one hundred and eighty-four contributed papers of which numbers 61, 81, 82, 114, 129, 155, 158, 178 and 183 were read by title. The abstracts of these papers are given in the following pages. An Author Index will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. Effect of Source Resistance on Electronic Stabilizer Performance. F. V. HUNT AND R. W. HICKMAN, *Harvard University.*—Our analysis of electronic voltage stabilizing circuits[1] has been extended to include the effect of the internal resistance of the power source on the performance of the stabilizer. In order to avoid the necessity of carrying through this computation for every stabilizer circuit it is shown that: (1) the variational performance of a stabilizer operating from a power source having zero internal resistance is completely characterized by the stabilization ratio S_0 and the internal resistance R_0; (2) the variational performance of a stabilizer operating from a practical power source (e.g., rectifier) having an internal resistance R_r is similarly characterized by stabilization and resistance parameters S and R; (3) these over-all parameters S and R may be expressed in terms of the source resistance R_r, the factors S_0 and R_0, and small correction terms (in practice negligible) involving other circuit constants. These relations furnish a basis for evaluating economies in rectifier design, and the expression for the total internal resistance of the

stabilizer-source system suggests a simple experimental method of determining both S_0 and R_0 from bridge measurements of R as a function of an auxiliary resistance simulating R_r.

[1] Phys. Rev. **50**, 1094A (1936).

2. Circuits for the Control of Geiger Counters and for Scaling and Recording Their Impulses. THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—An analysis is given of the controlling action of a vacuum tube in circuits similar to those proposed by Neher and Harper and Neher and Pickering. A modification of the latter's circuit is described which avoids its principal disadvantage of a heavy current drain on the high voltage source. This circuit is incorporated into a four-tube network which controls the counter, scales down the impulses by any adjustable factor and records the scaled count. Several critical tests have shown that this circuit will satisfy most of the demands made of a scaling circuit for cosmic ray or nuclear physics experiments. The scaling circuit may be used with single counters or with coincidences. In the latter case $2n+2$ tubes are required for scaling and recording n-fold coincidences. A neon tube coupled multivibrator circuit for recording pulses of short duration is also described.

3. The Coaxial Tube Counter. SANBORN C. BROWN AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—A hollow anode tube counter offers many geometrical advantages, both as a source container and as a guard counter.[1] We have now realized successful operation of coaxial tube counters having anode diameters up to 13 mm, by making the amplifier extinguish the discharge in the counter, thus relaxing it for the next pulse. The amplifier circuit connections follow the original Neher-Harper[2] circuit, but with 10^8 to 10^9 ohms in the plate circuit and only a slightly negative grid bias. A typical coaxial tube counter has a 13 mm diameter Cu anode, 24 mm Cu cathode 8 cm long; is air filled at 10 mm Hg pressure and operates at 600 volts. The operating voltage depends on the grid bias on the amplifier, and on the pressure of the filling gas. The operating range is only about 50 volts wide, and the counting rate depends on the applied voltage. However, satisfactory operation is obtained by pentode[3] stabilization of the high voltage supply. For the same cathode dimensions the coaxial counters have a considerably lower background than the usual wire anode G-M counters. Beta-ray sources are placed inside the open ended, thin-walled hollow anode.

[1] Evans and Mugele, Rev. Sci. Inst. **7**, 441 (1936).
[2] Neher and Harper, Phys. Rev. **49**, 940 (1936).
[3] Evans, Rev. Sci. Inst. **5**, 371 (1934).

4. Bursts in Cosmic-Ray Ionization in the Equatorial Zone. S. A. KORFF, *Bartol Research Foundation.*—Bursts in the intensity of ionization produced by cosmic radiation at various altitudes in the equatorial zone have been collected and analyzed. An electroscope of the Millikan-Neher type was employed, and operated inside an 11 cm lead shield. The bursts were found to have the following properties: (1) The bursts increase with altitude approximately as the square of the total ionization. (2) The number of bursts as a function of their energy in ions may be expressed approximately by $N=AE^{-2.7}$, where N is the number of bursts of E ions, and A is a constant. (3) This distribution is found to be independent of altitude and of latitude. (4) At sea level, 10^{-3} of the total ionization in the electroscope over any long period is due to bursts larger than 3×10^6 ions.

5. Galactic Rotation and the Variation of Cosmic-Ray Intensity. I. A. GETTING,* *Harvard University.*—It has been shown[1] that if cosmic rays are distributed isotropically and homogeneously in extragalactic space, there should be a small sidereal variation in the intensity of cosmic radiation resulting from galactic rotation. The variation in intensity is of two kinds: (1) in the number of "rays," resulting from aberration and sweeping up of "rays"; and (2) in the energy of each "ray," due to Doppler effect, which alters the penetrability. The original article presented data of Hess and Steinmaurer[2] supporting the effect. Later data by Forbush[3] and Compton and Turner[4] show no significant confirmation. Some features which tend to reduce the sidereal variation are: fluctuations of higher magnitudes, smearing out by the terrestrial and solar magnetic fields, absorption and scattering within the Milky Way. A procedure for establishing the effect is to record the intensity far underground; for (1) the fractional variation in the number of "rays" is undiminished, (2) the effect of varying penetration is increased, especially in exponential absorption, (3) barometric disturbances are reduced, (4) all directions are always allowed by the magnetic field, (5) deflection by the magnetic field is reduced. Preliminary data taken at a depth of 65 feet of ground at Boston show an apparent maximum at about 22 hours sidereal time with an amplitude of the order of 0.4 percent. 650,000 counts were used to determine each hourly average. The period of observation is insufficient to prove the variation or to separate it from a solar effect, which, however, is not to be expected at this depth.

* Society of Fellows.
[1] A. H. Compton and I. A. Getting, Phys. Rev. **47**, 817 (1935).
[2] V. Hess and R. Steinmaurer, Berlin. Sitz. Ber. Akad. Wiss. 521 (1933).
[3] S. E. Forbush, Phys. Rev. **52**, 1254 (1937).
[4] A. H. Compton and R. N. Turner, Phys. Rev. **52**, 799 (1937).

6. On Variations in Cosmic-Ray Intensity Associated with Magnetic Storms. S. E. FORBUSH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington. (Introduced by John A. Fleming.)*—World-wide decreases of three to five percent in daily means of cosmic-ray intensity are found to be associated with changes in the earth's magnetic field during two major magnetic storms. The additional evidence obtained from the last of these storms tends to confirm our hypothesis[1] that the changes in cosmic-ray intensity are caused by the dipole component of the field of the storm. From January 16 to 17, 1938, the daily mean horizontal magnetic intensity at the equator decreased about 0.0010 gauss; there was a corresponding decrease of about 4 percent in cosmic-ray intensity at each of three widely separated stations. We find other decreases

of similar magnitude in horizontal magnetic intensity at the equator which were accompanied by little or no apparent decrease in cosmic-ray intensity. This suggests large variations in the radius of the current-system which encircles the earth during magnetic storms, and would indicate that the current-system for the dipole component of those magnetic storms which affect cosmic-ray intensity may have a radius several times that of the earth.

[1] S. E. Forbush, Phys. Rev. **51**, 1108–1109 (1937).

7. Energy Distribution of Incident Cosmic-Ray Electrons. I. S. BOWEN, R. A. MILLIKAN AND H. V. NEHER, *California Institute of Technology.*—The complete curve of energy distribution of incoming cosmic-ray electrons has been obtained by measurements on ionization made practically up to the top of the atmosphere in four different latitudes. The maximum of the incoming intensity is at an energy of 6 billion electron-volts and falls off to about one-third this value both at 1 billion electron-volts and at 18 billion electron-volts. Some natural inferences from this distribution are presented.

8. A Method of Identifying the Primary Cosmic Rays. E. J. SCHREMP, *Washington University.*—A method of identifying the primary cosmic rays, based on the existence of finite allowed bands outside the main cone, and applied to Johnson's east-west directional intensity data[1] three years ago, appeared to furnish striking evidence that the observed primaries were exclusively positrons and negatrons. Two difficulties rendered the proof incomplete. First, the quantitative form of the bands was then unknown; second, the experimental errors in Johnson's data could not be exactly appraised. The first difficulty has since been removed,[2] and though the second remains, it now appears of interest to describe the method used: The above bands, in an equivalent spectral representation, lead to energy bands delimited by spectral discontinuities ($i=1, 2, 3, \cdots$. for particle species j at energies $\epsilon_{ij}(r, \lambda, \eta, \theta)$, functions of position (r, λ) on the earth and direction (η, θ) in the sky. At an atmospheric depth h the energy spectra are $f_j(\epsilon, h; r, \lambda, \eta, \theta)$ and the intensities are $I_j(h; r, \lambda, \eta, \theta) = \int_0^\infty f_j(\epsilon, h; r, \lambda, \eta, \theta) d\epsilon$. The approximate preservation of this band structure in $f_j(\epsilon, h; r, \lambda, \eta, \theta)$ implies that $I_j(h; r, \lambda, \eta, \theta)$ will vary irregularly at range limits $h_{ij}(r, \lambda, \eta, \theta)$ corresponding to $\epsilon_{ij}(r, \lambda, \eta, \theta)$ and also whenever $\epsilon_{ij}(r, \lambda, \eta, \theta)$ varies sharply with its arguments. Such intensity irregularities were found, and clearly indicated only positrons and negatrons.

[1] T. H. Johnson, Phys. Rev. **48**, 287 (1935).
[2] E. J. Schremp, Phys. Rev. **51**, 1006A (1937). Full papers by Dr. R. Albagli and the writer will appear shortly.

9. Stopping-Power for Cosmic-Ray Electrons. J. H. BARTLETT, JR., *University of Illinois.*—The most accurate wave functions known at present for a heavy element are those found by Hartree[1] for mercury. On the basis of these, the charge distribution and the atomic form factor have been calculated. The form factor is rather different from that found with a Thomas-Fermi atom, so that one should expect corresponding changes in the stopping-power results. Preliminary calculations of these have been made, and it is found that the stopping power deviates somewhat from that previously determined.[2]

[1] Phys. Rev. **46**, 738 (1934).
[2] See Bethe and Heitler, Proc. Roy. Soc. **146**, 96 (1934).

10. The Absorption of the Penetrating Component of the Cosmic Radiation. W. M. NIELSEN, *Duke University* AND K. Z. MORGAN, *Lenoir-Rhyne College.*—To investigate the nature of the penetrating component of the cosmic radiation we have made observations with G.M. counters in Linville caverns at a depth below rock of approximately seventy-five feet. Measurements were made inside and outside the cavern over a range of lead thicknesses up to approximately 500 g/cm² between the counters. The results are: 1. The difference in counting rate (with no absorber between counters) inside and outside the cavern is in satisfactory agreement with previous investigations.[1, 2] 2. The absorption coefficient of the more penetrating ionizing radiation in the cavern is approximately 0.0002 cm²/g. This observation shows that the penetrating component is to be associated with a charged particle. It is therefore not necessary to assume the transmission of cosmic radiation to large depths by uncharged particles (e.g., neutrinos). 3. Comparison of the absorption of the penetrating component inside and outside the cavern shows that the radiation undergoes a hardening under large depths of material. 4. The percentage of the radiation of the less penetrating type is very nearly the same inside and outside the cavern (25 percent and 30 percent, respectively). This indicates that such soft particles are in approximate equilibrium with the penetrating component even at the earth's surface.

[1] A. Ehmert, Zeits. f. Physik **106**, 751 (1937).
[2] V. C. Wilson, Phys. Rev. **53**, 337 (1938).

11. Range of Cosmic-Ray Particles. ARTHUR BRAMLEY, *Washington, D. C.*—A comparison of theoretical energy losses for cosmic-ray particles indicates that the energy losses resulting from the existence of the Fermi interaction between light particles and the nucleus can become greater than the energy losses from radiation. The cross section for energy losses arising from the Fermi interaction varies as a power of g^2, the Fermi constant. This energy loss will have a maximum probability of occurrence for that energy at which g^2 has its maximum. This mechanism favors large energy losses through neutrinos which are rapidly reabsorbed. (a) For ordinary electrons these losses should become noticeable around 100 Mev, the maximum may lie higher. (b) If the heavy particle[1] is an electron with a large spin then it is plausible to assume that similar conclusions hold for it; an additional process of this type is the transformation to an ordinary electron accompanied by a sufficient number of neutrinos to conserve the spin. Since for the heavy particle the Fermi process is not masked by radiation, the probability of its occurrence is larger than for the ordinary electron with the same Fermi constant.

[1] Bramley, Phys. Rev. **52**, 248A (1937).

12. A Compact 750 kv Van de Graaff Generator for High Currents. J. B. FISK* AND I. A. GETTING,* *Harvard University.*—A compact Van de Graaff generator delivering 1 ma at 750 kv has been built for use in nuclear physics. The generator, operated in air at atmospheric pressure, incorporates two new features: (1) reentrant electrodes,[1] and (2) close spacing of belts with opposite sign charges. The reentrant electrodes prevent sparking along insulating supports and thereby increase the ultimate attainable voltage. Three charging belts are used. The one belt, running clockwise, is sandwiched between the other two, which are traveling counter-clockwise. The clearance between belts is only $\frac{1}{2}$ inch. Simple electrostatic consideration shows that if an isolated single belt can carry a charge σ per cm^2, then a sandwiched belt can carry 2σ. Actual measurements verify this feature. The use of seamless woven charging belts, vibration isolation between belts, and sturdy construction reduce vibration and noise to a low level.

* Society of Fellows.
[1] First used by Trump at the Huntington Hospital.

13. An X-Ray Generator Especially Designed for Biological Experiments. G. FAILLA, *Memorial Hospital.*—To fulfil the very desirable requirement of high intensity of radiation for the study of the biological action of x-rays, the writer has designed a simple apparatus made up of standard parts, which has proven very satisfactory. It consists of a high tension transformer to which are connected directly two water cooled x-ray tubes in such a way that each utilizes the appropriate half of the alternating current wave. One tube is placed below the material to be irradiated and the other above, thus doubling the intensity of radiation. With such a machine installed at the Marine Biological Laboratory last summer, a radiation intensity of 7000 roentgens per minute is readily obtained, when the voltage is 200 kv and the tube current 30 ma. The surprising thing is that the tube life with this arrangement is longer than usual. In the case of two such machines used at the Memorial Hospital for the routine treatment of patients, one of the tubes has been in actual operation for over 3700 hours, and is still in good condition. This is an important item, considering that each tube costs about $450. Thus the elimination of the usual rectifiers, which reduces the complexity and cost of the apparatus, has also reduced the operating cost.

14. Substandards of Very Feeble Radioactivity. ROBLEY D. EVANS AND CLARK GOODMAN, *Massachusetts Institute of Technology.*—Accurate quantitative knowledge of the radioactive content of natural materials is essential in problems of geologic age, the earth's internal heat, marine sedimentation, and biological problems related to radium and thorium poisoning. The radium standards required for these analyses contain about 10^{-12} g Ra. Accurate standards at such low activities are difficult to establish. We have now calibrated a substandard radium solution containing 0.780×10^{-12} g Ra per cc, whose absolute radium content has been elaborately checked by six independent experimental methods. Using this standard, several gamma-ray standards in the range of 10^{-7} to 10^{-5} g Ra have also been calibrated. These are of particular use in artificial radioactivity yield studies and in quantitative radium poisoning investigations. We have found that commercial standards in this range of activity cannot be trusted. By exchanging analyzed specimens with the principal workers on the natural radioactivity of ordinary materials, we hope to bring a measure of quantitative reliability to the data of terrestrial radioactivity. We have found systematic differences of several hundred percent among several laboratories. These disclose faulty radium standards, and will permit the revaluation of geologic age and radioactivity data published by these laboratories, when their standards are rechecked. During the past two years about 20 workers in 8 countries have joined this international interchecking program for the revision of data and standards.

15. A New Physical Method for the Determination of Geologic Ages. CLARK GOODMAN AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—We have recently described new techniques for determining the rate of helium production in igneous rocks by direct counting of the alpha-rays,[1] and for the removal and measurement of the helium accumulated in a rock specimen during geological time.[2] These have now been successfully combined into a rapid, absolute, entirely physical technique for the measurement of geological ages up to about 400 million years which does not depend upon the measured decay constants of thorium and uranium, nor upon any laboratory standards of radioactive content. For older rocks a radium determination is also made.[3] This dictates the small correction necessary for the finite decay of uranium, actino-uranium and thorium during the lifetime of the oldest rocks. Direct comparison of this new "alpha-helium" method of age determination with the "radon-thoron-helium" method formerly employed by other workers[4] has: (a) confirmed the accuracy and reliability of the new absolute method; (b) disclosed an error of about 130 percent in the radium standardization employed in the previous helium age measurements,[4] with consequent lowering of the helium time scale; (c) established the absence of any strong unknown natural alpha-ray emitters in igneous rocks.

[1] Evans and Goodman, Phys. Rev. **52**, 255A (1937).
[2] Evans and Goodman, Phys. Rev. **51**, 595A (1937).
[3] Evans, R. S. I. **6**, 99–112 (1935).
[4] W. D. Urry, J. Chem. Phys. **4**, 34 (1936); **4**, 40 (1936). A. C. Lane and W. D. Urry, Bull. Geol. Soc. Am. **46**, 1101–1120 (1935).

16. The Measurement of Super-Voltage Radiation with the Standard Ionization Chamber. LAURISTON S. TAYLOR AND GEORGE SINGER, *National Bureau of Standards.*—Standard measurement of super-voltage x-rays is not in the satisfactory state existing for ordinary x-rays. Measurements with thimble chambers, while satisfying temporary demands, involve such factors as not to warrant their adoption as standards. The only known comparison of parallel plate and thimble chambers in the super-voltage region failed to offer a solution to the problem because of known design limitations of the standard chamber. To remove these uncertainties and at the same time determine all the necessary design characteristics for future use, a

large parallel plate chamber for a range of 100 kv to 1000 kv has been constructed. The chamber proper is of the guarded field type developed here and has a maximum plate separation of 48 cm. This is contained in a cylinder 8 feet long and so arranged that it can be adjusted as to position along the cylinder and as to plate separation. The cylinder operates at internal pressures of 1–15 atmospheres. By this means it is possible to study the effects of diaphragm and filter scattering as encountered under ordinary atmospheric conditions. All correction factors such as recombination losses at elevated pressure, air absorption, scattering, etc., are obtainable directly under the exact conditions of measurement. At the same time it is possible to remove the chamber from the cylinder and carry out measurements in free air as done by Lauritsen. Thus all known methods of using standard free air ionization chambers may be used in overlapping ranges, thereby definitely establishing their efficacy. The high voltage equipment used for this work was built especially for the purpose and it is hoped to avoid many of the difficulties encountered in attempting such measurements with hospital installations. The x-ray beam can be controlled as to canalization, extraneous scattering be held to a low minimum, inherent filtration be small, and at the same time allow adequate free space about the measuring equipment.

17. Crystal Structure of Sodium Formate, $NaHCO_2$. W. H. ZACHARIASEN, *University of Chicago.*—We have succeeded in making an accurate determination of the structure of the formate radical in the crystal lattice of sodium formate. Crystals of sodium formate are monoclinic. The space group is $C2/c$ (C_{2h}^6). The unit cell contains four molecules and has dimensions: $a=6.19\pm0.01$A, $b=6.72\pm0.01$A, $c=6.49\pm0.01$A, $\beta=121°\ 42'$. Sodium, carbon and hydrogen atoms are situated on twofold axes of rotation, while the oxygen atoms are in general positions. Accurate parameter values were obtained from a series of two-dimensional Fourier analyses. These values are:

	$2\pi x$	$2\pi y$	$2\pi z$
Na	90°	$-50.0°\pm0.5°$	90°
C	90°	$102.0°\pm0.5°$	90°
H	90°	~155°	90°
O	$15.5°\pm1°$	$70.0°\pm0.5°$	$66.5°\pm1°$

There is complete resonance between the two C−O bonds in the formate group. The C−O distances are 1.27 ± 0.01A. The bond angle is 124°. Sodium has six oxygen neighbors at an average distance of 2.44A.

18. Crystalline Transitions and Dielectric Constant. HANS VON R. JAFFE, *Wesleyan University.*—Proof is submitted that at a transition point from a pyroelectric[1] to a nonpyroelectric crystal class the dielectric constant k in the polar direction approaches infinity if the transition takes place without latent heat (thermodynamic transition of the second kind). A sharp though finite maximum for k can be expected for a transition with a latent heat small compared to the anomalous specific heat below the transition point. Conversely, the sharp maxima of k known, e.g., for Rochelle salt and for HBr, must be ascribed to such changes in crystal symmetry. For the proof in the case of absent latent heat, the free energy F of the pyroelectric crystal at a given temperature is regarded as function of the electric moment P. This function has two minima, at $+P_0$ and at $-P_0$ (P_0=natural electric moment). As the temperature approaches the transition point, the two minima coalesce into one at $P=0$; the second derivative with respect to P becomes $F''(P_0)=0$. The polarization for an applied field E is determined by the condition that the total free energy $F(P)-PE=$min., whence:

$$E=F'(P)=F'(P_0)+(P-P_0)F''(P_0)+(P-P_0)^2F'''(P_0)/2\cdots.$$

k is given by:

$$4\pi/(k-1)=dE/dP=F''(P_0)+(P-P_0)F'''(P_0)\cdots.$$

With $F''(P_0)=0$, k approaches infinity for small dielectric polarizations ($P-P_0\to0$).

[1] I.e., a class with at least one polar direction to which no other direction is equivalent.

19. A Vacuum Furnace for the Production of Single Crystals of Metals and Alloys. FOSTER C. NIX, *Bell Telephone Laboratories, Inc.*—A vacuum furnace has been developed for the production of single crystals of metals and alloys by the Bridgman method. The pressure at the point of solidification of pure copper or copper-gold alloys is between 10^{-3}–10^{-4} mm of Hg and decreases to 10^{-4}–10^{-5} mm of Hg at temperatures immediately below the solidification temperature. The heating element consists of a cylindrical core of silicon-free alundum wound with molybdenum wire and mounted inside an evacuated copper tube. The heating current is led through the furnace walls by copper-to-glass seals. The power used to lower the molten metal is transmitted through the furnace walls by means of a sylphon bellows. A lead disk is used to obtain the vacuum seal at the opening in the top of the furnace. The large copper tube is water-cooled in the vicinity of the heating element. Single crystals of copper and copper-gold alloys of several compositions near Cu_3Au have been prepared. The variations in the chemical composition along the length of the copper-gold single crystal rods were found to be less than 0.1 percent.

20. A Determination of e/m from the Refraction of X-Rays in a Diamond Prism.* J. A. BEARDEN, *Johns Hopkins University.*—Measurements of the index of refraction of the copper $K\beta$ line by a diamond prism have been made with an estimated accuracy of one part in 10,000. These measurements together with the quantum theory of dispersion and the ruled grating wave-length of the copper $K\beta$ line afford a method of evaluating e/m with an accuracy as great as that of any previous determinations by other methods. The value of e/m is given by the equation

$$e/m=\delta\left[\frac{\lambda^2\rho F}{2\pi W}\sum_1^s N_s\{1+A\}\right]^{-1}$$

where δ, λ, ρ, F, N_s and W have their usual meaning and A is the factor which takes into account the electronic binding. For carbon and a $\lambda^{2.75}$ law of absorption the value of the $\Sigma=6.0163\pm0.0006$. Using $\delta=9224\times10^{-8}$, $W=12.0040$,

$\rho=3.5154$, $F=9651.0$, $\lambda=1.39220$A, one obtains $e/m=(1.7585\pm0.0003)\times10^7$ e.m.u. This spectroscopic value is higher than most previous spectroscopic determinations but is somewhat lower than the free electron measurements. The difference is small and it does not appear necessary to assume two values of e/m depending on the method of measurement.

* This work was supported by a grant from the Rumford Committee of the American Academy of Arts and Sciences.

21. A Precision X-Ray Camera for High Temperatures. C. NUSBAUM, *Case School of Applied Science.*—In a previous abstract, a Seeman-Bohlin x-ray camera for high temperatures was described in which the angle subtended between the slit and the sample at the center of the camera was approximately 60°. This camera was used in the analysis of the cementite and graphite precipitation in cast iron at high temperatures. While possessing the feature of very short exposure times, this advantage was attained at the expense of the precision of the measurements. In the present camera, the sample is placed on the same circumference as the slit and directly opposite it. As only higher order lines are used in the measurements, the "drift" of the lines due to the inherent characteristics of the camera and any possible displacement of the reflecting surface of the sample from the effective circumference of the camera is of much smaller magnitude. If the "least square" method of solution by Cohen and Jette is used in the reduction of the observations, the precision of the measurement of lattice parameters at high temperatures is comparable with the precision at low temperatures.

22. X-Ray Analysis of the Structure of Tetramethyl Ammonium Dichloriodide Crystals. ROSE C. L. MOONEY, *Newcomb College, Tulane University.*—Crystals of tetramethyl ammonium dichloriodide, prepared by a method analogous to that used for the alkali trihalides, have been studied by x-ray diffraction methods for the purpose of measuring the dimensions of the dichloriodide group under favorable conditions. The diffraction data were obtained by means of single crystal oscillation photographs interpreted by the usual methods. The crystal is simple tetragonal. Its unit cell, which contains two molecules of $N(CH_3)_4ICl_2$, has the dimensions $a=9.18$A, $c=5.75$A. The calculated density is 1.728. The space group is $D_{2d}^3-P\bar{4}2_1m$, with carbon in the general positions, f, and with chlorine, iodine and nitrogen in the special positions e, c, and b respectively. Values for the six parameters involved in this atomic distribution have been found such that excellent agreement is obtained between observed intensities and calculated structure amplitudes. The structure may be pictured as a cesium chloride arrangement in which the symmetry has been lowered by the substitution of the large complex groups for the simple ions. The dichloriodide anion, in agreement with previous observations of such groups, is linear, with iodine as the central ion. The iodine-chlorine distance within the group is 2.35A, while the nearest approach of two halogen atoms not in the same group is 4.4A. Each chlorine is coordinated to six CH_3 groups at a distance of 3.89A.

23. X-Ray Investigation of the Form of Acetylsalicylic Acid in Certain Sugars. S. S. SIDHU, *University of Pittsburgh.*—X-ray studies of samples made of sucrose, glucose, and acetylsalicylic acid were made to determine if the latter is in solid solution with the sugars. The main constituent of the samples was sucrose and the amounts of acetylsalicylic acid varied from one and a half to twenty percent. The samples were prepared by melting and heating the sugar combinations to 160°C, removing essentially all the water and allowing to cool. The acetylsalicylic acid was then incorporated in one set of samples at 140°C and in another at a temperature between 110–115°C, that is, both above and below the melting point (133–5°C) of the compound. The former samples were far more hygroscopic than the latter, but in neither case did the acetylsalicylic acid seem to form a solid solution with the rest of the constituents. Further investigation is in progress both from the x-ray and chemical standpoints.

24. X-Ray Diffraction Study of Grain Boundaries in Steel. RAYMOND MORGAN, SYLVIA STECKLER AND EDWARD B. SCHWARTZ, *University of Pennsylvania.*—In a recent publication* it was shown that the grain boundary residue material left from the dissolution of electro-deposited iron in ammonium persulphate solution gave an electron diffraction pattern which might be accounted for by the presence of either Fe_3C or α-FeOOH. The question was raised whether the α-FeOOH, if present, was not formed during the process of dissolution of the iron. This work has been continued with the study of the grain boundaries in transformer steel and in a commercial steel of very low carbon content by the use of x-ray diffraction methods. The same process of dissolution in ammonium persulphate was used. Diffraction patterns of the grain boundaries for both of the materials indicate the presence of either Fe_3C or α-FeOOH as well as other compounds. Heating the grain boundary residues for about two hours at 650°C did not produce the transformation to α-Fe_2O_3 that would occur if α-FeOOH were present. Accordingly, it was concluded that in the case of the electro-deposited iron, α-FeOOH was not formed in the dissolution process and that Fe_3C was probably the grain boundary constituent. In the case of the two types of steel now under consideration, the grain boundary residues were quite different in appearance and the diffraction patterns also differed; nevertheless, in both cases the indications are that Fe_3C is present.

* Morgan, Steckler and Miller, J. Chem. Phys. **5**, 953 (1937).

25. Refractive Index and Dispersion of Distilled Water for Visible Radiation, at Temperatures 0 to 60°C. LEROY W. TILTON AND JOHN K. TAYLOR, *National Bureau of Standards. (Introduced by I. C. Gardner.)*—Minimum-deviation measurements, using specially designed hollow prisms and platinum resistance thermometers, have yielded highly precise data on the refractivity of distilled water at 133 sets of temperature–wave-length coordinates. These results have been represented by a general formula having 13 constants, the average residual being 1.2×10^{-6} in index. Comprehensive tables permit ready reading of

indices to six decimals. Precise values for the specific refraction and for partial dispersions are given, and the temperature of maximum refractivity is found to vary definitely with wave-length. All results are medial with respect to previously published data, and between 0 and 16°C there is remarkably close agreement with interferometrically determined indices as reported by Mlle. O. Jasse.[1]

[1] Comptes rendus **198**, 163 (1934).

26. Experimental and Theoretical Photoelectric Spectral Sensitivity of Strontium and Magnesium. R. J. CASHMAN AND ELSE BASSOE,* *Northwestern University.*—Photoelectric yields in amperes per watt have been obtained as a function of frequency for condensed layers of Sr and Mg formed by fractional distillation in a gettered vacuum. The frequency range for Sr was from the threshold (approximately 4500A) to 3000A or a change of about 1.4 e.v. The range for Mg was 3400 to 2000A or a change of 2.54 e.v. from the threshold. The response from both metals is characterized by the absence of a selective maximum for the range investigated. These results are to be contrasted with yields from bulk alkali metals, all of which show a selective maximum at about 1 e.v. from the threshold. The question arises as to whether the selective maximum observed is characteristic of the pure metal or of some surface property peculiar to the alkalies. In order to answer this question we have computed the theoretical spectral sensitivity of Sr and Mg using the quantum mechanical method of Mitchell[1] for the square top potential barrier and assuming 2 free electrons per atom. A comparison of these results with experimental data indicates that the selective maximum observed in the case of the alkali metals is to be expected. Further work is in progress using Ba as the emitter which will permit investigations over a greater frequency range.

* Now at Leeds and Northrup Company, Philadelphia, Pa.
[1] Mitchell, Proc. Roy. Soc. **A146**, 442 (1934); **A153**, 513 (1935).

27. A Study of the *K* Fluorescent X-Ray Lines of Chemical Compounds.* LEONARD OBERT AND C. H. SHAW, *Johns Hopkins University.*—The width and index of asymmetry of the fluorescent $K\alpha_1$, $K\alpha_2$ and $K\beta_1$ emission lines of pure Zn, Cu, Fe, Mn, Cr and 26 compounds, including the halides and sulfides of Cu and Fe, have been measured with a double crystal spectrometer. The changes between the shapes of the lines of the metals and their oxides are in good agreement with those determined by Roseberry and Bearden[1] for the same emission lines produced by direct excitation (electron impact), and indicate that the method of excitation does not influence the shape of the lines. However, the present results give the width of the $K\alpha_1$ line of CuF_2 as 9 percent greater than the width of the pure metal, whereas Wilhelmy[2] found a 25 percent widening for direct excitation. A study of the Cu and Fe halide and sulfide lines shows some regularities in the change of the width and index of asymmetry with the percentage composition, the most outstanding of which are for the iron sulfides FeS, Fe_3S_4, Fe_2S_3, FeS_2. As the percentage of sulfur increases both the width and the index of asymmetry decrease for all lines, the maximum change being as much as 42 percent for the width of the $K\alpha_1$ lines.

* This work was supported by a grant from the Penrose Fund of the American Philosophical Society.
[1] Roseberry and Bearden, Phys. Rev. **50**, 204 (1936).
[2] Wilhelmy, Zeits. f. Physik **97**, 312 (1935).

28. The Effect of Temperature on the Reflection of X-Rays from Cadmium. W. M. SCHWARZ, *Washington University.*—Cadmium crystallizes in the hexagonal form with an axial ratio of 1.886, being very similar to Zn in its structural properties. For hexagonal crystals Zener[1] has shown that the Debye-Waller temperature factor takes the form:

$$M=(a\cos^2\psi+b\sin^2\psi)[\varphi(x)+(x/4)](\sin^2\theta)/\lambda^2,$$

where a and b are functions of the atomic vibrations and ψ is the angle that the normal to the particular atomic plane in question makes with the c axis. a and b are approximately linear functions of the temperature. By assuming them linear M may be determined from the ratio of the intensities of reflection at two different temperatures. The temperatures employed were those of room temperature and of liquid air. Cu K_α radiation was reflected from powdered Cd crystals and the intensity recorded photographically. The results closely parallel the situation in Zn where an anisotropy of thermal vibrations has been found to exist.[2]

[1] C. Zener, Phys. Rev. **49**, 122 (1936).
[2] G. W. Brindley, Phil. Mag. **21**, 790 (1936). G. E. M. Jauncey and W. A. Bruce, Phys. Rev. **50**, 408 (1936). E. O. Wollan and G. G. Harvey, Phys. Rev. **51**, 1054 (1937).

29. Luminescence of Pure Crystals. D. H. KABAKJIAN, *University of Pennsylvania.*—It has been asserted by many investigators that luminescence in solid compounds is due to the presence of small quantities of impurities and that pure substances do not luminesce. According to modern theories of the solid state, pure crystals should show the property of luminescence if the following two conditions are fulfilled: (1) Permissible but unoccupied energy levels should exist in the crystal and (2) energy absorbed from the exciting source should be sufficient to displace electrons from normal to the higher levels. The writer has already shown that intense luminescence can be excited in certain pure zinc borate compounds, especially when these are obtained in a crystalline state. It is now found that a fairly large number of crystals can be made luminescent by using rays from radioactive sources. The luminescence of six pure crystals, $RaBr_2$, $RaCl_2$, $RaSO_4$, $BaCl_2$, $BaBr_2$, $BaSO_4$, has been studied. With a proper heat treatment, maximum luminescence in these crystals is produced with the highest degree of purity obtainable. However, the variations of brightness with the temperatures of heat treatment seem difficult to explain by any known theory.

30. Relative Emission Spectra of Zinc Silicates and Other Cathodoluminescent Materials. H. W. LEVERENZ, *RCA Mfg. Co., Inc.*—Specpure α-zinc silicate has a broad, weak luminescence peaked at 4200A. The 4200A band

gradually disappears as manganese activator is included in the crystal and simultaneously produces a narrow, strong band peaked at 5250A. The zinc oxide-silica ratio is much more critical, with respect to activator concentration and efficiency, if excess zinc oxide is present. A "deficiency structure" hypothesis is advanced to account for the activation phenomena. X-ray powder photographs, made by Professor B. E. Warren, of M.I.T., demonstrate differences in various substitution products of zinc silicate, and show the α- and β-crystal forms. Spectral efficiency curves are presented for manganese activated β-zinc silicates, α-zinc germanates, α-zinc beryllium silicates and the latter system containing group IV-*a* silicates (titanium to thorium). Group IV-*a* silicates resurrect the pure zinc silicate's emission spectrum and allow synthesis of phosphors having practically white emission colors. Data are presented for luminescent silicates of other metals.

31. A Proposed New Mechanism in Excited Neon. E. W. PIKE, *RCA Manufacturing Co., Camden, N. J.*—It has generally been assumed that excited neon atoms in neon at pressures of about 1 mm Hg lost their energy by emission of the resonance lines, either directly, or after a transition to the resonance state induced by a collision with a normal atom in the case of metastable atoms. A study of the probable energy levels of the NeNe′ molecule (generously supplied by Professor R. A. Mulliken) suggests, however, that this energy is lost rather by transitions between these molecular levels during collisions with normal atoms. The consequences of this assumed mechanism provide explanations for a variety of puzzling phenomena in neon discharges, including the unabsorbed radiation in the far ultraviolet first observed by Langmuir and Found in its detailed properties, and some curious properties of the Townsend discharge in pure neon.

32. Cold Sensation by Radiation. JAMES D. HARDY AND T. W. OPPEL, *Russell Sage Institute of Pathology, New York Hospital and Cornell Medical School.*—Using the radiation technique which we have described, the end organs in the skin which are sensitive to cold were stimulated. The source of "cold radiation" was a block of solid CO_2, 25 cm×25 cm. The rays were concentrated onto the skin by a large, silver cone, and a fivefold increase in intensity obtained. As the loss of radiant heat from the skin to the CO_2 produces a positive effect on the skin, i.e., the stimulation of cold sensation, it is somewhat easier to think of the skin as being exposed to "cold" radiation where the heat loss is increased by radiation alone. The foreheads of ten subjects were tested and the individual sensitivity to cold radiation found to be approximately the same. Two subjects were studied in detail by determining the minimum stimulating intensity of cold radiation for areas of different sizes. Areas smaller than 3 cm^2 could not be stimulated with the intensity of radiation available. The size of the exposed area was increased so as to include the entire upper part of the body. The thermal changes produced on the skin surface by these radiations were measured to ± 0.005°C with a radiometer. The results of the experiments are: 1. The number of cold end organs per unit area is greater than the number of heat endings. 2. The threshold of thermal excitation for a cold end organ is a fall in skin temperature of 0.004°C per second. This skin temperature change is more than five times as great as that necessary to stimulate a heat ending. 3. Cold radiation produces about twice the change in skin temperature, calorie for calorie, as does heat radiation. 4. Temperature sensation does not depend upon vascular changes in the skin. 5. Heat and cold sensation are not mediated by the same end organ.

33. The Biological Effects of Low Voltage Electrons. CHARLES E. BUCHWALD AND CARYL P. HASKINS, *Massachusetts Institute of Technology and Haskins Laboratory.*—A study has been made of the biological effects of electrons of relatively low voltage upon certain unicellular organisms. A special type of low voltage cathode-ray tube containing a rotatable target holding demountable slides has been designed and built for this purpose. It is capable of producing electron beams of good homogeneity, both in velocity and density, at voltages from 1 to 15 kv, at low density, in vacuum of the order of 10^{-5} mm of mercury. Total dosages of the order of 10^{-7} coulombs per square centimeter are given the irradiated material. Investigations have been made of the rate of death of spores of the Ascomycete mold *Aspergillus niger* under bombardment of this beam as a function both of total incident dosage and of voltage. A study of the killing curves as a function of dosage at constant voltage and as a function of voltage at constant survival ratio of the material appears to yield information of the mechanism of cell death under x-ray bombardment at varying mean integral ranges of released secondaries. It is planned to extend the voltage range used and to investigate the rate of killing of cancerous *versus* noncancerous cell groups in tissue culture. Mutations have also been produced in the material bombarded.

34. An Electronic Absorption Photometer. J. B. H. KUPER, *Washington Biophysical Institute.*—Improvements in the type of logarithmic photo-cell amplifier suggested by Russell[1] have indicated the possibility of employing two such amplifiers connected in opposition as a direct reading photometer for absorption measurements; a vacuum tube voltmeter used as the indicating instrument may then be calibrated to read directly photographic density or extinction coefficient depending on the application. It has been found possible to get sufficiently good matching of tube characteristics by adjustment of electrode voltages when using type 954 pentodes. The use of a pentode circuit gives much greater sensitivity than the triode arrangement suggested by Russell. Limitations of the device with regard to sensitivity, stability, and accuracy of logarithmic response will be discussed, and suggestions offered for overcoming them as far as possible.

[1] Russell, Rev. Sci. Inst. 8, 495 (1937).

35. Further Concentration of N^{15}. H. G. THODE, JOHN E. GORHAM AND H. C. UREY, *Columbia University.*—A 46-fold change in the ratio of the nitrogen isotopes has been effected by the use of the exchange reaction between ammonia gas and ammonium nitrate solution, using a two

stage distillation column as suggested by Urey, Huffman, Thode and Fox.[1] The first column consists of a 1-inch glass tube 40 feet in length packed with glass spirals, and the second column of a $\frac{3}{8}$-inch glass tube 25 feet in length also packed with glass spirals. On the basis of preliminary experiments each of these was calculated to give approximately a 10-fold increase. The two columns produced 14.8 percent N^{15} in two weeks, and the concentration was continuing to rise. The transport was about 0.15 grams of N^{15} per 24 hours. A third section consisting of a 3-inch glass tube 50 feet in length packed with Berl saddles is being constructed. This should increase the transport by a factor of 10, and should increase the concentration which can be produced at the present time. The concentration of S^{34} has been increased by the use of the $\frac{3}{8}$-inch column, using the exchange reaction between sulfur dioxide and sodium bisulfite solution. S^{34} concentrates in the solution, and hence the same apparatus can be used for work on this isotope, though probably much smaller changes in concentration can be effected.

[1] J. Chem. Phys. **5**, 856–868 (1937).

36. Note on the Binding Energy of Li^6. K. G. CARROLL AND HENRY MARGENAU, *Yale University*.—A perturbation calculation[1] suggests that the simple symmetrical interaction between nuclear particles which suffices to explain the binding energies of the 2, 3 and 4 particle nuclei fails to yield the observed energy of the ground state of Li^6 (−31 Mev). To obtain further evidence on this point a variational calculation was made with six suitably chosen doubly-excited functions in addition to the normal state function. The energy of the ground state in the first approximation (−4.8 Mev) was lowered by 3.9 Mev, while a second-order perturbation calculation with the same functions depressed the ground state by 5.5 Mev. Inclusion of a greater number of functions is necessary before a satisfactory estimate of the convergence limit can be made, but the present result indicates that a variational calculation gives an even smaller value of the binding energy than does the second-order perturbation theory.

[1] Inglis, Phys. Rev. **51**, 531 (1937).

37. The Scattering of Alpha-Particles by Argon, Oxygen, and Neon. GORDON BRUBAKER, *Yale University*.—Measurements have been made of the scattering of alpha-particles between 35° and 130° by argon, oxygen, and neon. A new type of apparatus in which the particles are detected by annular proportional counters has been developed, which makes it possible to study two ranges of angles simultaneously. Anomalies have been observed in the scattering by all three elements. The results of Riezler for oxygen and neon have been confirmed and extended to higher particle energies and larger angles. At the larger angles the ratio of observed to classical scattering for oxygen rises to 4 at 6.7 Mev particle energy, higher than can be explained by *s* scattering alone. In the case of neon, the observed to classical ratio falls below one, then rises again to unity at 6.9 Mev. For argon the anomaly consists in a decrease below the classical value beginning, at the higher angles, at 5.5 Mev and continuing to the highest energies used. The form of the anomaly indicates that it should be attributed to overcoming of the barrier, although it occurs at a lower energy than the generally accepted barrier height would lead one to expect.

38. The Angular Distribution of the Protons from the Deuteron-Deuteron Reaction. R. O. HAXBY, J. S. ALLEN AND J. H. WILLIAMS, *University of Minnesota*.—A knowledge of the angular distributions of the disintegration products of light elements is important in the comparison of different nuclear theories and in the determination of nuclear energy levels. Therefore it was thought worth while to repeat the measurements of Kempton, Browne and Maasdorp[1] and Neuert.[2] For this purpose a chamber was constructed with which it was possible to measure accurately the angular position of an ionization chamber placed inside the vacuum. Preliminary measurements on $Li^6+H^2\rightarrow He^4+He^4$ gave spherical symmetry in the center of mass system within the accuracy of the measurements, a few percent. Observations on the protons from $H^2+H^2\rightarrow H^3+H^1$ at 190 kv were transformed to the center of mass system and gave the expected symmetry about 90°. The ratios to 90° fit the expression $(1+0.7\cos^2\theta)$ quite well, agreeing with Kempton, Browne and Maasdorp.[1]

[1] Kempton, Browne and Maasdorp, Proc. Roy. Soc. **157**, 386 (1936).
[2] Neuert, Physik. Zeits. **38**, 122 (1937).

39. Scattering Cross Sections of Various Elements for D-D Neutrons. W. H. ZINN, S. SEELY AND V. W. COHEN, *Columbia University*.—The total collision cross sections of a number of nuclei for 2.8 Mev neutrons have been measured by a method similar to the one used by Dunning.[1] The monochromatic neutrons were produced by bombarding heavy ice with 110 kv deuterons. The neutrons were detected by a small helium-filled ion chamber coupled to a linear amplifier. The geometrical arrangement was such that the number of neutrons scattered into the detector by the absorber was of the order of 1.0 percent and the number scattered by the walls of the room and apparatus was approximately 3.0 percent of the total detected. The results are given in the table. In calculating the cross sections of hydrogen and deuterium from the data on water the cross section for oxygen given by Ladenburg and Kanner[2] has been used. The inaccuracy is estimated as less than 5 percent. Comparison of these cross sections with those obtained by Dunning[1] for Rn-Be neutrons does not show any marked differences for the heavier nuclei. The values for hydrogen obtained from water and paraffin are in good mutual agreement and substantiate the discrepancy between theory and experiment pointed out by Ladenburg and Kanner.[3]

Element	$\sigma\times10^{24}$
H (paraffin)	2.15
H (water)	2.2
D (heavy water)	2.12
C	1.92
Al	2.39
S	2.94
Fe	3.03
Cu	2.75
Zn	3.14
Sn	4.33
Pb	6.09

[1] Dunning, Phys. Rev. **45**, 586 (1934).
[2] Ladenburg and Kanner, Phys. Rev. **52**, 1255 (1937).
[3] Ladenburg and Kanner, Phys. Rev. **52**, 911 (1937).

40. Multiple Ejection of Neutrons from Excited Nuclei. R. L. THORNTON AND J. M. CORK, *University of Michigan.*—It has been shown that almost without exception elements bombarded with very energetic neutrons form radioactive isotopes according to the reaction $(n, 2n)$. In certain elements, notably, fluorine, scandium and copper, assignments given radioactive isotopes should make it possible to detect the process $(n, 3n)$. Such a positive result has been reported in the case of scandium 100 percent mass 45. This conclusion was based upon the assignment of Walke of a 4-hr. period to Sc^{42} and the 53-hr. period to Sc^{44} both produced by alpha-particles on potassium and a 4-hr. period in Sc^{43} due to alpha-particles on Ca^{40}. To check this result neutrons of varying energies were allowed to activate scandium and the ratio of the 4-hr. $(n, 3n)$ to the 53-hr. $(n, 2n)$ activities observed. It is shown that for neutrons from 10 to 20 Mev this ratio is essentially constant. This indicates that the two periods are due to isomers of Sc^{44}. Relative activation functions for the $(n, 2n)$ reaction have been obtained for certain elements, namely, oxygen, nitrogen, carbon, copper, and silver. These are of very different form and there appears some evidence of anomalous behavior for oxygen and copper.

41. The Isotopic Weight of Helium by Direct Comparison with Oxygen. K. T. BAINBRIDGE, *Harvard University.*—Helium has been compared directly with oxygen by means of the doublet $He_2^+ - 0^{++}$. The separation is 0.00772 ± 0.00012 mass units corresponding to a helium mass of 4.00386 ± 0.00006. In combination with the doublets $D_2^+ - He^+$ and $DHe^+ - C^{++}$ a new set of "fundamental doublets" is provided from which the mass values of C^{12} and D^2 secured agree with those previously reported.

42. The Isotopic Constitution of Uranium and the Half-Life of Actino-Uranium. ALFRED O. NIER,* *Harvard University.*—A mass-spectrographic study of the isotopes of uranium has been made using UBr_4 and UCl_4 vapor bombarded by electrons as a source of uranium ions. The U^{238}/U^{235} and U^{238}/U^{234} ratios were found to be 139.0 ± 1.0 and $17{,}000 \pm 2000$, respectively. The former ratio was checked in three different samples of widely different geographic origin and geologic age. Upper limits for the abundance of other isotopes in respect to U^{238} are: U^{242}, U^{241}, U^{240}, 1/65,000; U^{239} and U^{237}, 1/12,000; U^{236}, U^{233}, U^{232}, and U^{231}, 1/35,000. Kovarik and Adams[1] found a total of 24,770 alpha-particles per second given off by a gram of uranium ($U^{238}+U^{234}+U^{235}$). From a consideration of the Pb^{207}/Pb^{206} ratio (corrected for common lead) for a number of radiogenic lead samples (unpublished results of author) together with the Pb/U ratio for these leads and the data given above, a value, 0.046 ± 0.002, is computed for the ratio of the activity of the actinium series to the activity of the uranium series. The half-lives calculated for the three uranium isotopes are, then, on this basis: U^{238} (UI), 4.56×10^9 years; U^{234} (UII), 2.68×10^5 years; U^{235} (AcU), 7.14×10^8 years. The uranium and lead samples used in this work were kindly prepared and furnished by Professor G. P. Baxter of Harvard University department of chemistry.

* National Research Fellow.
[1] Phys. Rev. **40**, 718 (1932).

43. On the Scattering of Fast Neutrons. R. F. BACHER AND D. C. SWANSON, *Cornell University.*—Experiments on the scattering of fast neutrons, previously reported,* indicated that the energy of the neutrons scattered from lead and iron is much lower than that of the incident neutrons. These experiments have been extended to include measurements made in the fast neutron "beam" with and without a thick lead scatterer. The neutron energies were determined by finding the direction and range of recoil protons produced in a cloud chamber filled with CH_4 under pressure. In order to be sure that experimental conditions were not changed, pictures were taken with and without scatterer in series of five, alternately. Although the maximum energy observable was not as high as that previously obtainable with the helium filled chamber, there is a considerable decrease in energy found for the neutrons which passed through the lead. The ratio of those neutrons which have energies below 3 Mev to those with energies above, changes from 1 without scatterer to 2 with scatterer.

* Bacher and Swanson, Bull. Am. Phys. Soc. **13**, 12 (1938).

44. The Scattering of Protons and Deuterons by Deuterium and by Helium. N. P. HEYDENBURG AND R. B. ROBERTS, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—We have measured the scattering of deuterons by deuterium gas on an absolute basis as a function of angle between 15° and 45° and find ratios to the scattering expected from the Mott theory for coulomb interaction varying from 1.30 at a 15° scattering angle to 2.80, 3.25, and 4.10 at 45° for incident energies at the scattering volume of 640, 743, and 855 kv, respectively. This indicates an additional repulsive force between deuterons at close distances of approach. The scattering of protons by helium was found to be classical between 20° and 45° scattering angles at 700 and 1000 kv proton-energy. This is in agreement with the results of Chadwick and Bieler for the scattering of helium by hydrogen for the same relative velocities. However, the scattering of deuterons by helium showed a marked anomaly. Here the ratio of the scattering observed to that predicted by the Rutherford-Darwin formula increased from unity at 20° to 2.0 at 55° for deuterons of 667 kv energy and from unity at 20° to 4.45 at 75° for deuterons of 887 kv energy.

45. Alpha-Particle Mean Range Standards. M. STANLEY LIVINGSTON AND M. G. HOLLOWAY, *Cornell University.*—An experimental measurement of the ionization of alpha-particles near the end of their range[1] has resulted in an improved specific ionization curve for a single alpha. From this curve and the distribution functions characteristic of various straggling coefficients average ionization (Bragg) curves have been constructed, matching the observed Bragg curves as to shape. An empirical relation is obtained from which the mean ranges of particle groups may be determined from the observed ionization curves. The analysis shows that the true mean ranges of natural alpha-particles are 0.037 cm greater than the previously accepted standards,[2] with a smaller probable error. Graphical integration of the single particle specific ionization curve results in a

range-energy relation for alpha-particles, matched in the region of natural alphas, with five to ten times the accuracy of previous range-energy relations in the low energy region. Involved in the analysis is a definition of the mean range of an alpha-particle group. This is the value obtained from extrapolation to zero ionization of the ionization curve of the average alpha by means of the "range exponent" found to hold over the last mm of path.

[1] Holloway and Livingston, Bull. Am. Phys. Soc. **13**, 8 (1938).
[2] Lewis and Wynn-Williams, Proc. Roy. Soc. **136**, 349 (1932).

46. Oscillograph Data on the Electrode Capacitance of Conductivity Cells. S. F. ACREE,[1] *National Bureau of Standards.* (*Introduced by Lyman J. Briggs.*)—In 1912–6 precision work at 60–4000 cycles (sine wave) with inductance and capacitance bridges showed that conductivity cells have an apparent series electrode capacitance of 10 to 5000 microfarads. Oscillograms (G.E. vibrator type) were also made of the wave forms of the total impressed e.m.f., the current, and the electrode e.m.f. of concentric cylindrical bright Pt electrodes ($\frac{1}{2}''$ dia.$\times 3''$ long, separated 1 mm) for different time periods after closing and opening the circuit, at 60 and 240 cycles (sine wave), and with solutions of HCl, H_2SO_4, and NaCl. These cell dimensions facilitated determination of the resistance, capacitance, and transient effects by scaling the oscillograms, with the following conclusions. Both the steady state and transient relations of the total impressed e.m.f., electrode e.m.f., resistance, and capacitance are simulated by equivalent resistors and capacitors in series. The resistances and capacitances computed from the steady state and transient curves are identical. The electrode capacitance (about 7000 microfarads) is constant at 60 and 240 cycles and at any impressed e.m.f. below polarization voltage (1.3 v). Above polarization voltage (i.e. from 1.5 to 4 v) the current wave form departed from sinusoidal but became approximately sinusoidal again at 7 v impressed e.m.f., and the capacitance rose to 48,000 microfarads. Transient phenomena are absent when the circuit is closed or opened at peak current, but are very decided when the circuit is closed or opened at the zero of the current wave form. (Lantern slides.)

[1] In cooperation with Professor Edward Bennett, G. H. Gray, and Harold Goldberg, University of Wisconsin.

47. On the Electrical Breakdown in Alkali Halides. R. J. SEEGER AND E. TELLER, *George Washington University.*—According to measurements of von Hippel[1] electrical breakdown occurs in alkali halides at electric fields of about 10^6 volts per centimeter. He suggests that this breakdown will take place if the field becomes great enough to compensate for the energy loss of free electrons of any velocity. Calculating the energy loss from the interaction of the electrons with the ions of the lattice one obtains for the breakdown-field E_b in electrostatic units

$$E_b \sim \frac{2\pi^2 \nu e m}{h}\left(\frac{1}{n_\infty^2}-\frac{1}{\kappa}\right),$$

in which ν is the optical frequency of the lattice, n_∞ is the index of refraction for infinite wave length and κ is the dielectric constant. The symbol m represents the "effective mass" of the electron for its motion in the lattice. It is the only quantity in the expression for E_b which cannot be determined directly from experiment. It must at least equal, however, the ordinary mass of the electron and probably does not differ from this in order of magnitude. The experimental values of E_b are obtained if m is assumed to be between one and three times the mass of the electron.

[1] A. von Hippel, J. App. Phys. **8**, 815–832 (1937).

48. Impulse Breakdown in Long Discharge Tubes. J. R. DIETRICH, L. B. SNODDY AND J. W. BEAMS, *University of Virginia.*—Impulse breakdown in a discharge tube 14.2 cm diameter and 1200 cm long has been investigated by a method similar to that previously described.[1,2] The input circuit has been modified to permit the removal of the potential from the tube at any desired time. Average speeds of propagation of the voltage wave over a 6.4 meter length have been determined (positive potentials 61 to 125 kv). At constant voltage the speed increases rapidly in the pressure range 0.012 to 0.2 mm (at 125 kv from 8×10^8 to 5×10^9 cm per sec). Above this the rate of increase is much slower. The light accompanying the initial wave appears as a rather sharply defined column. The column diameter increases from 0.6 to 10 cm in the pressure range 0.024 to 0.175 mm (125 kv). The column diameter at constant voltage and pressure is approximately the same for voltage application times from 1.3×10^{-7} to 480×10^{-7} sec. All observations were for dry air.

[1] Phys. Rev. **50**, 469 (1936).
[2] Phys. Rev. **52**, 739 (1937).

49. The Resistivity and Power Input in a Columnar Discharge under Conditions of Nearly Complete Ionization. FRED L. MOHLER, *National Bureau of Standards.*—Measurements of the potential gradient in the cesium positive column under conditions of over 50 percent ionization have been made with pressures ranging from 0.003 mm to 2 mm and current densities ranging from 5 to 150 amperes per cm^2. Data include electron temperature, T_e, and concentration, n_e, and the flow of ions to the tube walls. The experimental values of the resistivity, R, can be compared with theoretical values for a completely ionized gas. The best agreement is found with an equation derived by Gvosdover

$$R\ (\text{ohms cm}) = \frac{14.8\times10^3}{T_e^{\frac{1}{2}}}\log\cdot 72\times10^6 T_e^2/n_e^{\frac{1}{2}}.$$

Theoretical values for 6000° decrease from 0.15 to 0.1 ohms for values of n_e between 1×10^{13} and 3×10^{15}. Observed values range from 0.12 to 0.06 ohms at this temperature. At pressures below 0.1 mm the power input is largely accounted for by recombination on the walls and observed values of the recombination energy are consistent with the Tonks, Langmuir theory for this.

50. The Concentration of an Ideal Solution in a Centrifugal Field of Force, as a Function of the Time. WILLIAM J. ARCHIBALD, *University of Virginia.* (*Introduced by J. W. Beams.*)—The differential equation[1] for the settling of molecules and particles in an ideal liquid solution or suspen-

sion in a centrifugal field of force has been solved and put in a usable form. For the case of a sector shaped cell extending to the center of the rotor, two sets of curves showing the concentration as a function of time and position have been computed. From these curves it is possible to determine when the equilibrium state has been reached to any degree of approximation, for a centrifuge which is free of stirring. These curves are of special value in connection with the measurement of molecular weights by centrifuging.

[1] Lamm, Archiv. f. Mat. Astron. och Fysik **21B**, No. 2. Faxen, ibid.

51. The Phase Shifts in Controlled Multivibrators from 200,000 to 1 Cycle Per Second. W. D. GEORGE, *National Bureau of Standards. (Introduced by L. J. Briggs.)*—As ordinarily used in obtaining sub-multiple frequencies the output of a multivibrator may be considered as having an accuracy equal to the control frequency. In obtaining accurate time intervals from a standard piezo-oscillator a frequency division as great as 5,000,000 to 1 is used. Accurate one-second time intervals are regularly broadcast from the bureau's radio station WWV as a modulation on standard radiofrequencies. Tests of the output frequency of 1 cycle per second at first showed random phase shifts of several parts in 10^5. This paper describes methods of increasing the short time accuracy of this frequency. A description of the oscillograph technique is given and a circuit arrangement for supplying one-second intervals accurate to better than a part in 10^6 is described.

52. Electrically Driven Vacuum-Type Centrifuge.* SHEPPARD A. BLACK, J. W. BEAMS AND L. B. SNODDY, *University of Virginia.*—The centrifuge is spun in a vacuum chamber by an electric motor situated either vertically above or below the chamber.[1] A small flexible metal shaft, common to both motor armature and centrifuge, passes into the vacuum chamber through a vacuum tight oil gland. The vertical thrust of the shaft is taken up by an air cushion support either on the armature of the motor or on a separate bearing plate attached to the shaft. The motor, of the shaded-pole single-phase induction type, is driven by an audiofrequency power amplifier of three hundred watts maximum output. The frequency supplied to the amplifier is the beat note between the outputs of two piezo-electric oscillators, one of which is equipped with a crystal whose frequency can be varied. A centrifuge four inches in diameter has been spun at 1000 r.p.s. with a constant slip of 72 r.p.s. The rotational speed attainable appears to be limited only by the mechanical strength of the armature and the centrifuge.

* Supported by a grant from the Division of Natural Sciences of the Rockefeller Foundation.
[1] Science **85**, 185 (1937).

53. The Centrifugal Distortion of Axial Molecules. ZAKA I. SLAWSKY, *University of Michigan.*—The theory of the semi-rigid rotators developed by Wilson and Howard[1] has been applied to the axial molecules YX_3 and ZYX_3. It is found that the change in the rotational energy, δW, caused by the centrifugal distortion, can be expressed in terms of the quantum numbers J and K and as a function of the potential constants and the molecular dimensions. The formula is evaluated explicitly for NH_3 and ND_3 and for the former is:

$$\delta W/hc = -\{0.000625J^2(J+1)^2 - 0.000950K^2J(J+1) - 0.000799J(J+1) + 0.000630K^4 + 0.00189K^2\}.$$

The pure rotation lines of NH_3 and ND_3 are calculated and compared with the observations of Wright and Randall,[2] and of Barnes.[3] The agreement is very satisfactory. The theory predicts that the rotation lines are multiple. The spacing of this fine structure was too small to be observable in the region mapped by Wright and Randall[2] but should be possible to detect in the case of the higher members of the rotation series.

[1] E. Bright Wilson, Jr. and J. B. Howard, J. Chem. Phys. **4**, 260 (1936).
[2] N. Wright and H. M. Randall, Phys. Rev. **44**, 391 (1933).
[3] R. B. Barnes, Phys. Rev. **47**, 658 (1935).

54. A Decisive Ionospheric Investigation Concerning the Lorentz Polarization Correction. H. G. BOOKER AND L. V. BERKNER, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—Some years ago considerable discussion took place concerning the relation between thr constitution of the ionosphere and its refractive index foe radio waves. The question at issue was whether the force per unit charge exerted by the electric field of a radio wave upon an elementary charged particle in the ionosphere should be taken simply as the Maxwellian electric intensity **E** (the Sellmeyer theory), or whether there should be added a contribution $(4\pi/3)\mathbf{P}$ (the Lorentz theory). The discussion culminated in a theoretical treatment of the subject by Darwin which seemed to point to the conclusion that the Sellmeyer theory should hold good in the ionosphere at radiofrequencies. For reflection from the ionosphere of radio waves of frequency less than the gyromagnetic frequency, there is in middle latitudes a clear-cut distinction in the behavior of the extraordinary wave according to the two theories. Over the past year a large number of records showing magneto-ionic splitting of ionospheric echoes at these wave frequencies have been obtained. We are led to believe that it is impossible to interpret these observations in terms of the Sellmeyer theory but that no objection exists to their interpretation in terms of the Lorentz theory.

55. On the Trouton-Noble Experiment. PRESTON B. CARWILE, *Lehigh University.*—FitzGerald, Trouton and Noble[1] gave reasons for believing that a charged parallel-plate condenser, moving obliquely to its own field, should experience a torque tending to make the field parallel with the line of motion. On the other hand, Larmor[2] advanced reasons for expecting a torque of the same magnitude but in the opposite sense. Trouton and Noble,[1] using a charged condenser suspended with its field oblique to the motion of the earth around the sun, were unable to observe any torque. The absence of observed torque has been confirmed by Tomaschek[3] and by Fenner.[4] One might suspect at first glance that the FitzGerald-Trouton-Noble torque and the Larmor torque simply neutralize. More careful considera-

tion makes this view untenable. Assuming Ampere's law $d\mathbf{H}=(id\mathbf{l}\times\mathbf{r})/r^3$ and its reciprocal[5] $d\mathbf{E}=-(\dot{\phi}d\mathbf{l}\times\mathbf{r})/(4\pi r^3)$ (but without assuming FitzGerald-Lorentz contraction) we can show that FitzGerald-Trouton-Noble *forces* should exist but that among themselves they should produce no net torque. The application of the reciprocal to Ampere's law brings to light a torque, not heretofore mentioned in the literature, which just neutralizes the Larmor torque. The total torque to be expected on the condenser is zero. Hence this experiment does not furnish a criterion for the existence of absolute motion. Several fundamental implications emerge.

[1] F. T. Trouton and H. R. Noble, Phil. Trans. Roy. Soc. (London) **202A**, 165 (1904).
[2] J. Larmor, *Fitzgerald's Scientific Papers* (1902), p. 566.
[3] R. Tomaschek, Ann. d. Physik **78**, 743 (1925); also **80**, 509 (1925).
[4] E. Fenner, Ann. d. Physik **29**, 332 (1937).
[5] Preston B. Carwile, Phil. Mag. **25**, 175 (1938).

56. The Supercooling and Freezing of Water. N. Ernest Dorsey, *National Bureau of Standards.*—The following results, partly new and partly confirming those of others, have been obtained in a preliminary study of the supercooling and freezing of water contained in sealed glass bulbs about 2 cm in diameter by 4 cm long, and half-filled. Numerous specimens from various sources, both natural and artificial, have been studied. Some were air-free; most contained air at atmospheric pressure. Each normal specimen freezes spontaneously at a definite, characteristic temperature (its spontaneous-freezing-point), which is reproducible and does not depend upon either the rate or the duration of the cooling. If the spontaneous-freezing-point depends upon the constitution of the water, then that constitution is at each instant the one that is characteristic of the existing temperature; there is no perceptible lag as the temperature is varied in the range below 25°C. This seems to be incompatible with certain ideas recently current. The value of the spontaneous-freezing-point varies widely from specimen to specimen; values distributed throughout the range −3 to −21°C have been observed. Prolonged heating may produce a marked lowering of the spontaneous-freezing-point. This lowering seems to be permanent, persisting unchanged for months. This suggests that the effect is not due to any change in the constitution of the water itself, but to a change in some foreign inclusion. All the observations are consistent with the idea that the spontaneous-freezing-point is determined by the size of the largest mote contained in the sample, within certain as yet unspecified limits. Solution, precipitation, agglomeration, etc. change the sizes of the motes, thus causing erratic variations in the spontaneous-freezing-point; such variations are often observed. Supercooling water by 12 to 15°C is not at all difficult, and does not demand either quiescence or the use of minute volumes.

57. Effect of Carbon on the Critical Cooling Rate of Iron-Carbon Alloys. Thomas G. Digges, *National Bureau of Standards.* (*Introduced by L. J. Briggs.*)—For a steel to harden by quenching, its ferrite or alpha iron must be heated to a temperature sufficiently high to transform into gamma iron in order to dissolve the carbon and thus form austenite. The hardness and structure of a quenched steel depend primarily on the temperature at which the austenite decomposes during cooling and the stability of the quenched austenite is influenced by its composition and grain size. The effect of carbon on the hardenability of high purity iron-carbon alloys and plain carbon steels was studied by means of determinations of the critical cooling rate and austenitic grain size. The critical cooling rate, that is, the slowest cooling rate for which the steel will completely harden, was used as an index of the hardenability of these alloys and steels. For the materials having a constant grain size and all carbon in solution at the time of quenching, the critical cooling rate decreased continuously with increase in the carbon content. Comparison of the critical cooling rates of the alloys and steels, under similar conditions with respect to austenitic grain size, carbon content, and with all carbon in solution, shows that the alloys have considerably higher rates than the steels, that is, the alloys are comparatively shallow hardening. Details concerning the precautions necessary in the preparation of the high purity iron-carbon alloys and plain carbon steels, the members of each series differing only in carbon, and data on the influence of carbon on the hardenability of these alloys and steels are described in a complete report.[1]

[1] To be published, Nat. Bur. Stand. J. Research **20**, May (1938).

58. Thermal Expansion and Effects of Heat Treatments on the Growth, Density and Structure of Some Heat-Resisting Alloys. Peter Hidnert, *National Bureau of Standards.*—Coefficients of linear expansion for various temperature ranges between 20 and 1000°C were obtained on some new heat-resisting alloys: an iron-chromium-aluminum alloy and three iron-chromium-aluminum-cobalt alloys. No polymorphic transition was observed in these alloys between 20 and 1000°C. The alloys exhibited growth (0.82 to 2.81 percent) after various heat treatments at temperatures up to 1400°C. Additional heat treatments would probably cause additional growth. The densities of the mechanically worked alloys increased 1.12 to 2.50 percent as a result of various heat treatments at temperatures to 1400°C. Tremendous grain growth also occurred in the alloys as a result of various heat treatments at elevated temperatures.[1]

[1] The results obtained will be published in the *Journal of Research of the National Bureau of Standards.*

59. The Origin of Deformation Textures. Charles S. Barrett, *Carnegie Institute of Technology.*—That metal single crystals will seek a single final orientation when subjected to homogeneous plastic deformation has been widely believed as a result of experiments by Polanyi, Schmid, Sachs, Taylor, Elam, and others. We have discovered, however, that this is not the usual case for single crystals of iron deformed in compression. Most iron crystals after compression consist of fragments possessing *two* orientations, with [111] and [100] axes in the axis of compression, respectively. Crystals starting with [100] near the axis will end as distorted crystals with [100] parallel to the axis, while those starting with [111] near

the axis will end with [111] parallel to the axis; all others cease to be single crystals and become fragments having both [111] and [100] orientations in proportions depending upon the initial orientation. These results hold not only for single crystals, but also for individual grains of polycrystalline specimens. They disclose, therefore, the origin of the compression texture of polycrystalline iron, which we have re-determined and find to be a fiber texture with [111] and [100] parallel to the compression axis. Details of these and related experiments with various metals, types of deformation and recrystallization will be reported in the metallurgical journals.

60. An Absolute Viscometer for Lubricating Oils at High Pressure. B. W. THOMAS, R. B. DOW AND W. R. HAM, *Pennsylvania State College.*—An absolute viscometer of the rotating tube type is mounted inside a hardened steel pressure chamber of $8\frac{1}{2}$ inches external diameter and 15 inches in length. The speed of the motor driven rotating tube is measured externally with a Western Electric counter. The inner cylinder is restrained in its rotation by means of a calibrated helical spring of piano wire. Also within the inner cylinder there is a two mil slide wire, the change of resistance of which determines the angular displacement. The viscometer is maintained at constant temperatures in a thermostatically controlled water bath. The pressure is obtained by the usual type of hydraulic pump. Pressure is measured by the change of resistance of a conventional manganin resistance coil. A Pennsylvania neutral, its acetone extracted Raffinate, and Extract, have each been investigated at three temperatures for pressures up to 36,000 lb./sq. in. Isothermal viscosity-pressure curves, Isobaric viscosity-temperature curves and Isobaric viscosity indices have been computed.

61. The Viscosity of Sols Made from X-Irradiated Apple Pectin. C. H. DWIGHT AND H. KERSTEN, *University of Cincinnati.*—Work previously reported upon the viscosity of sols made from x-irradiated agar has been extended to apple pectin. The conclusions drawn are: (1) Irradiation of dry apple pectin powder by soft x-rays (1.54A) profoundly affects the viscosity of the resulting sol; (2) The effect of *p*H is not very important in comparison with the effects due to irradiation; and (3) There is no appreciable recovery of the dry pectin powder from the irradiation, even after eighty-five days.

62. On the Theory of the Viscosity of Suspensions of Ellipsoidal Particles. EUGENE GUTH, *University of Notre Dame. (Introduced by George B. Collins.)*—Einstein's hydrodynamical theory of the viscosity of spherical particles was extended to suspensions of ellipsoidal particles. Using the work of Jeffery and of the author and O. Gold, one gets an equation connecting the viscosity of the suspension η with the viscosity of the solvent η_0, the total volume of the suspended particles v, the volume V of the suspension and the ratio r of the major and minor axis of the suspended prolate spheroids:

$$\eta=\eta_0[1+f_1(r)(v/V)+f_2(r)(v/V)^2+\cdots].$$

Generally $f_1(r)$ and $f_2(r)$ depend on the initial orientation of the suspended particles, the maximal and minimal values being 2 and $r/(2\ln 2r-3)+2$, respectively, for $r\gg 1$. The maximal value of $f_2(r)$ is: $0.04(r^3/(2\ln 2r-3))$. All this holds for particles in a laminar stream. For particles in a pure dilatational stream an extension of the method used for the case of spherical particles[1] leads to the unambiguous result: $f_1(r)=0.07r^2$; $f_2(r)=1.6r^4$. For small suspended particles the influence of the Brownian movement was considered, leading to the formula:

$$f_1(r)=r^2/(8\ln 2r-12)\sim 2.5+(1/16)r^2.$$

The formulae were tested partly by model suspensions.[2]

[1] Guth and Gold, Phys. Rev. **53**, 322 (1938).
[2] The last formula is applicable to solutions of high molecular substances of rod-like shape, such as rubber and cellulose solutions and the changing of the viscosity of lubricating oils by the addition of small quantities of some high molecular compounds.

63. Physics of Lubrication, III. Note on the Theory of Air-Lubricated Journal Bearings. MAYO D. HERSEY, *Kingsbury Machine Works, Inc.*—The thermodynamic characteristics of air-lubricated bearings differ from those outlined for oil-film bearings in Chapter V, *Theory of Lubrication*,[1] due to the increase in viscosity of a gas with rising temperature. Both the coefficient of friction and load-capacity as usually defined increase indefinitely with speed instead of approaching a limit. For a full bearing under high speed conditions satisfying Petroff's law, the equilibrium temperature rise T in the film is given by $AT^n=BK(T+T_0)^m$. The left side represents power carried off by radiation, convection, etc., as a function of temperature elevation T; the known factor B, depending on bearing design, is proportional to the square of the speed; $K(T+T_0)^m$ expresses film viscosity in terms of the unknown T and absolute temperature T_0 of surroundings. For moderate temperature elevations, case 1, $n=1$, $m=4/5$; for higher ranges, case 2, n is assumed $=3/2$, with $m=3/4$. Convenient approximations are discussed, and the exact solution given for case 2.

[1] Wiley, 1936.

64. Film Lubrication of the Journal Bearing of Finite Width. SELBY M. SKINNER, *University of Chicago.*—The exact solution for the pressure distribution in the fitted journal bearing of finite width, c, is obtained as $\Sigma\Phi_n \sin[(2n+1)\pi z/c]$ where Φ_n is the solution of a non-homogeneous hypergeometric equation in $\cos^2\theta$. The general case of the journal bearing is partially developed and shown similarly to depend upon solution of a generalized Mathieu (or Hill's) equation. In view of computational difficulties other methods are sought. In the literature, this has been done by arbitrary assumptions as to pressure distribution, neglect of terms in the d.e., or use of infinite width. The true film thickness is here shown to be approximated very closely by an exponential function, particularly in the important case when the film converges over its entire length. Two exact solutions are obtained for the pressure distribution in such an exponential film, which converge more rapidly the smaller or the greater the width length ratio, ρ, is, respectively; both are more con-

venient to use than Michell's solution for the plane bearing. The 90° bearing is computed for various values of ρ; total load, center of pressure, frictional moment, and quantity of lubricant required are given. In particular, the load coefficient starts from 0 when ρ is zero, with a concave curvature upwards, changes curvature, and finally (from about $\rho=3$) approaches the (finite) value for infinite width, asymptotically.

65. The Application of Thermal Diffusion to the Study of Turbulent Air Flow. H. K. SKRAMSTAD AND G. B. SCHUBAUER, *National Bureau of Standards.*—Since the diffusion of heat in a fluid depends upon the turbulence present, measurements of the rate of diffusion are used to study the nature of turbulence and determine its intensity. To measure the intensity of turbulence in an air stream a line source of heat, obtained from an electrically-heated fine wire, is mounted in a wind tunnel normal to the direction of the air flow, and a thermocouple is placed a short distance downstream and traversed across the heated wake. From the temperature distributions obtained, after making corrections for the molecular diffusion, the root-mean-square velocity normal to the direction of the air stream is calculated. The results show close agreement with the component of turbulence in the direction of the air stream measured by a hot-wire anemometer. The method is being applied at present to the study of turbulence in a thick boundary layer of a flat plate, and measurements have been made of the diffusion normal to the plate at different positions in the boundary layer. Work is in progress to measure the rate of diffusion parallel to the plate and normal to the air stream.

66. Precise Control and Measurement of the Speed of a Rotating Shaft Having a Mechanical Load of 200 Watts. FRANK WENNER AND IRVIN L. COOTER, *National Bureau of Standards.*—The shaft is driven by a d.c. motor and is directly connected to a d.c. generator. A resistance load on the generator is varied by means of a thyratron, contacts on the rotating shaft, and a self-inductor. Time pickups from a crystal clock are made each 0.011 second. At each time pickup the circuit through the resistance is closed if the shaft is ahead of the clock by 0.00001 second or more, and opened approximately 0.01 second later.

In operation the shaft is alternately ahead and behind the clock, this oscillation being stabilized by the self-inductor. The period of oscillation is determined mainly by the electrical time constant of the circuit while its amplitude is determined mainly by inertia and the resistance load. The period is approximately 0.2 second and the amplitude expressed as a displacement in time is approximately 0.00005 second. For the purpose at hand the speed is constant within 1 or 2 parts in a million. Over successive intervals of 15 minutes or more the average speed is the same within 1 part in ten million and is known to a corresponding accuracy.

67. The Nature of Energy Losses in Air Capacitors. A. V. ASTIN, *National Bureau of Standards.*—If the phase defect angle of an air capacitor is measured with an alternating current bridge capable of showing phase angle changes of the order of microradians, a definite dependence of the energy losses in the capacitor on the properties of its electrode surface is revealed. Using capacitors of the guard ring type an indication is obtained of an electrode surface film of oxide and water whose effect on the phase angle of the capacitor is equivalent to that of a series resistor. Approximations of film thickness and conductivity may be made from these measurements. Aluminum electrode capacitors have the largest phase defect angles of several materials investigated; silver plated electrodes, the smallest. Indication has also been obtained that the phase angle of a capacitor is affected when the field between the electrodes is nonuniform, the nonuniformity arising either from surface irregularities or edge effects. The defect angle of a capacitor with a nonuniform field increases regularly with increasing humidity, possibly due to the motion of the water dipoles in the nonhomogeneous field.

68. Aerodynamics Applied to the Golf Club. S. J. CROOKER, *Purcellville, Virginia.* (*Introduced by H. L. Dryden.*)—Measurements of golf club head velocity by photoelectric cell and high speed camera show the best players may swing as fast as 125 m.p.h. At such airplane speed the air resistance is important, which if reduced permits greater club velocity and a longer drive. Application of wind-tunnel research data to the design of the scientifically perfect golf club has led to interesting results. N.A.C.A. Report No. 291 by Dr. Zahm indicates the minimum resistance of airship hulls is obtained when the fineness ratio $L/D=2$. Such basic streamlined shape for the golf club head, with the nose flattened to provide ample striking face, has proven satisfactory. Wind-tunnel tests show traditional style golf club heads have 15 times more air resistance than the streamlined head. Dynamic and ballistic analyses, checked by field tests, prove the low resistance club increases the free flight distance of the golf ball by 15 yards; which means a golfer like Jimmy Thomson using the streamlined club should attain a carry of 275 yards.

69. Energy Variations in a Cyclotron Ion Beam. G. K. GREEN AND P. GERALD KRUGER, *University of Illinois.*—The 1 Mev deuteron beam from a small cyclotron has been examined for energy variation with a magnetic analyzer. The analysis was made on a section of the beam 0.5 cm wide at a distance of 300 cm from the dee slit where the beam is 60 cm wide if no external focusing is applied. It has been found that: (1) The ions traversing the small section have energies which extend some 3 percent from their observed mean. This is to be expected because there is a large radiofrequency component of the deflecting potential. These energies agree with those calculated from the observed variation of mean energy with respect to deflecting potential and the assumption that ions emerge over about 40° of the radiofrequency cycle. Geometrical considerations indicate that this energy range should be smaller for large cyclotrons, and for operation at higher energies. The effects of the radiofrequency component of

the deflecting potential can be removed by proper shielding. (2) The variation of mean energy with respect to the cyclotron magnetic field, H, is approximately proportional to $2H\Delta H$ which is required if the energy is proportional to H^2. (3) The simple analyzing fields used provide a small area of beams with energy variation of $\pm\frac{1}{2}$ percent and a current density of 2×10^{-8} amp./cm^2. This is sufficient for the precise investigation of the scattering of ions with a suitably designed scattering chamber. The current density can be increased by a more efficient design of external focusing device.

70. The Ion Optics of a Five Section Proton Accelerating Tube. J. S. ALLEN AND J. H. WILLIAMS, *University of Minnesota.*—The focal length of an electrostatic lens consisting of two coaxial cylinders has been shown to be given approximately by

$$\frac{1}{f}=\frac{3}{16}\int_{-\infty}^{\infty}\frac{\phi'^2}{\phi^2}dx, \qquad (1)$$

where ϕ is the potential at any point along the axis, being zero when the velocity of the ions is zero. ϕ' is the derivative taken with respect to the distance along the axis. Eq. (1) reduces to[1]

$$f=2.8R/\gamma^2 \qquad (2)$$

for cylinders of radius R, at potentials of ϕ_1 and ϕ_2, respectively. $\gamma=(\phi_2-\phi_1)/(\phi_2+\phi_1)$. This equation is valid only when $\gamma\ll1$. From graphical integration of (1) it was indicated that even when $\gamma\approx1$, the focal length was given by an expression similar to (2). By means of a five-section ion accelerating tube with electrodes at known potentials this equation was checked experimentally. It was found that the focal lengths of the different lenses were given more accurately by

$$f=2.8R/(1+2\gamma^4)\gamma^2 \qquad (3)$$

than by Eq. (2).

[1] W. W. Hansen and D. L. Webster, R. S. I. 7, 17 (1936).

71. Design and Construction of the Minnesota Pressure Electrostatic Generator. JOHN T. TATE, L. H. RUMBAUGH AND J. H. WILLIAMS, *University of Minnesota.*—As the initial step in a program of biological and physical research, an electrostatic generator operating under pressure is being constructed. The apparatus is enclosed in a vertical steel pressure vessel which is rated at 100 pounds per square inch. This tank is eighteen feet in diameter and thirty-six feet in length over-all, being capped with hemispherical ends. The steel blimp forms the roof of a cylindrical observation room which is below ground level. This room is separated from the control room by six feet of earth and concrete and is connected with the physics laboratory by a winding tunnel. Details of the nine-foot diameter corona cap, twenty-foot vertical porcelain insulating column, six and one-half-foot corona rings, thirty-six-inch belts and mechanical supports will be given. A conservative calculation of the voltage to be expected when operating at one hundred pounds per square inch of *air* surrounding the generator predicts four million volts.

72. Disintegration Constant of Thorium. ALOIS F. KOVARIK AND NORMAN I. ADAMS, JR., *Yale University.*—The determination of this constant was undertaken at the request of the National Research Council's Committee on the Age of the Earth. The material used was thorium oxide obtained from the mineral thorite, samples of which came from the same lot as that used by Geiger and Rutherford in the original determination of the constant. Technique was developed to cover the material impounding the thoron but permitting the α-particles to emerge. Thorium plus ionium activity was determined by counting the α-particles and the ionium activity was determined from the radium content of the mineral. Branching ratio of thorium C was also determined. The experiments were carried on over a period of several years in order to check the variation of the radiothorium through its minimum. Preliminary results were published in a "Letter to the Editor" in 1936. The final weighted mean values of the results are $\lambda=1.581\times10^{-18}$ sec.$^{-1}$ (4.990×10^{-11} year^{-1}) of half-value period $T=1.389\times10^{10}$ years; and the branching ratio of thorium C is 0.663. Details of the method of counting will be presented.

73. Formation of an Excited He^3 in the Disintegration of Deuterium by Deuterons. T. W. BONNER, *Rice Institute, Houston, Texas.*—The energy distribution of the neutrons from the reaction $H^2+H^2\rightarrow He^3+n+Q_1$ has been studied. Two homogeneous neutron groups with energies of 1.08 and 2.50 Mev have been observed at 90° to the 0.11 Mev deuterons. The emission of 1.08 Mev neutrons has been found to be approximately 1/10 as likely as the emission of 2.50 Mev neutrons. The corresponding values of Q_1 are $Q_1^0=3.29\pm0.08$ Mev and $Q_1^1=1.40\pm0.11$ Mev. The low energy group results when the He^3 is left excited to a level of 1.89 ± 0.11 Mev. The mass of He^3 has been calculated from the value of Q_1^0 and the mass-spectrographic value of $H^2=2.01473$. The result is $He=3.01700$. This result indicates that H^3 may be unstable going into He^3 with the emission of an electron.

74. The Passage of Fast Neutrons Through Lead. EMMETT HUDSPETH AND T. W. BONNER, *Rice Institute, Houston, Texas.*—The energy distribution of the neutrons from the reaction $H^2+H^2\rightarrow He^3+n^1$ has been determined after they passed through 3 cm of lead. The neutron energies were found from the energies of the recoil protons observed in a cloud chamber. The maximum neutron energy (2.50 Mev) is unaffected by the lead within the experimental error of 0.1 Mev. The energy distribution curve of the protons in the forward direction (0–10°) is only slightly affected by the 3 cm of lead. The effect of the lead is to increase the relative number of protons with energies in the interval 1.2 to 2.0 Mev. The results indicate that 10–15 percent of the 2.5 Mev neutrons make inelastic collisions in the lead with energy losses of from 0.5 to 1.3 Mev.

75. Scattering and Loss of Energy of Fast Electrons and Positrons in Lead. JACQUENETTE OPPENHEIMER AND W. A. FOWLER, *California Institute of Technology.*—A cloud chamber investigation has been made of the scattering and

loss of energy in a thin lead lamina (0.33 mm) of fast electrons and positrons (5.0 to 17.0 Mev) produced as secondaries by the gamma-radiation from Li^7+H^1. A comparison of the experimental scattering versus angle in the plane of the chamber with the Mott-Rutherford theory of single scattering shows good agreement above $\theta=10°$. Below this angle the experimental points behave in a manner reasonably consistent with multiple scattering. The average loss of energy for two groups of tracks of mean energy 9.0 Mev and 13.5 Mev was found to be 35 Mev/cm and 54 Mev/cm, respectively. These values are roughly 1.5 times the theoretical values, a result in agreement with the findings of Crane and co-workers at Ann Arbor. From the observed scattering it does not seem possible to account completely for this excessive loss of energy on the basis of a longer effective path in the lamina. Two out of 97 tracks in the 9.0 Mev group and five out of 179 tracks in the 13.5 Mev group lost more than 200 Mev/cm. The small excess over the large radiative losses to be expected theoretically is not statistically significant. No difference in the behavior of electrons and positrons was found.

76. The Disintegration of Al by Alpha-Particles. H. L. SCHULTZ,* *Yale University.*—Continuing work on $\alpha-n$ type reactions using the sensitive BF_3 ionization chamber paraffin method of detection, the excitation function for the emission of neutrons from Al^{27} has been studied. Ra C′ particles were employed to bombard a 4 mm Al target. The data indicate weak resonance maxima in the yield curve in good agreement with the results of Waring and Chang who observed the positron emission from P^{30}. Evidence for an irregularity above the theoretically expected barrier height as given by Bethe is obtained. That no marked discontinuities in the yield of neutrons occur for the range 5.4 to 6.6 Mev (where Duncanson and Miller found small or zero proton yield) is confirmed. Thus, these results also are in accord with Bohr's theory of the formation of compound nuclei and the competition between nuclear processes.

* Sterling Fellow.

77. Transmutation of Titanium by Th C′ Alpha-Particles. W. L. DAVIDSON, JR. AND ERNEST POLLARD, *Yale University.*—Under bombardment by Th C′ alpha-particles a considerable yield of protons has been observed from a target of titanium metal. These almost certainly arise from the reaction, $Ti^{48}+He^4\rightarrow V^{51}+H^1$, in which the stable isotope of vanadium is formed. The absorption curve for the protons has been obtained and shows the presence of two well-separated groups, corresponding to nuclear energy change $[Q]$ values of 0.0 and -3.7 Mev. This spacing of levels is unusually great, and may perhaps be linked with the fact that the product nucleus V^{51} has five neutrons in excess of protons. Using Dempster's value of 47.9651 for the mass of Ti^{48}, the value 50.9609 for the mass of V^{51} can be deduced.

78. Formation of Be^7. R. B. ROBERTS AND N. P. HEYDENBURG, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—Three reactions which might lead to the formation of Be^7 are:

(1) $B^{10}+H^1\rightarrow Be^7+He^4+Q_1$
(2) $Li^6+H^1\rightarrow Be^7+h\nu$
(3) $Li^6+H^2\rightarrow Be^7+n^1+Q_3$

The range-number curve of the alpha-particles emitted by boron under 200 kv proton bombardment was measured down to 3 mm. No departure from the expected distribution of alpha-particles from $B^{11}+H^1$ was observed. This means that either the yield of reaction (1) is too small to be observed or Q_1 is less than 0.6 Mev. Bothe and Gentner have observed a gamma-ray resonance from $Li+H^1$ at 200 kv. We have observed this resonance and using separated isotope targets (Rumbaugh) have found that it is produced by Li^7. Other known gamma-rays from lithium have already been assigned to Li^7. The energies of the neutrons emitted by Li^6 (isotope target) under deuteron bombardment have been measured using a cloud chamber. Of 200 tracks approximately half are too long to have been produced by neutrons from the reaction $Li^6+H^2\rightarrow He^3+He^4+n^1$. The expected yields from contaminations are not sufficient to account for the number of higher energy neutrons observed. No radioactivity could be observed from lithium after deuteron bombardment except that of Li^8. It seems probable that Be^7 is formed according to reaction (3) and is converted to Li^7 only by K electron capture.

79. Studies of the Properties of Slow Neutrons. J. G. HOFFMAN AND M. STANLEY LIVINGSTON, *Cornell University.*—The slow neutron collimator[1] and BF_3 gas chamber have been used to determine the angular distribution of slow neutrons coming from the surface of the standard paraffin cylinder source used for radioactivity studies of slow neutrons. The distribution is found to follow the Fermi law, $\cos\theta+3\frac{1}{2}\cos^2\theta$, to within the accuracy of the measurements. The mean free path of slow neutrons in paraffin, as detected by B, has been measured through the scattering by thin paraffin sheets placed between collimator and analyzer. The value obtained, $\lambda=2.85\pm0.10$ mm, results in a total cross section of 44×10^{-24} cm² for hydrogen without correcting for the C scattering. A similar measurement of the mean free path of Cd penetrating neutrons shows a complex structure, indicating a group of strongly scattered neutrons ($\frac{1}{4}$ total) and the expected higher energy group having a mean free path of about 8.5 mm and a cross section of 15×10^{-24} cm². The presence of the strongly scattered group, supposedly of thermal energies, suggests a band of partial transmission between the thermal and the resonance groups of Cd.

[1] Hoffman and Livingston, Bull. Am. Phys. Soc. 13, No. 6 (1938).

80. On the Neutron Core of Stars. G. GAMOW AND E. TELLER, *George Washington University.*—It was proposed by Landau[1] that there is in the interior of the stars a neutron core, the density of which is comparable to that of atomic nuclei. The matter of the rest of the star obeys the ideal gas law almost up to the surface of the core. The gravitational energy liberated during the steady condensation of gaseous matter into the core is sufficient to explain stellar radiation. However, the equations of internal equilibrium of stars applied to the region of the

ideal gas law show that in the neighborhood of the core temperature will rise with r^{-1} and density with $r^{-3/2-n/2}$ where $-n$ is the exponent in the temperature dependence of opacity. (The most probable value is $n=3.5$.) Thus the densities and temperatures in the neighborhood of the core will reach the extremely high values more than 10^9 degrees and 10^9 g cm^{-3}. Under such conditions all kinds of nuclear reactions will proceed at a great rate and will make the total energy production of the star many orders of magnitude greater than the observed radiation. Therefore the core model as well as any other model leading to such high temperatures seems to be ruled out.

[1] Nature **141**, 333 (1938).

81. The Optical Properties of Fluorite in the 6μ Region. DUDLEY WILLIAMS, *University of Florida.**—The absorption of various varieties of fluorite has been measured in the 6μ region. In the case of the colored varieties intense bands occur and even in the spectrum of colorless fluorite weak bands are found. For example, in the transmission of a 2.5 mm sample a depression of six percent was observed. The presence of these bands raised a question as to which types of fluorite are suitable prism materials for use in the 6μ region. Accordingly, the absorption of water as measured with a fluorite prism containing a yellow-brown impurity was compared with similar data obtained with rocksalt and colorless fluorite prisms. Some evidence of anomalous dispersion is found in the case of the colored prism material.

* To be read by title.

82. Mercury-Thallium Molecular Bands.* J. G. WINANS AND FRANCIS J. DAVIS, *University of Wisconsin.*—Four bands or band systems have been obtained which can be attributed to mercury thallium molecules. The source was a quartz tube containing Hg and Tl and heated by a Bunsen burner and blow torch. A Tesla discharge was produced through external electrodes or fluorescence excited by light of λ2537 from an SC 2537 tube. The arrangement was like that used for sensitized fluorescence of Tin.[1] The pressure of mercury or thallium could be controlled by the temperature. With high pressure of Hg (about 10 cm) and high concentration of Tl (between 600°–700°C), the bands were very strong; while with high pressure of mercury alone or high Tl concentration alone the bands did not appear. These bands were also obtained in sensitized fluorescence of the Hg-Tl mixture. Preliminary measurements of the wave-lengths at the maxima gave (a) 6558 (4), 6481 (6), 6434 (5), (b) 5225 (10), 5199 (5), (c) 4585 (7), 4537 (5), 4502 (5), 4472 (4), 4448 (3), 4424 (2), 4401 (1), 4381 (1), 4366 (1), (d) 4296 (1). Intensities are estimated from the blackening on Wratten M plates. Closely spaced flutings (about 30 cm^{-1}) superimposed bands (a) and (b). These flutings for band (a) extended from 6558 to 5500, for (b) from 5225 to 4900. Band (c) consisted of continuous maxima with no evidence of fine structure. Band (d) was too faint for sure observations of fine structure.

* To be read by title.
[1] J. G. Winans and R. M. Williams, Phys. Rev. **52**, 930 (1937).

83. The Potential Functions of the Methyl Halides. DAVID M. DENNISON AND Z. I. SLAWSKY, *University of Michigan.*—The problem of the potential functions of the methyl halides is reexamined in an attempt to find a function which is both adequate and simple. A valence form of potential was tried which contained four constants: k_1, the C–H elongation; c, the C–X elongation; k_2, the deformation of the H–C–H angle; and k_3, the deformation of the X–C–H angle. It was found that this simple valence potential must be modified by the inclusion of a cross product term between the X–C distance and the X–C–H angle, thus introducing a fifth constant, k_4. The constants k_1 and k_2 were determined from the methane frequencies ($k_1=4.88\times10^5$ and $k_2=0.443\times10^5$) and were taken to be the same for all the methyl halides. By adjusting the three remaining constants it was possible to predict eight quantities, the six fundamental frequencies and two of the fine structure spacings. The agreement with the observed values was satisfactory, the average deviation being less than 1 percent.

84. The Face-Centered to Body-Centered Transitions in the Alkali-Halides. ROBERT BYRON JACOBS, *Harvard University.*—An x-ray examination of highly purified RbI made at 4500 atmospheres pressure and at room temperature has shown that the form stable under these conditions is that of the body-centered cube (CsCl type). This is in accordance with expectation, since the alkali-halides are only known to crystallize in this form and in that of the face-centered cube (NaCl type). The semi-empirical methods developed by Born and Meyer may be used here for the calculation of the theoretical lattice spacing of the high-pressure modifications. For the rubidium salts the theoretical spacings (calculated at equilibrium pressures and room temperature) agree with the measured values, within the limits of error of the same. Similar calculations for the potassium salts agree not quite so well. AgI has previously been found to be of the NaCl type at high pressures. Calculations of its theoretical lattice constant are in agreement with the observed value. For this calculation the crystal is assumed to be purely ionic, whereas AgI (ZnS type) is known to have some homopolar energy. The present calculations allow one to make a fair estimate of the amount of the same.

85. Rotational Structure of the $^3\Sigma-{}^3\Pi$ Bands of BF. FRED W. PAUL AND HAROLD P. KNAUSS, *Ohio State University.*—The band spectrum of BF has been excited in an electrodeless ring discharge, using equipment described by Strong and Knauss[1] with an improved oscillator. All of the previously reported bands, including those previously obtained only at lower dispersion, have now been photographed with the 21-foot grating, and several additional bands have appeared. Good plates were obtained in the second order of the grating, and on these the triplet-triplet bands of the A and B systems were well resolved. Measurements have been made on the fine structure of the (0,0), (0,1), (0,2), and (1,0) bands of the A system. The observed lines fit empirical formulas of the conventional sort very well, except in the neighborhood of the heads of the branches. The coupling is intermediate, nearer case b than

case *a*. In the absence of an adequate theory for bands of this type, the coefficients of the empirical equations cannot be interpreted as valid molecular constants, although they serve to describe the molecule.

[1] Phys. Rev. **49**, 740 (1936).

86. New Absorption Bands of Water Vapor in the Extreme Ultraviolet. JOHN J. HOPFIELD, *Libbey-Owens-Ford Glass Company.*—The absorption spectrum of water vapor has been extended in the extreme ultraviolet. Several systems of bands are evident and progressions in some of them are apparent, but aside from these relations no other numerical connection has yet been found. The bands have a diffuse appearance characteristic of triatomic molecules. The bands that seem to be closely associated are grouped together in the following list. 995.9 (1), 999.1 (1), 1005.1 (2), 1013.4 (4), 1028.3 (6), 1054.3 (10); 1076.4 (4), 1090.0 (4), 1098.4 (2), 1114.4 (4), shows structure, 1122.5 (4) same, 1127.9 (5) same; 1152.2 (1), 1171.2 (1), 1192.3 (3) double, 1219.7 (8), 1239.3 (6); a system of very diffuse and faint bands λλ1260, 1268, 1281, 1293, 1308, 1321, 1335, —, 1355, 1366, 1377; the well known continuous band in the region λλ1500–1800. Another system of bands can be traced in the region λ900–970, and under the present conditions the spectrum fades to continuous absorption on the short wave-length side of λ900.

87. Bands of the *D* System of SrH. KENNETH R. MORE* AND S. D. CORNELL, *Yale University.*—Rotational analyses are made of the (0,0), (0,1), (1,1), (2,0), (3,0), and (4,0) bands of the *D* system of SrH as observed in absorption. These bands, together with the (0,2) and (0,3) emission bands given by Watson, Fredrickson, and Hogan, are arranged in a vibrational array. The molecular constants determined are the following: for $X\ ^2\Sigma$, $\omega_e=1206.2$, $x_e\omega_e=17.0$; for $D\ ^2\Sigma$, $\omega_e=1014.1$, $x_e\omega_e=15.4$, $B_e=1.925$, $\alpha=0.024$. Heats of dissociation are calculated and potential energy curves drawn for the known states of the SrH molecule. The curves indicate that the perturbations in the *D* state are probably caused by interactions with the *E* state, and that the perturbations and predissociation in the *C* state are caused by interactions with the *D* and *E* states.

* Sterling Fellow.

88. Isotopic Shift in the Spectrum of Magnesium MgI. K. W. MEISSNER, *Frankfurt/Main. (Introduced by R. Ladenburg.)*—The greatest part of MgI lines in the region from 3830A to 8803A has been investigated by means of an atomic beam as light source and of a Fabry-Perot interferometer as resolving instrument. The lines of the single line series (3^1P-m^1D) and the line (3^1P-5^1S) show a structure more manifold than found by Bacher and Sawyer in an earlier investigation. These lines consist of three components, a strong line and two weaker ones on the high frequency side. The components, nearly equally spaced, correspond to the isotopes Mg_{24}, Mg_{25}, and Mg_{26}. The amount of the line shift has been measured with the greatest possible accuracy and the isotopic shift of the terms 3^1P_1, m^1D_{12} ($m=3, 4, 5, 6, 7$), and 5^1S_0 could be calculated by the fact that the line shift decreases regularly for the higher series members. The green triplet $3^3P_{210}-4^3S_1$ consists of sharp lines. The triplet $3^3P_{012}-3^3D_{123}$ near 3830A could be resolved, though the satellites, produced by the triplicity of the *D* term, are separated only a few thousandths A from their main components.

89. Infra-Red Arc Spectrum of Germanium. C. C. KIESS, *National Bureau of Standards.*—No description of the arc spectrum of germanium longer than wave-length 4686A has ever been published. For theoretical reasons, however, it is known that a portion of this spectrum must lie in the infra-red. Recently, the grating spectrographs of the bureau have been used to record the longer waves of Ge I on the Eastman type Q and Z plates. Twenty-one lines have been measured between 8790A and 11,715A, and of these 12 have been classified as combinations between the $5p$, ^3S, ^3P, ^3D, and ^1D terms with the previously known $5s^3P^0$ and $^1P^0$ terms. In addition to the infra-red lines, the Ge arc also emits a group of yellow lines which have been observed previously by Lunt[1] with a Geissler tube containing $GeCl_4$. In analogy with a similar group that exists in Si I these lines probably originate in the $6p$ terms combining with the $5s$ terms, but their exact classification is still uncertain.

[1] Monthly Notices, Roy. Astron. Soc. **85**, 38 (1924).

90. Theory of Complex Spectra. GEORGE H. SHORTLEY AND BERNARD FRIED, *Ohio State University.*—Because spectroscopic analysis is beginning to involve configurations with high azimuthal quantum numbers, we have extended the tables of the Slater coefficients *a*, *b*, and *c* to the case of electron pairs involving *g* electrons. With these we have calculated the Russell-Saunders energies for configurations gp, gd, gf, gg, g^2, p^5g, d^9g, etc. For the cases d^9f and d^9g we have transformed the electrostatic-energy matrix to *jj* coupling. In several cases we have found ways of simplifying the computational methods previously used; in particular we obtain a simple formula which gives immediately the coefficients of the *G*'s for almost-closed-shell configurations of the type $l^{m-1}l'$. We have applied these results to the configurations $3d^94f$ and $3d^95f$ of Cu II, recently analyzed by Shenstone. Neglecting interaction between levels having different parent levels, we obtain the parameters from the means of the pairs of levels of the same *J* value and predict the separations within these pairs. The predicted and observed separations for $5f$ agree excellently; while the agreement is very poor for the $4f$, consistent with the perturbation of this configuration by the overlapping $3d^84s4p$ which manifests itself by the presence of strong two-electron jumps. A similar calculation for $3d^95g$ gives excellent agreement.

91. Raman Spectra of Disubstituted Acetylenes in the Region 2100–2300 cm^{-1}. FORREST F. CLEVELAND AND M. J. MURRAY, *Lynchburg College, Lynchburg, Virginia.*—The work previously reported[1] has been continued. The six compounds studied were of the type $R\cdot C\vdots C\cdot R'$, where R represents C_6H_5- and R′ is: (1) $-CH_2\cdot Cl$, (2) $-CH_2\cdot CH_2\cdot Cl$, (3) $-CH_2\cdot CH_2\cdot CH_2\cdot Cl$, (4) $-CH_2\cdot Br$, (5) $-CH_2\cdot OH$, (6) $-CH_2\cdot CH_2\cdot OH$. With the improved

definition made possible by stopping the camera lens down to 5 mm, it has been found that the strong acetylenic frequency near 2230 cm^{-1} is not single, but multiple. Moreover, careful reexamination of the plates has revealed the presence of several weak lines not found previously. Six lines were observed in this region for compound (1), seven for (2), two for (3), six for (4), five for (5), and two for (6), the number observed depending upon the strength of the continuous background. In order to determine whether these frequencies were those characteristic of the benzene ring or of the triple-bond, measurements were made on $C_6H_5 \cdot HC{:}\,CH \cdot CH_2 \cdot Cl$. Comparison of the results obtained with those of Grassmann and Weiler[2] for C_6H_6 and with those of J. W. Murray and Andrews[3] and Kahovec and Reitz[4] for $C_6H_5 \cdot Cl$, $C_6H_5 \cdot Br$, and $C_6H_5 \cdot I$ makes it appear possible to assign the frequencies 2127, 2142, 2156, 2176, and 2293 to the monosubstituted benzene ring, although 2293 has also been reported for compounds containing the group $-CH_2 \cdot C{:}\,C \cdot CH_2-$. The remaining frequencies, 2214(10), 2231(10), and 2263(3) for compound (1), 2204(3), 2221(10), and 2246(10) for (2), 2220(10) and 2236(10) for (3), 2218(10), 2234(10), and 2262(3) for (4), 2202(2), 2231(3), and 2242(10) for (5), and 2212(1) and 2233(10) for (6), appear with greater intensity and are probably those characteristic of the triple-bond.

[1] F. F. Cleveland and M. J. Murray, Phys. Rev. **53**, 330 (1938).
[2] P. Grassmann and J. Weiler, Zeits. f. Physik **86**, 321 (1933).
[3] J. W. Murray and D. H. Andrews, J. Chem. Phys. **1**, 406 (1933).
[4] L. Kahovec and A. W. Reitz, Akad. Wiss. Wien, Ber. **10**, 1045 (1936).

92. On the Analysis of the Absorption Spectrum of Benzene at 2700–2200A. H. SPONER AND G. NORDHEIM, *Duke University* AND A. L. SKLAR, *The Catholic University of America.*—An interpretation of this band system in the light of new experimental[1] and theoretical[2] data is attempted. Sklar's proposed forbidden transition $^1A_{1g} \rightarrow {}^1B_{2u}$ ($\Gamma_1 \rightarrow \Gamma_{10}$ group theoretical notation) can be confirmed from the spectral and thermal properties of a weak progression starting 1133 cm^{-1} to the long wave-length side of the most intense progression. The forbidden transition is made allowed through the excitation of vibrations of symmetry $E_g^+(\Gamma_5)$. In agreement with this a band starting from the vibrational level 1178 cm^{-1} has been observed at very high pressures. The corresponding vibration in the upper level, 972 cm^{-1}, in combination with the totally symmetrical frequencies of 920 cm^{-1} gives rise to the known strongest progressions. Kistiakowsky's explanation of the 160 cm^{-1} progression as 404→244 has been adopted, the 404 now becoming definitely an E_u^+ (Γ_{11}) vibration.[3] The first member of this progression now becomes a 1→1 band implying a shift of 160 cm^{-1} of the electronic transition. The E_u^+, being a non-totally symmetrical vibration, can occur strongly only in transitions for which $\Delta v = 0$; odd changes in v are rigidly forbidden by symmetry. This is in agreement with our analysis. The apparent progression of 80 cm^{-1} turned out to be connected with the B_{2g} (Γ_4) vibration.

[1] G. B. Kistiakowsky and A. K. Solomon, J. Chem. Phys. **5**, 609 (1937).
[2] A. L. Sklar, J. Chem. Phys. **5**, 669 (1937).
[3] Already suggested by R. C. Lord and D. H. Andrews, J. Phys. Chem. **41**, 149 (1937).

93. Comparison of the Absorption Spectra of Gaseous and Solid Benzene. A. L. SKLAR, *The Catholic University of America* AND H. SPONER AND G. NORDHEIM, *Duke University.*—The gross features of both spectra show some striking similarities, an intense progression 972+v 920 cm^{-1} being present in both cases, whereas the weak progression of the vapor (1133 cm^{-1} to long waves) is absent in the solid.[1] Each band of the common series has many neighbors which in the vapor decrease in intensity as one recedes from the parent band (160 cm^{-1} progression), but in the solid spectrum the neighbors increase in intensity, the farthest neighbor being the strongest. The reported interpretation of these satellites in the crystal as being the 160 cm^{-1} progression contradicts Kistiakowsky's explanation of this spacing in the vapor spectrum. The above-mentioned intensity considerations together with the possibility of correlating the lines differently shows that the 160 cm^{-1} progression in the solid is spurious. A strong progression 972+2565 cm^{-1} has been found in both the solid and vapor spectra, and in addition a progression −160+2565 in the vapor as is expected from selection rules. We interpret the 2565 cm^{-1} (2540 in the solid) frequency as the totally symmetrical hydrogen vibration. Not all bands expected by selection rules have been found in the spectra as is often the case. For instance, the 606 cm^{-1}, E_g^+ (Γ_5) vibration does not occur as 0−1 transition, though plausible reasons can be given for its absence.

[1] A. Kronenberger, Zeits. f. Physik **63**, 494 (1930).

94. The Infra-Red Absorption of Mixtures of Phenol and Ethyl Alcohol. J. W. WHITE AND E. K. PLYLER, *University of North Carolina.*—A study has been made of the absorption of mixtures of phenol and ethyl alcohol in the region from 6μ to 12μ. In the region of 6.7μ there appears an absorption band which shows changes in intensity and position for the different concentrations. The shape or sharpness of the absorption bands is greatly influenced by the concentration of the solution. The change in the bands points to a considerable association taking place between phenol and ethyl alcohol. In the region of 2.7μ the effects are much more marked. This is possibly due to the interaction of the OH groups of the two substances.

95. Infra-Red Absorption Spectrum of Methyl Alcohol. AVIS BORDEN AND E. F. BARKER, *University of Michigan.*—Using a grating spectrometer having a KBr foreprism ten bands of methyl alcohol vapor were plotted in the region from 2.7μ to 26μ. This molecule has bands at 3683, 2978, 2845, 2054, 1477, 1455, 1340, 1034.18, 756 cm^{-1} and a band of long wave-length between 380 and 620 cm^{-1}. From the fine structure of the bands the moments of inertia, A and B, were found to be, respectively, 35.18×10^{-40} and 33.83×10^{-40} g cm^2. The low frequency band is probably due to the vibration of the hydroxyl hydrogen atom perpendicular to the O−H bond and perpendicular to the figure axis of the molecule. The presence of this band indicates that the hydroxyl group is not free to rotate in the ground state. The band at 756^{-1}, however, consists of equally spaced lines about 40 cm^{-1} apart which is just the spacing to be expected if the hydroxyl group were free to

rotate. Since these lines are very weak and occur at such high frequencies it appears that free rotation exists only in states of high excitation.

96. The New Magnetic Laboratory at M. I. T. F. BITTER, *Massachusetts Institute of Technology.*—For the operation of air-core solenoids producing intense magnetic fields over considerable volumes, as described in recent issues of the *Review of Scientific Instruments*, heavy currents and large water supplies are required. These are being installed at M. I. T. and the magnets already built should be in operation shortly. The power is provided by a 1700 kw motor generator set capable of delivering 10,000 amperes at 170 volts continuously, or more for short times, and can be varied continuously from 0 to full load. The current can be delivered to any one of four stations, one in the spectroscopy laboratory, and three in an adjacent laboratory. The cooling of the magnets is to be accomplished by clean water, probably distilled water, pumped at the rate of 800 gallons per minute around a closed circuit containing any one of the magnets and a heat exchanger. The heat exchanger will be cooled by means of river water pumped from the Charles at the rate of approximately 550 gallons per minute. The magnets themselves will be described elsewhere. They are designed to produce fields ranging from 100,000 gauss in a tube $1\frac{1}{8}''$ in diameter to 65,000 gauss in a tube $4\frac{1}{2}''$ in diameter.

97. A Capacity Controlled Magnetic Suspension. C. S. SMITH, *University of Virginia. (Introduced by J. W. Beams.)*—A stable magnetic suspension photoelectrically controlled has been described by Holmes.[1] In the present work the suspended system afforded capacity coupling between a cylinder surrounding it and a pickup plate below it. Audio or radiofrequency was applied to the cylinder. Voltage developed on the pickup plate was amplified, rectified, and made to control the current in the lifting solenoid. Downward displacement of the supported member would cause an increase of current in the solenoid, thus affording stability. A small Duraluminum rotor attached to an iron rod was supported in the manner described and driven to 1175 rev./sec. by a rotating magnetic field.

[1] F. T. Holmes, Rev. Sci. Inst. **8**, 444 (1937).

98. The Measurement of Magnetic Fields and Susceptibilities in Solenoids. A. R. KAUFMAN, *Massachusetts Institute of Technology. (Introduced by F. Bitter.)*—In the course of working with the new solenoidal magnets at M. I. T. it was found inconvenient and difficult to obtain precise absolute determinations of field intensities. The following method has been found very satisfactory. A uniformly wound cylindrical coil having N turns per cm of length and a cross section of A sq. cm is suspended from the arm of a balance in such a way that its axis coincides with the axis of the magnet. Its lower end is at the center of the magnet where the field is H_1, and its upper end outside the magnet where the field has some small value H_2. The total force acting on the coil when a current of I amperes is passed through it is $F=(NAI/10)(H_1-H_2)$ dynes. All these quantities can be measured exactly. The above device may readily be used to measure the susceptibility of long rods. The coil is simply wound on a hollow cylinder inside of which the specimen is inserted. This ensemble is then suspended from a balance as described above and the force exerted on the specimen is counteracted by sending a current through the coil. After this measurement the field may be determined as described above without removing the specimen from the apparatus. Absolute accuracies of one part in 1000 have been obtained both in susceptibility and field measurements. With careful construction this precision can probably be made as great as one part in 10,000.

99. Magnetic Susceptibility Variations of Lead Oxide. MAX PETERSEN, *Lehigh University.*—Lead oxide (PbO) exists in two enantiotropic crystalline forms. Of these the (yellow) orthorhombic is at ordinary temperatures less stable than the (red) tetragonal, into which form some specimens of yellow are slowly transformed spontaneously. Since both of these forms can be made by different processes in a wide range of particle size a study of their magnetic susceptibilities has been made to determine whether due to particle size or other variation in the structure, particularly of the orthorhombic crystal form, variations of magnetic susceptibility would be found. Such variations are found, ranging over about 3 percent in the orthorhombic form. The red crystal form is apparently invariant in its susceptibility at -0.164×10^{-6}. That of the orthorhombic oxide ranges from about -0.164 to -0.169×10^{-6} according to its state. There appear to be two forms of orthorhombic crystals.

100. Some Properties of Ferromagnetic Impurities. F. W. CONSTANT AND J. M. FORMWALT, *Duke University.*—As described in a recent letter a method has been developed whereby a permanent magnetic moment as small as 2×10^{-7} per cc may be measured in any small solid specimen; this is less than 10^{-7} percent of that found for Armco iron. Magnetic moments per cc from 10^{-5} to 8×10^{-2} were found for the various metals tested, indicating very minute ferromagnetic impurities. Further measurements have been made on (1) the coercive force necessary to reduce the magnetization of the impurities to zero, (2) the variation in the magnetic behavior of the impurity with the state of the metal, (3) the effect of cold work and (4) the effect of heat treatment. Coercive forces as large as 500 oersteds indicate a very hard, strained state. Whereas cold work appears to precipitate out further ferromagnetic impurities, annealing has the opposite effect.

101. Motion Photomicrographs of Magnetic Colloid Patterns Which Form on Cobalt Crystals. W. C. ELMORE, *Massachusetts Institute of Technology.*—The division of the spontaneous magnetization of ferromagnetic crystals into domains gives rise to superficial stray fields which can be studied by depositing fine magnetic powder on the crystal. If the powder particles are of colloidal size then the stray fields serve merely to concentrate swarms of the particles over certain areas of the surface. The colloid swarms will move about when the stray field pattern is modified by

applied fields. Motion photomicrographs (magnification 12.5× and 90× on 16 mm film) will be shown of colloid patterns found on electrolytically polished surfaces (chiefly basal and prism planes) of large cobalt grains. The behavior of these patterns when a magnetic field is applied normal (in some cases parallel) to the surface will be illustrated. Preceding the film a brief discussion will be given of the magnetic structure of cobalt at room temperature.

102. An Alternating Current Method for Measuring Effective Mutual Inductance. H. L. CURTIS, A. V. ASTIN AND C. MATILDA SPARKS, *National Bureau of Standards.*—The value of a mutual inductance as measured with alternating current of a given frequency depends on the distributed capacitance in the primary and secondary windings and on the capacitance between them. The method here described measures the effective mutual inductance* when a terminal of the primary is directly connected to a terminal of the secondary. The method is a bridge which combines a modification of Maxwell's method for comparing the mutual inductance between two coils with the self-inductance of one of them, and of the Maxwell-Wien method of measuring a self-inductance in terms of resistance and capacitance. Two separate balances of the bridge are required, one for comparing the inductances and the other for measuring the self-inductance. The arrangement permits both of these balances to be made by varying a capacitance and a resistance. The effective mutual inductance is obtained from the bridge resistances and from the difference between the two capacitances obtained at the two balances. With this method, the primary and secondary may be interchanged without affecting the result.

* Butterworth, Proc. Phys. Soc. London **33**, 312 (1921).

103. The Mutual Inductance Between Two Coaxia Helical Wires. CHESTER SNOW, *National Bureau of Standards.*—This reports the derivation of a formula for the mutual inductance between two coaxial helical wires which in addition to the well-known current sheet formula contains small correction terms, one of which is due to the axial components of current, a second due to the finite diameters of the wires, and a third which is a Fourier series in their relative terminal azimuths. The second term depends on the type of assumptions made as to the current distribution in the wires.

104. The Zeeman Effect in Argon. J. B. GREEN, B. FRIED AND J. F. EICHELBERGER, *Ohio State University.*—Measurements of about two hundred lines in the spectrum of argon excited by electrodeless discharge (see previous abstract) at about 29,000 gauss have now given information for the determination of the g values of the $3p^56s$, $3p^57s$, $3p^54d$, and $3p^55d$ configurations, in addition to the configurations already measured by Pogany[1] and by Terrien and Dykstra.[2] A least-squares solution of the $3p^54d$, together with Sampson's[3] least-squares solution of the $3p^55d$, yielded parameters from which the g values could be determined theoretically. Both the $3p^56s$ and $3p^57s$ show deviations from the g sum rule while the comparison between the calculated and observed values of the $3p^54d$ and $3p^55d$ configurations is very unsatisfactory. These unsatisfactory agreements may be attributed to interactions among the lower levels of the $3p^55d$ and the $3p^57s$ and the upper levels of the $3p^56d$ which come very close together, between the upper levels of the $3p^55d$ and $3p^57s$; and between the $3p^54d$ and $3p^56s$ configurations. When a level is well separated from other levels which might be expected to perturb it (like the d_5 levels) the agreement between theory and experiment is very satisfactory. In the case of the S_1'' and S_1'''' levels of the $3p^55d$ configurations, there is an inversion of the levels with respect to the $3p^54d$ configuration, but the Z.E. serves to show that Sampson's[3] correlation of these two levels is incorrect.

[1] Pogany, Zeits. f. Physik **93**, 364 (1935).
[2] Terrien and Dykstra, J. de phys. et rad. **5**, 439 (1934).
[3] Sampson, Phys. Rev. **52**, 1157 (1937).

105. The Zeeman Effect in Neon. J. A. PEOPLES, JR. AND J. B. GREEN, *Ohio State University.*—Measurements on about two hundred and fifty lines of the spectrum of neon in fields of 27,000–32,000 gauss have now been completed. The neon discharge was excited by means of an electrodeless high frequency discharge (about 40 megacycles) at right angles to the magnetic field and to the line of sight. The lines, extending from about λλ3100–9000A, include transitions involving all of the levels of the $2p^54p$, the $2p^53d$, $2p^54d$ configurations, and parts of others. A large number of "forbidden" lines also appear. Sampson's[1] calculations for the parameters of the $2p^53d$ configuration and Shortley's[2] for the parameters of the $2p^54d$ configuration have been used to calculate the g values. The agreement between theoretical and experimentally determined values is excellent.

[1] Phys. Rev. **52**, 1157 (1937).
[2] Phys. Rev. **44**, 671 (1933).

106. The Hollow Cathode Discharge as a Source for Zeeman Effect. RUSSELL A. FISHER, ARTHUR S. FRY AND JOHN R. PLATT, *Northwestern University.*—Through reducing the dimensions and altering the geometry a form of Schüler's metal hollow cathode discharge tube has been adapted for operation in magnetic fields. When the dimensions and the shape and position of the anode relative to the cathode and magnetic field direction are properly selected the effect of the field is to intensify rather than to extinguish the discharge. Although the operation of the tube is quite critical in regard to the geometry and to the pressure of the exciting gas, under optimum conditions it provides an extremely stable source which has been operated in fields up to 12,000 gauss (the limit of the magnet employed) with no limit upon its functioning being encountered. Since the spectroscopic attributes of the hollow cathode discharge tube are retained in the magnetic field this source produces extremely sharp Zeeman patterns which are resolvable by interferometric methods. Examples of the ordinary weak-field Zeeman effect and of the hyperfine structure Zeeman effect in both the weak-field and Back-Goudsmit forms have been obtained in the spectra of several elements including bismuth, manganese, indium and thallium.

107. On the Nature of the Hall Effect. ERNST WEBER, *Polytechnic Institute of Brooklyn.*—In the explanation of

the Hall effect it is tenaciously assumed that the lateral force upon the electron flow, produced by the perpendicular magnetic field, does not cause a lateral motion of the electrons, but rather that a balancing force is generated which causes the e.m.f. of the Hall effect. Attempts to show a unilateral deviation of the electron flow have failed in the past. It is experimentally demonstrated that under the simultaneous action of the electric field in the direction of the main current and the magnetic field perpendicular to the current the electron flow is actually nonuniform, so that the Hall effect is an effect caused by a primary deflection of the current. To explain the opposite sign of the Hall effect in certain metals it is only necessary to assume a dependence of the mutual forces between electrons upon their local density. Phenomenologically one can express this latter action as a viscosity effect and bring it in direct relationship to the resistance increase which is caused by the presence of the magnetic field.

108. Diffusion of Hydrogen Through Nickel. W. R. HAM AND C. B. POST, *Pennsylvania State College.*—The diffusion of hydrogen through the purest nickel available[1] between temperatures of 150° and 1100°C has been investigated. The results are as follows: The data between 380° and 1050° are sufficiently accurate to determine the power factor Z of the diffusion equation, $R=Ap^yT^Ze^{-b/T}$, where R=rate, p=pressure, and T=temperature absolute. The value of Z found is $+1/2$. The slope of isobars below the Curie point is 6600 as taken by two independent methods. Above the Curie the slope is 5750, both values being obtained from the simple equation, $R=Ae^{-b/T}$, with impressed hydrogen pressure, atmospheric and constant. All isotherms have a value of exactly 0.50, for nickel that has been decarburized, but before complete decarburization there is a maximum in the Curie region that may be as great as 0.55. There is always a small but definite discontinuity in the isobars at the Curie point, equivalent to a temperature change of about 10°C. All hydrogen diffusion data indicate that the Curie transition is rather abrupt, and there is on the whole no diffusion evidence of a gradual transition of electrons in nickel atoms from absolute zero (or any low temperature) up to the Curie point.

[1] From the International Nickel Company.

109. On Methods of Producing Gas Free Surfaces. H. E. FARNSWORTH, *Brown University* AND RALPH P. WINCH, *Williams College.*—In experiments now in progress on photoelectric long wave limits of and contact potential differences between different faces of silver single crystals we have compared two methods of obtaining outgassed surfaces. The arrangement is such that the silver crystals can be outgassed by electron bombardment for long periods of time, and also a thin silver film may be deposited on the crystal faces by evaporation from another silver source which previously has been melted in vacuum and further outgassed by bombardment. After outgassing the crystals by bombardment for 500 hours a thin film of silver was deposited by evaporation on one of the crystal faces. The pressure during deposition was less than 4×10^{-8} mm Hg. The results indicate that the surface obtained by deposition is less gas free than that obtained by the electron bombardment. This is not in accord with the assumption made by some experimenters.

110. Reduction of Barium Oxide by Metals at High Temperature. JOHN P. BLEWETT, *General Electric Company.*—When barium oxide and various metals are heated together at high temperature, barium is evolved. Measurements have been made of the rate of evolution of barium from mixtures of barium oxide with titanium, nickel, and molybdenum. Two electrical methods have been employed to measure the density of the barium atom beam emitted from the furnace in which the reaction takes place. The first method involves measurement of the barium ion current from a tungsten filament maintained at a temperature greater than 2000°K in the barium beam. A fraction of the barium atoms which strike the filament comes off as positive ions, the relation between atoms and ions being given by the Saha-Langmuir relation. This relation has been checked, and, incidentally, provides an accurate method for measuring the work function of tungsten. The second method depends on the rate of activation of a tungsten filament held at a temperature of less than 1000°K in the barium beam. The concentration of barium for which maximum electron emission takes place has been measured and corresponds to $(4.1\pm0.3)\times10^{14}$ atoms per square cm of true tungsten surface.

111. Some Notes on the Effect of the Solubility of Glass on the Behavior of Glass Electrodes. DONALD HUBBARD, *National Bureau of Standards.* (*Introduced by L. J. Briggs.*)—Applying an interferometer method for determining the relative solubility of optical glasses to a glass which is commonly used for making glass electrodes, the following results were obtained: 1. The solubility increases rapidly for most alkaline solutions as the pH increases above 8.5 or 9. 2. There is a slight decrease in solubility as the pH changes from 8.5 to 2, but between these concentrations the solubility is much less than for alkalinities above pH 8.5. 3. The solubility decreases rapidly in the acid region beyond a pH 2. Considering these statements in connection with the performance of glass electrodes, these regions of marked solubility change (pH 8.5 and 2) correspond exactly to the two regions of pronounced voltage departures exhibited by electrodes made from this glass. That the voltage anomalies of the glass electrode are definitely associated with the solubility of the glass has been further demonstrated by the use of glasses which do not have the marked solubility change in the "super-acid" region, and by measurements made in alkaline solutions in which soluble silicates are not formed, such as aqueous solutions of ammonia.

112. Characteristics of the Copper Arc in Air. A. B. WHITE, *Massachusetts Institute of Technology.*—The voltage characteristics of the atmospheric copper arc have been recorded under various conditions of arc current, arc length and electrode condition. A recording magnetic oscillograph was used as a voltmeter, employing a biasing voltage in the measuring circuit across the arc to increase

the sensitivity of the oscillograph to full scale deflection for 15 volts applied above or below the biasing e.m.f. The oscillograph was coupled to the measuring circuit by an amplifier of high input impedance. A push-button control allowed the oscillograph to be put in immediate operation to record carefully selected arc conditions as observed. While taking measurements the arc was continuously observed through a neutral filter. Arc length was measured by projection on a calibrated ground glass screen. Three forms of the arc were differentiated and their characteristics obtained. Transition from one form to another was found to depend upon conditions of temperature and oxide formation at the electrodes.

113. A New Type of Thermionic Cathode: The Migration Cathode. ALBERT W. HULL, *General Electric Company.*—A finely-woven molybdenum "stocking" is filled with granules of fused BaO-Al_2O_3 mixture, and mounted as a filament inside a molybdenum cup. The wall of the stocking is impervious to electric discharge, but allows barium to diffuse and migrate over the surface, forming a monatomic coating. The molybdenum cup protects this monatomic coating from external oxidizing influences, and aids the coating process by re-evaporation of Ba. A cathode of this type has operated in mercury vapor for 24,000 hours, furnishing 20 amperes crest current at an emission efficiency of 0.45 amp./watt. Large stockings, 2.5 inches in diameter$\times$6 inches long, with the barium oxide on the outside and the electron emission on the inside, have given 200 amperes emission at an efficiency of 0.63 amp./watt. The calculated life of these large cathodes is 20 years.

114. A Reversible Clean-Up Effect in Low Pressure Mercury Vapor Discharges.* CARL KENTY, *General Electric Vapor Lamp Co.*—In a steady positive column discharge in Hg vapor at low pressures, it has been found that an equilibrium condition of clean-up exists at the walls and that a large exchange of Hg between the space and the walls continually takes place. The exchange is sufficiently great that if the arc is suddenly shut off, the pressure may rise temporarily to several times its normal value, as shown by an ionization gauge, while if the current is suddenly increased from a low value to a high one, the lowering of pressure may be so extreme as to put the arc out or cause voltage surges to appear across the tube. Tests indicate that excited atoms are not involved in this clean-up, and also that the observed effects are not due to gases other than Hg vapor. The Hg appears to be held on or in the surface with varying degrees of binding. The effect is ascribed to the penetration of ions by virtue of their high energies (15 volts) to various depths into the surface. Evidence shows that Hg is dislodged by ion bombardment, as well as cleaned up by it, and it is mainly the balance between these two effects which determines the equilibrium amount of Hg on the wall. A similar clean-up is found for an iron surface. The effect has a considerable significance for practical discharge tubes. A fuller account of these experiments will be published.

* To be read by title.

115. Vaporization of Mercury from Anchored Cathode Spot. LEWI TONKS, *General Electric Company.*—This has been measured by a method which greatly reduced the uncertainties inherent in previous measurements on a free cathode spot, namely, transfer of mercury by spray, general vaporization from the exposed mercury surface, undesired condensation and vaporization at arc tube surfaces, and return of condensed mercury to the pool. The mercury vaporized was measured directly by means of a calibrated feed, and the mercury surface was small (max. about 0.1 cm^2) and could be varied. Expressed in milligrams per coulomb, the rate of vaporization increased with arc current, exposed mercury surface, and cathode cooling water temperature. The vaporization rate extrapolated to zero current (range 0.7 to 4.2 amp.) was 0.23 to 0.26; extrapolated to 0°C cooling water temperature, it was 0.27 to 0.3. These values exceed Kobel's 0.017, which is certainly low, and lie within von Issendorf's range -0.3 to $+1.3$. The results do not preclude an increase of rate with current. They reduce the energy per particle in the cathode vapor stream to a reasonable value.

116. Construction of Filament Surfaces. R. P. JOHNSON, *General Electric Company.*—An incandescent tungsten filament gradually loses its die marks and acquires a large scale surface structure, oriented with respect to the lattice, which depends on whether the lamp was evacuated or gas-filled, and on whether it was run on a.c. or d.c. In neutral gas, with a.c., the filament tends to expose smooth concave (110) faces. a.c. vacuum filaments remain smooth and nearly round. The d.c. vacuum structure is step-like, is polarized with respect to the current, and seems to be due to a drift of W ions in the field along the filament. Surface migration of Th adsorbed on W, during d.c. heating, has been demonstrated in a simple electron-optical tube. Structure identical in form with the d.c. structure appears on a.c. filaments where a temperature gradient exists, and is attributable directly to surface diffusion in the temperature gradient. On d.c. gas filaments the d.c. structure and the gas structure are concurrent. No small-scale structure is found microscopically; probably the only substructure is atomic in scale. Preliminary study of Ta, Mo, Pt, Fe and Ni filaments in vacuum indicates that these metals also develop a roughened surface on d.c. heating, but remain smooth on a.c.

117. Secondary Electron Emission from Thorium-Coated Tungsten. EDWARD A. COOMES, *Massachusetts Institute of Technology.*—The secondary electron emission from a tungsten target covered with thorium evaporated onto it from a thoriated-tungsten filament, has been investigated over an energy range for primary electrons of 100 to 1000 volts. The tube used was essentially of the same construction as that previously described,[1] with additional improvements in gun design and collector geometry. The state of the target surface was ascertained from thermionic emission measurements. Preliminary observations indicated the secondary emission coefficient to be independent of primary current and of target temperature; measurements were taken for primary currents

from 0.05 to 1.0 microampere, and for temperatures from room temperature to 1200°K. For clean thorium on clean tungsten the secondary emission coefficient changed slightly for primary energies below 200 volts, but decreased at higher voltages with increasing amounts of thorium. One can be reasonably certain that no marked increase in secondary emission takes place with a reduction in the work function of tungsten by a monomolecular layer of pure thorium. When the thorium-coated tungsten was treated with oxygen released from the thoriated-tungsten filament the work function increased, but there obtained also an increase in the secondary emission coefficient; further change in work function by evaporation of thorium caused a variation of the secondary emission coefficient much like other experimenters have observed.[2]

[1] Phys. Rev. 51, 1008 (1937).
[2] Treloar, Proc. Phys. Soc. 49, 392 (1937).

118. Relative Work Functions and Adsorptivities of the Crystallographic Planes of Tungsten. S. T. MARTIN, *Massachusetts Institute of Technology.*—A single crystal of tungsten, ground and polished spherical, diameter 1 centimeter, is placed concentrically in a bulb whose interior surface is coated with fluorescent material. Electrons emerging from the sphere can be made to go radially to the surrounding bulb, making the latter a magnified electron image of the sphere. The major details of the design were conceived by W. Shockley. Some of the tungsten planes are known to have different work functions from others.* It has been found that the 211 and a set of planes whose normals lie in the neighborhood of the 110 direction have the greatest work function. Two other sets with normals in the neighborhoods of the 100 and 111 directions have the least. Apparently clean tungsten adsorbs caesium on the 211 planes in preference to all others. Very minute traces of gas (pressure less than 10^{-8} mm of Hg as measured with ion gauge in sealed-off tube) completely alter the relative adsorptivities of the different planes, in general making them greater. Planes with normals in the neighborhood of the 311 directions seem to be of major importance on a contaminated surface. 110 planes are poor adsorbers for most observed conditions.

* Shockley and Johnson, Phys. Rev. 49, 436 (1936). Mendenhall and DeVoe, ibid. 51, 346 (1937).

119. Electronic Energy Bands in Metallic Tungsten. MILLARD F. MANNING, *University of Toledo* AND MARVIN I. CHODOROW, *Massachusetts Institute of Technology.*—The Wigner-Seitz-Slater cellular method has been used to calculate the electronic energy bands in metallic tungsten. Using results published previously by the authors,[1, 2] E *vs.* k curves for the symmetry lines have been calculated. From these, energy contours in k space have been drawn, and from these, estimates of the number of states per unit energy range have been made. From these, it has been found possible to draw conclusions about the properties of metallic tungsten. With less certainty, the calculations can be extended to metallic tantalum. In particular, the calculations give interpretations of the high resistance, high electronic specific heat, and high paramagnetic susceptibility of these elements. The calculations give quantitative support to many of the suggestions that have been made by Mott[3] concerning the electronic structure of the transition metals.

[1] Manning and Chodorow, Phys. Rev. 50, 399 (1936).
[2] Chodorow and Manning, Phys. Rev. 52, 731 (1937).
[3] N. F. Mott, Proc. Roy. Soc. A153, 699 (1936).

120. The Multiple Scattering of Electrons.* M. E. ROSE, *Cornell University.*—The multiple scattering of electrons can be described in terms of the cross section for single scattering by introducing the "transport mean free path," λ. This mean free path determines, for example, the average forward motion along the path of a beam of electrons initially collimated. From this a criterion for multiple scattering in all directions of motion may be obtained, foil thickness $\gtrless\lambda$. The transmission of electrons through a foil is obtained for large energy, small thickness-small energy loss. The transmitted and back-scattered intensities vary essentially inversely as the foil thickness. When the motion of the electrons is almost random in direction, the scattering can be treated as a diffusion process with an energy dependent diffusion coefficient. Here the energy loss can be taken into account. This treatment can be applied to the emergence of β-particles from a radioactive target; it is also applicable to the passage of electrons through a thick foil when the penetration is of order and larger than λ. The complete solution of the problem of multiple scattering then requires a treatment of the intermediate region where the transition from scattering with small energy loss to diffusion takes place.

* H. A. Bethe, M. E. Rose and L. P. Smith, Proc. Am. Phil. Soc. (in print).

121. On the Production of Heavy Electrons. L. W. NORDHEIM, *Duke University* AND E. TELLER, *George Washington University.*—On the hypothesis[1] that nuclear forces are due to a field of heavy electrons (of mass $\mu\sim137$ m) a possible mechanism for their actual production consists in an emission of such particles by energetic protons or neutrons when passing through matter. A relativistic invariant theory for this field can be developed in close analogy to ordinary radiation theory; the nuclear potential being of the form $J(r)=(G/r)\exp(-r\mu c/\hbar)$, i.e. a screened-off coulomb field. The probabilities of emission and scattering (Compton effect) can be obtained qualitively from the corresponding ones in radiation theory substituting for $e^2/\hbar c\to G^2/\hbar c=\mu/M\backsim 1/10$ (giving zero binding energy for the deuteron; M=mass of proton) and $e^2/mc^2\to G^2/Mc^2$. The actual cross sections are, therefore, rather small. The detailed computation, using the Pauli-Weisskopf[2] wave equation, shows, however, some differences (depending on the form of the Hamiltonian), the most important one being a factor of $\backsim(M/\mu)^2$ for primary energies of order Mc^2. As the lifetime of heavy electrons is only of order 10^{-6} sec. (estimated from β-decay) they had to be produced in the atmosphere itself. The probabilities for production and scattering of heavy electrons obtained from this theory seem then to be rather too small

to account for the appearance of a large number of these particles in the cosmic radiation.

[1] First proposed by H. Yukawa, Proc. Phys. Math. Soc. Japan **17** 48 (1935).
[2] Helv. Phys. Acta **7**, 709 (1934).

122. Electromagnetic and Gravitational Radiation. L. INFELD, *Institute for Advanced Study. (Introduced by H. P. Robertson.)*—It is known that the gravitational equations can be solved, in the first approximation, by means of retarded potential. This would suggest that, in the case of motion of a double star, gravitational radiation plays a similar role to that of the electrodynamic radiation in the motion of charged particles. A more thorough examination, generalizing the method already developed by Einstein, Infeld and Hoffmann, shows, however, that this is not the case. Gravitational radiation plays no essential role in the motion of double stars.

123. Binding Energy of O^{16}. G. HORVAY, *Columbia University* AND E. FEENBERG, *New York University, Washington Square College.*—A variational calculation has been made to determine the binding energy of the O^{16} nucleus using the most suitable combination of the functions ψ_0, $\psi_1 = W\psi_0$, $\psi_2 = M\psi_0$ for the wave function. ψ_0 denotes the 16 row determinant constructed from $1s$ and $2p$ oscillator functions; W and M are the ordinary and Majorana interaction operators, respectively. With a simple saturation type Hamiltonian containing Majorana and ordinary interactions in the ratio four to one preliminary calculations yield energies of $-92\ mc^2$ with ψ_0 alone and $-113\ mc^2$ with the best combination of ψ_0, ψ_1, ψ_2. The method provides a reasonable estimate of the improvement to be expected from a perturbation calculation which includes both second and third order contributions to the energy. Our result indicates that the formal series expansion for the energy given by perturbation theory converges very slowly. Results for the binding energy obtained from the matrix elements of the first, second and third powers of the Hamiltonian will also be presented.

124. The Barytron Theory of Nuclear Forces. H. A. BETHE, *Cornell University.*—Yukawa, Bhabha and Kemmer have suggested that the forces between nuclear particles are due to the emission and reabsorption of particles of about 200 times electronic mass (barytrons) which obey Bose statistics and may be identical with the penetrating cosmic rays. The magnitude of nuclear forces ($\ll 200\ mc^2$) suggests that the interaction between heavy particles (neutrons, protons) and barytrons can be treated as a perturbation. Then the approximate equality of forces between like and unlike heavy particles can only be explained if neutral as well as charged barytrons can be emitted. The saturation of nuclear forces requires that like particles of parallel spin repel each other; this means that the barytrons must be represented by a vector field (similar to the electromagnetic field) rather than by a scalar. Denoting the quantities corresponding to scalar and vector potential by φ and $\mathbf{A}$, the interaction between heavy particles and barytrons has the form $a\rho\varphi + b\boldsymbol{\sigma}\cdot\text{curl}\,\mathbf{A}$ where ρ is the density and $\boldsymbol{\sigma}$ the spin density of the heavy particles. The constants a, b for both neutral and charged barytrons may be chosen to fit the empirical nuclear forces, which gives just sufficient freedom. It seems that ρ must have opposite sign for neutrons and protons, analogous to positive and negative charges in electrodynamics.

125. The Spacing of Nuclear Energy Levels. J. BARDEEN, *Harvard University* AND E. FEENBERG, *New York University, Washington Square College.*—The results of Wigner[1] on mass defects and stability relations make possible a calculation of level density for intermediate nuclei ($A < 60$) which takes properly into account the dependence of nuclear energies on symmetry character. In general a configuration of neutrons and protons in single particle orbits contains many different types of symmetry compatible with the exclusion principle. The various symmetry types arising from one configuration all have the same kinetic energy, but differ in potential energy; decreasing symmetry (increasing number of nodes) is associated with decreasing potential energy. Our results are illustrated by the following table which reveals a striking dependence of level density on the isotopic number.

Density of Levels (Nuclear Type $4n \pm 1$)*

Excitation Energy	With Constant Potential Energy	With Dependence of Potential Energy on Symmetry Character Taken from Reference 1			
		$\lvert N-Z\rvert = 1$	$\lvert N-Z\rvert = 3$	$\lvert N-Z\rvert = 5$	$\lvert N-Z\rvert = 7$
0	2	2	2	2	2
2	46	10	16	18	18
5	1,080	114	220	292	316
10	54,000	3,400	6,900	9,900	11,700
15	1,267,000	59,000	118,000	177,000	221,000

The energy unit is the spacing between adjacent single particle levels at the top of the normal state distribution (approximately $100/A \cdot mc^2$). Similar results have been found for even nuclei. Thus the average spacing between adjacent levels in A^{40} ($N-Z=4$) should be considerably smaller than in Ca^{40} ($N-Z=0$). Transmutation experiments on isobars will make possible a test of the theory.

* Including all values of spin and orbital angular momentum.
[1] Phys. Rev. **51**, 947 (1937).

126. On the Superposition of Nuclear Forces. H. PRIMAKOFF, *New York University.*—Field theories of nuclear forces fall into two classes: (1) light particle field (l.p.f.) carries charge; (2) l.p.f. carries no charge. For an l.p.f. of the latter type (positron-electron pair field), the saturation property is obtained by use[1] of a heavy particle potential which cannot be expressed as a sum of interactions between pairs (failure of force superposition). A charge bearing l.p.f. (electron-neutrino; "dynaton"[2]) leads, in first approximation, to a potential between the heavy particles which can be expressed as a *sum* of short range exchange interactions between pairs (two-body forces). Applying the usual formalism to the charge-bearing l.p.f., it is shown that, independently of the type of virtual light particles and of the details of their interaction with the heavy particles, there arise, in higher approximations,

short range exchange three-body, four-body, . . . , n-body forces, i.e. potentials which may be expressed as a sum of interactions between triples, quadruples, . . . , n-tuples of particles. The ratio of the magnitudes of the three-body and two-body forces is[3] $\backsimeq\frac{\hbar}{Mc}\frac{1}{R}\backsimeq\frac{v}{c}$, of the n-body and two-body forces is $\backsimeq\left(\frac{\hbar}{Mc}\frac{1}{R}\right)^{n-2}$.

[1] Critchfield and Teller, N. Y. meeting, 1938.
[2] Fermi, Zeits. f. Physik **88**, 161 (1934). Yukawa, Phys.-Math. Soc. Jap. **19** (1937).
[3] $\hbar/Mc$ = heavy particle Compton wave-length; R = range of nuclear force; v = velocity of heavy particles in nucleus.

127. Remarks on Resonance Scattering of Charged Particles. OTTO HALPERN AND M. H. JOHNSON, JR., *New York University.*—It is known that the scattering of neutrons by nuclei due to spin dependent forces induces in general spin-transitions of the neutron and the nucleus. Similar effects are to be expected for the interaction between charged particles and nuclei. In the latter case the process becomes complicated on account of the partial interference of the Coulombian scattering with the scattering due to nuclear forces. The relative amount of coherent and incoherent scattering depends on the scattering amplitude for the various states of different angular momentum of the combined system and on the spins of the interacting particles. Observations on the resonance-scattering of protons by light nuclei should permit the determination of the angular momentum of the intermediate state and of the cross sections for coherent and incoherent scattering separately.

128. Variational Theory of the Alpha-Particle. W. A. TYRRELL, JR. AND HENRY MARGENAU, *Yale University.*—The variational scheme previously employed[1] in a calculation of the binding energy of H^3 has been applied to the ground state as well as to the excited states of the alpha-particle. Harmonic oscillator functions in normal coordinates and an interaction potential of Gaussian form are used. Seven suitably chosen functions, none more than quadruply excited, lower H_{00} (=25.7 Mev, disregarding Coulomb energy) by 0.82 Mev. Certain conclusions as to convergence of the variational method will be discussed. Second-order perturbation calculations have also been made to investigate a possible empirical connection between perturbation and variational calculations with the present type of functions. Comparison of results of the two methods at various stages of the calculation and also previous work lead us to believe that for H^3 and He^4 a *second-order* perturbation calculation without further refinements depresses the zero order energy slightly *less* than a variational calculation with the same functions. For example, the 7 functions mentioned above lower H_{00} by 0.74 Mev perturbationally. The P states of the alpha-particles turn out to be unstable with the usual choice of nuclear constants. As regards the $2S$-state, we find that 8 functions adjusted for maximum depression of the ground state do not push it into the discrete spectrum.

[1] Margenau and Warren, Phys. Rev. **52**, 790 (1937).

129. The Invariant Theory of Isotropic Turbulence. H. P. ROBERTSON, *Princeton University.*—The statistical theory of isotropic turbulence, as developed by G. I. Taylor, Th. v. Kármán and associates, can most naturally be formulated and most conveniently handled with the aid of the classical theory of invariants of the rotation group. This leads to a calculus of correlation forms (such as the correlation between velocity or vorticity vectors at two or more points in the fluid) in terms of which covariant operations on forms are reduced to corresponding, but simpler, operations on the scalars characterizing the forms.

130. Perturbation Theory of the Nuclear Magnetic Moment of Li^7. D. R. INGLIS, *Princeton University.**—The discrepancy between the first-order result (Hartree model) and the experimental value[1] of the magnetic moment of Li^7, pointed out by Rose and Bethe for a particular (unsymmetrical) form of interaction, persists with a rather general symmetrical form of interaction. The discrepancy in the orbital contribution is of the order 30 percent [assuming that the intrinsic magnetic moment of the proton spin is not greatly altered by the binding process, as seems to be indicated by its equality to that[1] of F^{19} (probably a ^2S)]. This leaves scope for improvement by a better calculation. In the good approximation which neglects the triplet part of the ground state and takes the space factor symmetrical, the second order effect of the spin-independent interactions arises entirely from the excitation of the s shell, and is of the right sign (the s shell having a higher proportion of protons) but several times too small (*ca.* 0.02 heavy magnetons) to account for the discrepancy. The perturbation theory starting with a central field appears to converge more rapidly in calculating magnetic moments than for binding energies, because the large numbers of small contributions to a magnetic moment are of both signs and largely cancel.

* On leave of absence from the University of Pittsburgh.
[1] Rabi, Millman, Kutch, Zacharias, Phys. Rev. **53**, 495 (1938).

131. Light Signals Around a Closed Path. HERBERT E. IVES, *Bell Telephone Laboratories, Inc.*—In the Sagnac experiment[1] a light signal is split optically into two beams which are sent in opposite directions around a rotating closed path. On return to the origin they arrive at different times, indicating velocities of $c+v$ and $c-v$, where v is the linear velocity of the source and c the velocity of light as ordinarily measured. It is claimed by Langevin[2] that if "local time" is used, the velocity of light around the circuit is c. It is shown that a stationary set of mirrors in polygonal arrangement reproduces all the essentials of the Sagnac experiment, without recourse to rotation. If the light source is carried by a moving band which touches all the mirrors, then clocks which vary in rate with velocity according to the Larmor-Lorentz theory, transported around this band at infinitesimal relative speed, indicate "local time." Such clocks on return to the moving origin indicate that the light signals have the velocity c. But to do this the clocks must traverse the same path as the light signals, and in the same direction. We therefore must have two clocks,

one for each signal. These two clocks when returned to coincidence of position give two different readings at the same time. Their difference of setting is represented by the same formula as that for the difference of times of arrival of the light signals as indicated by a clock attached to the light source.

[1] Comptes rendus **157**, 708–1410 (1912).
[2] Comptes rendus **205**, 304 (1937).

132. The Widths and Relative Intensities of *L* Series Lines of the Rare Earth Elements. C. H. SHAW,* *The Johns Hopkins University.*—The widths, relative intensities and wave-lengths of the L series lines of the rare earth elements should be of especial interest in the study of the variations of the above quantities with atomic number. Most of the rare earths have a hexagonal close-packed crystal structure; the rest a face-centered cubic. Within these groups, then, the effects of adding electrons to the N shell can be studied without also raising questions such as the differing influence of the crystal structure. The technique of forming x-ray targets of these soft metals suitable for ionization intensity measurements is described. Preliminary to the main program of the rare earths the L lines of W(74) were measured by means of the double crystal spectrometer. These results are compared with previous ones on Au(79).[1]

* This work was supported by a grant from the Penrose Fund of the American Philosophical Society.
[1] Richtmyer, Barnes and Ramberg, Phys. Rev. **46**, 843 (1934).

133. The Second Spectrum of Xenon. C. J. HUMPHREYS, *National Bureau of Standards.*—The description of xenon spark spectra, reported in a preliminary paper,[1] has been extended by new observations in the visible and infra-red and now comprises wave-lengths and intensity estimates of 2600 lines between 2200 and 10,200A. Probably three-fourths of these are shown, by the variations in intensity with different amounts of inductance in the discharge circuit, to belong to Xe II. The analysis, as revised and extended, accounts for 553 lines as combinations of 92 energy levels, and includes nearly all the intense lines. The ground doublet of Xe II ($5s^25p^5\ ^2P$) is known. The higher excited states are built upon the ^3P, ^1D, and ^1S states of Xe^{++} by the addition of an ns, np, or nd electron to the normal $5s^25p^4$ configuration,[2] and are described by doublet and quartet terms. Nearly all levels of first excited states are accounted for, although complete quantum designations cannot be assigned unambiguously in every instance. Use of extensive extreme ultraviolet data, furnished by J. C. Boyce, which contain the combinations of even terms with the low doublet, has aided greatly in the location and confirmation of these levels.

[1] C. J. Humphreys, T. L. deBruin and W. F. Meggers, Nat. Bur. Stand. J. Research **6**, 287 (1931), RP275.
[2] C. J. Humphreys, Nat. Bur. Stand. J. Research **16**, 639 (1936), RP898.

134. Extension of the Analyses of the Spectra of Neutral Osmium and Iridium. WALTER ALBERTSON, *Massachusetts Institute of Technology.*—New wave-length measurements have been made for the arc spectra of osmium and iridium, using the 35 foot, 30,000 line per inch grating at M. I. T., dispersion 0.4A/mm in the second order. The present data include over 4500 lines for Os I and 3100 lines for Ir I. 2169 of the Os I lines have been classified as combinations between 234 energy states, while 1937 of the Ir I lines are accounted for as combinations between 214 energy states. The normal electron configuration of Ir I is $5d^76s^2$ and the lowest level from $5d^86s$ is 2835 cm^{-1} above the ground state. In Os I $5d^66s^2\ ^5D_4$ is 5144 cm^{-1} below $5d^76s\ ^5F_5$. The configuration interaction is very pronounced, particularly in iridium, where the two low ^4F multiplets completely overlap. The I. P. of Ir I is about 9.2 volts as compared with 8.7 volts for Os I. The assistance of the W.P.A. in the wave-length measurements and in the analyses is gratefully acknowledged.

135. Infra-Red Absorption Spectra of Light and Heavy Acetic Acids. R. C. HERMAN AND R. HOFSTADTER, *Princeton University.*—Absorption spectra of light and heavy acetic acid vapors (CH_3COOH and CH_3COOD) have been investigated at various temperatures, with a rocksalt prism spectrometer from 1 to 15.5μ. Acetic acid vapor consists chiefly of dimers at room temperature, while at 140°C and a pressure of 15 mm it is almost completely dissociated into single molecules. A mass-spectroscopic analysis, kindly performed by Drs. Hipple and Delfosse on the CH_3COOD, showed about 95 percent D in the acid position. The intensities of the O—H and O—D bonded frequencies at 3.25 and 4.3μ, respectively, were found very sensitive to temperature, practically disappearing at 140°C. This we associate with the breaking of the hydrogen bond. Gillette and Daniels[1] do not mention this marked decrease of intensity in the 3.25μ band of CH_3COOH. The dependence on temperature of the intensity of the 4.3μ band in CH_3COOD is being studied at present in order to obtain dissociation data. Assuming that the O—H—O or O—D—O group in the dimer can be treated approximately as an asymmetric linear triatomic molecule (O—O distance 2.67A) and applying Badger's formula,[2] we find for the shorter O—H and O—D distances 1.075±0.015A. This value leads to frequencies within about 2 percent of those determined experimentally.

[1] Gillette and Daniels, J. Am. Chem. Soc. **58**, 1139 (1936).
[2] Badger, J. Chem. Phys. **2**, 128 (1934).

136. Further Description and Classification of the Spectrum of Singly Ionized Cerium, Ce II. GEORGE R. HARRISON AND WALTER E. ALBERTSON, *Massachusetts Institute of Technology.*—The previously known list of 2800 Ce II lines has been extended to include more than 6000 lines, and 12,000 lines due to Ce I and Ce II have been photographed with a 10-meter concave grating between 8000A and 2400A, using arcs carrying currents of from 55 to 90 amperes. Measurements on a computing-recording comparator give wave-lengths consistent in most cases to 0.003A or better. Our preliminary classification of Ce II[1] has been extended, with the assistance of the spectral interval sorter and interval recorder, to include nearly 2000 lines, ascribed to transitions between 122 mid-lying levels and 44 low levels to which J values have been assigned. Most differences between computed and observed wave-numbers are less than 0.03 cm^{-1}. The number and distribu-

tion of low lying levels indicates great interaction between the two electron configurations $4f5d6s$ and $4f5d^2$, accounting for the absence of obvious multiplet relationships.

[1] Phys. Rev. **52**, 1209 (1937).

137. An Extension of the Bi I Spectrum. H. E. CLEARMAN, JR., *Princeton University.*—The spectrum of the bismuth arc was observed in the region 1350–2000A by a modification of a method due to Selwyn.[1] A fluorite lens was mounted in a vacuum tight holder in front of the slit of a vacuum spectrograph. The arc was run in a tube filled with pure nitrogen, immediately in front of the lens. Many new lines were observed in this region, including several greatly broadened by autoionization. Previous analyses have located only a few low terms. As series based on different states of the ion are widely separated, it was found possible, with the new measurements, to trace several series. The three even series based on $p^2\,{}^3P_0$ of the ion were found, and also several series based on higher states of the ion. Certain of the latter show autoionization.

[1] Selwyn, Proc. Phys. Soc. **41**, 392 (1929). Shenstone, unpublished.

138. Absorption Spectra of Heavy Formic Acid. ROBERT HOFSTADTER, *Princeton University.*—Infra-red absorption spectra of the monomer and dimer of heavy formic acid vapor (HCOOD) have been studied in the range 1–15.5μ. As in earlier work* on light formic acid (HCOOH) the monomer spectrum was obtained at high temperature and low pressure (125°C and 12 mm Hg). Although the samples studied were not entirely free from HCOOH, the amount present did not disturb the main features of the monomer spectrum of HCOOD, but made the interpretation of the dimer spectrum less definite. Further work is now going on with the purpose of preparing pure HCOOD. The bands appearing in the monomer spectrum, along with rough intensity figures in parentheses, are as follows: 3572 (0), 2943 (1), 2632 (2), 2325 (0), 1755 (10), 1163 (8), 1082 (2?), 1031 (4), 981 (6) cm^{-1}. Calculations were made for a triatomic skeleton model of the HCOOD monomer with the force constants obtained from light formic acid.* The calculated values were 1741, 1083, 572 cm^{-1}. Apparently the simple model does not lead to a satisfactory interpretation.

* Bonner and Hofstadter, Phys. Rev. **52**, 249 (1937).

139. Pressure Shifts of Spectral Lines. HENRY MARGENAU AND W. S. WILSON, *Yale University.*—Some of the details of pressure shifts caused by foreign gases may be understood by supposing the simultaneous action of two types of perturbation: one termed the statistical, the other the velocity effect. The frequency distribution due to the former effect alone has been calculated, and several simple assumptions have been made about the latter,[1] leading to reasonable agreement with experimental data. In the present paper we have considered certain refinements of the theory. In particular, the "block function" used previously for the frequency distribution of the velocity effect has been replaced by a function of the dispersion type. This leads to unfamiliar functions for the total frequency distribution, which were evaluated numerically. The latter agrees with experimental contours about as well as the results of simpler calculations. The dependence of the line maximum on the pressure (P) of the perturbing gas is of some interest: if the half-width of the velocity effect is taken to be proportional to the pressure, the maximum varies approximately as $P^{\frac{3}{5}}$ for small P. Better agreement with experiment, according to which $\lambda_{max} \backsim P$ for small P, is obtained by supposing the half-width of the velocity distribution to be proportional to $P^{\frac{1}{2}}$.

[1] See H. Margenau and W. W. Watson, Rev. Mod. Phys. **8**, 22 (1936).

140. A New Continuum in the Spectrum of Helium. A. G. SHENSTONE, *Princeton University.*—When a direct current discharge of several amperes per sq. cm is run in helium at atmospheric pressure between water-cooled electrodes, a continuum appears which extends from the red to at least λ2300. The line spectrum is most intense near the electrodes. The very intense band spectrum is confined almost completely to the electrodes. The continuum is strong at the tip of the anode and at a point about halfway between the electrodes, but is missing at the cathode. It has no obvious connection with either the line or the band spectra. Can it possibly be an electron deceleration spectrum? The original purpose of this experiment was to search for Corona lines, but none at all were found.

141. The Absorption Spectrum as a Quantitative Test for Free Hydroxyl. O. OLDENBERG AND F. F. RIEKE, *Harvard University and Johns Hopkins University.*—In order to make the absorption spectrum of hydroxyl radicals applicable to a *quantitative test* for free hydroxyl in gases, the f values (probabilities of transition) have been determined for the various lines of the hydroxyl band 3064A. The values of the most intense lines are around 2×10^{-4}. These small values, indicating a half-forbidden transition, are explained by the idea that the corresponding transition in the O atom ($^1D \rightarrow {}^3P$) is forbidden. The lifetime of the excited molecules is 4×10^{-6} sec. Such a lifetime makes previous results, in which *collisions during the lifetime* reduce abnormally high rotation, more striking, because the lifetime is so long that a considerable persistence of rotation in collisions must be assumed. Contradictory results of other authors are reinterpreted by the consideration that the widths of the absorption lines affect the observed absorption coefficient. The results are applied to the computation of the rate constant of the reaction by which free hydroxyl is consumed after interrupting an electric discharge through water vapor. In preceding papers this process was found to be a triple collision—$H+OH+M \rightarrow H_2O+M$. Its efficiency is higher than 100 percent if one bases it on gas kinetic values of the molecular diameters and duration of collisions.

142. A Simple Method for Determining Counting Losses of Single Scale Recorders. HAROLD LIFSCHUTZ AND O. S. DUFFENDACK, *University of Michigan.*—The counting losses of a single scale recorder were determined by simultaneously recording the pulses supplied by a constant radioactive source through a Geiger-Müller tube coupled by means of a Neher-Harper circuit to the single scale and to a scale-of-eight recorder in parallel. The single scale

recorder was of the self-stopping thyratron type operating a Cenco counter, the electrical circuit being so much faster than the counter that the losses depended mostly on the latter. The scale-of-eight was found to follow a vacuum tube type scale-of-sixteen[1] without loss up to 11,000 random pulses per minute, and therefore its reading was taken as the true input. The counts recorded by the single scale counter plotted against the input gave a curve of the shape predicted by the Schiff-Volz[2] theory with a maximum at 2100 counts per minute, giving a theoretical resolution time $\tau = 1/eN_{\max} = 1.04 \times 10^{-2}$ sec. The percentage loss of counts plotted against the input rate gave a nearly straight line up to 6500 counts per minute where the loss was 80 percent. The resolution time given by the slope of this line was 0.66×10^{-2} sec. The discrepancy shows that this theory cannot be used to give a reliable value of the resolution time of such a circuit. This method of calibrating a single scale recorder obviates the necessity of using any theoretical corrections and permits the use of such single scale recorders for collecting reliable data at input rates up to about 4000 counts per minute.

[1] Lifschutz and Lawson, Rev. Sci. Inst. 9, 83 (1938).
[2] Schiff, Phys. Rev. 50, 88 (1936).

143. Abnormal Ionization in the *E* Region of the Ionosphere. JOHN ALVIN PIERCE, *Harvard University*. (*Introduced by Harry R. Mimno.*)—Records of the field-strength of 10 megacycle signals have been made at a distance of 30 kilometers from the transmitter. "Bursts" of received energy, of a few minutes duration, were noted at times when no reflection from the *F* layer was present. When the density of ionization in the *F* layer was above the critical value for this frequency, occasional short periods of strong absorption at a low level have greatly reduced the strength of the reflected signal. Both of these phenomena are apparently due to small volumes of dense ionization in the *E* region, and they are consistent with a theory that such local ionization is caused by the transit of a single large meteor. Examination of astronomical data on the number and size of meteors shows that this is a possible explanation of the abnormally intense ionization frequently observed in the *E* layer. The same data indicate that the constant meteoric bombardment of the atmosphere can maintain a continuous background level of ionization in the *E* region of about the magnitude which is observed during the night.

144. The Gamma-Radiations from Eu^{152} and Au^{198}. J. REGINALD RICHARDSON,* *University of Michigan*.—The momentum distribution of the electrons ejected from radiators of lead, cadmium, and carbon by the gamma-radiations of Eu^{152} and Au^{198} has been observed by means of a cloud chamber in a magnetic field. The distribution from europium exhibits three main groups corresponding to gamma-ray energies of 45 kv, 0.31 Mev, and 0.9 Mev and approximately equal relative numbers of quanta. The sample used had been purified by D. W. Stewart. He has found a very long period produced by slow neutrons in this element, but the gamma-radiation measured here accompanies the 9.2-hour activity of Eu^{152}. The 45 kv radiation is probably to be explained as the *K* radiation of Sm emitted after the capture of an orbital electron by Eu^{152}, which thus has the possibility of decaying either to Sm^{152}, or to Gd^{152} with the emission of an electron. Observations on the 2.7-day period of Au^{198} indicate three lines with energies 70 kv, 280 kv, and 430 kv and relative intensities 0.15, 1.0, 1.2. The beta-spectrum has an inspection upper limit of 0.85 Mev and the distribution shows that the 430 kv gamma-radiation is internally converted with a coefficient of 0.1. Thus the 70 kv radiation may be entirely *K* radiation emitted after internal conversion.

* National Research Fellow.

145. Gamma-Radiation Associated with Indium. B. R. CURTIS AND J. REGINALD RICHARDSON,* *University of Michigan*.—The energy of the gamma-radiation produced when indium is activated with slow neutrons has been studied using a large hydrogen-filled cloud chamber. Following the method developed by Richardson and Kurie, the problem has been studied using both the Compton recoil electrons from a carbon radiator of 35 mg/cm² thickness and the photoelectrons emitted from a lead sheet of 20 mg/cm² thickness. Measurements with a Geiger counter show that the radiation is associated with the 54-minute period. The ratio of the beta-rays to the gamma-rays shows definitely that more than one quantum is emitted per electron. The recoil electrons from the carbon radiator indicate that the energy of the gamma-radiation is complex and is resolved into three lines of 1.8, 1.3, and 1.0 Mev, the relative intensities of these lines being 0.3, 1.0, and 1.0 respectively. The momentum distribution of the photoelectrons emitted from the lead radiator indicates that two additional lines are present. These have energies of 0.4 and 0.2 Mev, with intensities of 0.3 and 0.1.

* National Research Fellow.

146. The Gamma-Radiation from Boron Bombarded by Deuterons. W. A. FOWLER, E. R. GAERTTNER* AND C. C. LAURITSEN, *California Institute of Technology*.—Employing a method already described in detail,[1] the gamma-ray spectrum from B+D has been obtained by observing the positron-electron pairs ejected from a thin lamina of lead (0.033 cm). 300 measurable pairs reveal four prominent lines of quantum energies 2.2 ± 0.3, 4.4 ± 0.3, 6.9 ± 0.4 and 9.1 ± 0.4 Mev with relative intensities approximately in the ratios 40 : 9 : 2.5 : 1, respectively, and some relatively weak unresolved lines in the neighborhood of 5.5 and 8 Mev. The 2.2 and 4.4 Mev groups can be attributed to levels in the B^{11} nucleus, and correspond to proton groups observed in the reaction $B^{10} + H^2 \rightarrow B^{11} + H^1$ by Cockcroft and Walton[2] and Cockcroft and Lewis.[3] The groups at 9.1 and 6.9 Mev, in addition to part of the group at 4.4 Mev, can perhaps be coupled with the neutrons of energy 3.9, 6.0 and 9.0 Mev observed by Bonner and Brubaker,[4] and seem to indicate excited states in C^{12}. As a check on these results, further work is now in progress[5] on the recoil electrons ejected from a thin lamina of carbon.

* National Research Fellow.
[1] Fowler, Gaerttner and Lauritsen, Phys. Rev. 53, 628 (1938).
[2] Cockcroft and Walton, Proc. Roy. Soc. 144, 704 (1934).
[3] Cockcroft and Lewis, Proc. Roy. Soc. 154, 246 (1936).
[4] Livingston and Bethe, Rev. Mod. Phys. 9, 327 (1937).
[5] Crane, Delsasso, Fowler and Lauritsen, Phys. Rev. 46, 1109 (1934).

147. A Cyclotron Magnet-Current Stabilizer. TOM PERRY, *University of Rochester.*—A circuit has been developed which utilizes commercial radio receiving tubes for maintaining the constancy of the cyclotron magnet current within 0.02 percent. It is essentially a two stage direct-coupled amplifier. The first stage amplifies the voltage fluctuations and applies them to the grids of three parallel triodes which form a variable shunt across the generator field resistance and regulate the generator output voltage. The device has the following features. Only a small fraction of the generator exciting current is carried by the regulating tubes. The correct magnet current can be maintained indefinitely by coupling the amplifier photoelectrically with the current measuring potentiometer. It is simple and inexpensive. No high voltage batteries are required for a reference potential. A "magic eye" tube is used to adjust the bias on the first tube to the correct value before the regulator action is started. The device can be used only on a separately excited generator and requires a drop of about sixty volts or more across the field resistance.

148. Additional Radioactivities Induced by High Energy Protons. C. V. STRAIN AND J. H. BUCK, *University of Rochester.*—Studies on proton induced radioactivities have been extended by increasing the energy of the proton beam to 6 Mev. Several new proton-neutron reactions have been observed. Among these are: $Ni^{61}(p,n)Cu^{61}$ (3.4 hr.); $Ni^{62}(p,n)Cu^{62}$ (10.5 min.); $Ni^{64}(p,n)Cu^{64}$ (12.8 hr.); $Cu^{63}(p,n)Zn^{63}$ (38 min.); $Se^{78}(p,n)Br^{78}$ (6.3 min.). With the increased activities at higher energies it has been possible to identify the 82-hr. period (electron) obtained[1] by bombardment of Zn as a Ga isotope. It is probably Ga^{70} and isomeric with the known 18-min. period (electron). Excitation functions and β-absorption data on some of these activities are being obtained.

[1] L. A. DuBridge, S. W. Barnes, J. H. Buck and C. V. Strain, Phys. Rev. **53**, 447 (1938).

149. Nuclear Excitation Functions for High Energy Charged Particles. M. S. PLESSET AND D. H. EWING, *University of Rochester.*—Nuclear excitation functions for incident charged particles of energies comparable to or greater than the nuclear potential barrier energy cannot be determined by the W. K. B. or similar approximations. Calculations have been made using exact Coulomb wave functions and the usual one-body model in which the transmutation yield is taken proportional to the incident particle density integrated over the nuclear volume. The excitation functions obtained in this way give an unsatisfactory dependence on the incident energy. Inasmuch as the number of particles which get to the nuclear region may be taken as an essential factor in the nuclear excitation, the following model is proposed. The Coulomb potential is used in to the nuclear boundary where it is modified by a vertical repulsive potential. This model is used to count the number of particles which penetrate to the nuclear region by calculating the number of particles anomalously scattered in this field. The excitation function is then taken to be proportional to this number. A reasonable variation of the yield with incident energy seems to be obtained in this way.

150. Absorption of Slow Neutrons by Chlorine. E. O. SALANT AND W. J. HORVATH, *Washington Square College, New York University.*—By irradiating CCl_4 with slow neutrons from a radium-beryllium source, we have found that the 35-minute period of chlorine reported by Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti and Segrè[1] is induced largely (over 90 percent in our arrangements) by C neutrons and that the initial activity of Cl is small, only a few percent of that of Mn. The absorption of neutrons of different energies by chlorine was then studied, with the following results (E is energy of neutrons, as measured by Goldsmith and Rasetti[2] and corrected for scattering by Bethe;[3] σ is total cross section of Cl):

Detector	Ag, 22″ and 2.3′	Rh 44″	In 54′	Ag, 22″ A group	Ag, 22″ B group	Mn 150′	Ag 2.3′	I 25′
E, Volts	0.028	1.3	1.6	3.0	5.5	60	120	140
$\sigma\times10^{24}$ cm^2	30	7.6	5.7	2.4	1.9	2.1	1.0	1.0
$10^{24}\sigma E^{\frac{1}{2}}$	5.0	8.65	7.2	4.2	4.6	16	15	14

Measurements of the boron absorption for Rh, In and Mn groups agree well with those of Goldsmith and Rasetti. The Cl cross section for C neutrons is somewhat lower than the value 39×10^{-24} cm^2 found by Dunning, Pegram, Fink and Mitchell.[4] The large values of $\sigma E^{\frac{1}{2}}$ at the higher energies can be accounted for by a scattering cross section of $1-2\times10^{-24}$ cm^2. The values of $\sigma E^{\frac{1}{2}}$ at the lower energies then indicate, with the inverse velocity law of absorption, a resonance band for Cl, between thermal energy and 1 volt. The absorption is too great to be attributed only to the capture resulting in the weak 35-minute activity, so that the resonance absorption is to be associated with some additional capture process in chlorine.

[1] Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti and Segrè, Proc. Roy. Soc. **149**, 522 (1935).
[2] Goldsmith and Rasetti, Phys. Rev. **50**, 328 (1936).
[3] Bethe, Rev. Mod. Phys. **9**, 69 (1937).
[4] Dunning, Pegram, Fink and Mitchell, Phys. Rev. **48**, 265 (1935).

151. The Atomic Distribution in Liquid White Phosphorus and the Amorphous Forms of Red and Black Phosphorus. NEWELL S. GINGRICH AND C. D. THOMAS, *University of Missouri.*—Monochromatic Mo K_α radiation was diffracted by liquid white phosphorus and red amorphous phosphorus at different temperatures and atomic distribution curves were obtained for those cases which seemed to be of interest. Liquid white phosphorus in thin-walled glass tubes about 1.5 mm in diameter gave a pattern showing three bands, the first and strongest one occurring at a scattering angle of 9° 3′ at 48°C and of 8° 48′ at 226°C. The second peak was weak but distinct in each case and the third peak was from two to three times as strong as the second peak when peak heights above the background were considered. Although in the 226°C case the sample appeared deep red in color after the exposure, the pattern was essentially identical to that for white phosphorus. A sample of white phosphorus at 271°C gave a combined pattern for liquid white and red amorphous phosphorus of about equal intensities. White phosphorus heated to 350°C for 7 hours and cooled to 50°C for an exposure gave a

pattern identical to that obtained previously[1] except that it showed a peak stronger than all others at a smaller angle than was included in the previous work. A pattern taken with the red phosphorus at 325°C was so nearly identical with that taken at 50°C that no further analysis was made. A Fourier analysis of the new red amorphous patterns was made showing a few small differences in the distribution curve previously obtained. Analyses for the liquid white phosphorus are being made, and work on patterns for black phosphorus is under way.

[1] Hultgen, Gingrich and Warren, J. Chem. Soc. 3, 351 (1935).

152. The Atomic Distribution in Liquid Potassium at 70°C and at 395°C. C. D. THOMAS AND NEWELL S. GINGRICH, *University of Missouri.*—X-ray diffraction patterns of liquid potassium at temperatures of 70°C, 200°C 295°C, and 395°C have been obtained photographically in a camera of 8.85 cm radius. Mo K_α radiation monochromated by crystal reflection was used and exposures of 30 to 60 hours were required for obtaining suitable patterns. Thin Pyrex tubes about 1.5 mm in diameter were used and for the lower temperature runs sufficiently thin tubes could be used so that the glass correction was almost negligible. At the higher temperatures disintegration of the tubes required the use of thicker walls and for these patterns an appreciable glass correction was made. After making further corrections for absorption, polarization and incoherent radiation, the final intensity curve was obtained. For the 70°C curve three maxima were observed, the position of the main one being at a scattering angle of 10° 36′. The curve for 395°C was similar to this except that the peaks were washed out relative to the background and shifted to slightly smaller angles, the scattering angle for the main peak being 10° 16′. A Fourier analysis after the method of Debye and Menke gave the atomic distributions at the two temperatures. The first peak in this curve for 70°C is at 4.64A and a second one appears at about 9.0A but after this the distribution is nearly random. The corresponding peaks for 395°C are approximately at 4.8A and 9.2A, respectively.

153. Inelastic Scattering of Electrons from a Silver Single Crystal. JOHN C. TURNBULL AND H. E. FARNSWORTH, *Brown University.*—Using the magnetic deflection method, measurements are obtained on electrons scattered inelastically through 90° from the (111) crystal face of silver. Discrete energy loss peaks are found at 3.7 and 7 ev energy loss, in fair agreement with previous results on polycrystalline silver. However, the intensities of these peaks depend on both the primary voltage and angle of incidence, while previous results for polycrystalline silver are independent of these variables. In general, the angle for maximum inelastic scattering is the same as that for the elastically diffracted electrons. There is, also, additional inelastic scattering which accompanies the elastically diffracted electrons, and which extends to an energy loss of 10 to 15 ev. The diffraction maxima of these inelastically scattered electrons occur at secondary energies equal to the critical voltages of the diffraction beams. This indicates the double process: loss of energy and subsequent diffraction of the electrons by the crystal lattice.

154. Ionization and Dissociation of Normal and Isobutane by Electron Impact. RICHARD F. BAKER AND JOHN T. TATE, *University of Minnesota.*—The processes and products of ionization and dissociation by electron impact in n-C_4H_{10} and i-C_4H_{10} have been studied with a mass spectrometer. Tables will be given showing the ions formed by 75-volt electrons, with relative abundances and appearance potentials. The ionization potential of butane is 9.8 ± 0.2 volts and is identical for the two isomers within the experimental error. The most abundant ion in both molecules is $C_3H_7^+$, indicating that the splitting off of a methyl group with ionization of the remaining radical is more probable than ionization of the complete molecule. The ion $C_2H_5^+$ is found to be far more abundant in n-butane than in isobutane, which is in accordance with the accepted straight and branched chain structures of the two isomers. It is shown qualitatively from the appearance potentials that the C—H bonding energy in butane is greater than the C—C bonding energy. The effects of thermal dissociation at the filament will be discussed.

155. Filtration of Oblique Plane Compressional Waves in a Stratified Medium.* R. B. LINDSAY, *Brown University.*—If a stratified medium consists of a series of alternate layers of two different substances (both fluid or one fluid and the other solid), of thickness $2l_1$ and $2l_2$, respectively, the problem is to determine theoretically the transmission of oblique compressional plane waves through the system. If the series is infinite, the system behaves as a band pass filter in which the transmission is controlled by $\cos W=\cos 2Q_1\cdot\cos 2Q_2-\frac{1}{2}\cdot(Z_2/Z_1+Z_1/Z_2)\sin 2Q_1\cdot\sin 2Q_2$, where $Z_1/Z_2=\rho_1c_1\cos\theta_2/\rho_2c_2\cos\theta_1$, $Q_1=k_1l_1\cos\theta_1$, $Q_2=k_2l_2\cos\theta_2$. The subscripts 1 and 2 refer to the two media, respectively. ρ and c are the density and compressional wave velocity respectively. The angle of incidence from medium 1 to medium 2 is θ_1 and that of refraction θ_2. $k=2\pi\nu/c$, where ν is the frequency. The transmission bands correspond to $|\cos W|\leq 1$ while the attenuation bands occur for $|\cos W|>1$. The interesting feature of the problem is the variation of the bands with θ_1. Study has also been made of the corresponding finite structure in both an infinite and a finite fluid medium.

* To be read by title.

156. A Fixed Path Acoustic Interferometer for the Study of Matter. I. F. ZARTMAN, *Muhlenberg College* AND J. C. HUBBARD, *Johns Hopkins University.*—The techniques of ultrasonics in the study of some properties of matter under different conditions have been extended by the development of a fixed path acoustic interferometer. In this device a fixed distance is maintained between a piezoelectric resonator and a reflector, variations being introduced by changing either the frequency (in solids and liquids) or the composition, the temperature or the pressure of the medium. The velocity of sound in solids, liquids and gases has been measured under sufficiently varied conditions to show the practicability of the method. Its adaptability to the study of gases at relatively low and high temperatures is especially indicated, owing to the absence of moving parts and the elimination of packed joints. The

method is also applicable to the measurement of acoustic absorption in the various media.

157. Ultrasonic Study of CO_2 Near Its Critical Point. J. C. HUBBARD AND C. M. HERGET, *The Johns Hopkins University.*—The acoustic properties of CO_2, liquid, vapor, and gas, in the neighborhood of the critical point have been studied, using the ultrasonic interferometer of A. H. Hodge.[1] The results will be discussed with respect to their bearing upon the ratios of specific heats.

[1] J. Chem. Phys. 5, 974 (1937).

158. The Vibrations of the Segments of a Circular Plate. A. W. FRIEND, J. K. STEWART AND R. C. COLWELL, *West Virginia University.*—Kirchhoff showed long ago that when a metal circular plate vibrated as a whole, the resulting nodal lines were radii or circumferences. It is possible, however, to vibrate the plate so that each flat toroid contained between two circular circumferences will vibrate in segments. Each one of these segments is bounded by the parts of two circles and the parts of two radii. The vibration of each segment can be regarded as the vibration of a square which is later transformed into the circular segment described above. The patterns on these segments may be joined together to form many new mathematical figures. The figures may also be obtained experimentally with a magnetostrictive oscillator driven by an electron tube.

159. Vibration Modes of Low Decrement for a Quartz Ring. KARL S. VAN DYKE, *Wesleyan University.*—Unusually low values for the logarithmic decrement have been found for a certain set of modes of vibration of a piezoelectric quartz ring. The modes appear to be compressional around the ring, the fundamental having two nodes, the second partial four nodes, the third six, etc. The first five members of the series have been recorded and their decrements measured in vacuum. The frequencies are very closely harmonic, starting with a fundamental whose wavelength in quartz corresponds to an average wave velocity, around the mean circumference of the ring, of 7×10^5 cm/sec. The plane of the ring contains the electric and the optic axes of the quartz, while the driving field is applied normal to this plane with electrodes not in contact with the resonator. The piezoelectric excitation is presumably due to the ϵ_{14} constant. The logarithmic decrement of the series of partials remains approximately constant at about 2×10^{-6} as the frequencies increase except for the fundamental which has about twice this value. The ring has a diameter of 6.3 cm outside and 2.8 cm inside, a thickness of 2.3 cm, and a rectangular cross section. The fundamental frequency is 45 kc. The surface had been etched in hydrofluoric acid.

160. Vibration of Rotating Propeller Blades. WALTER RAMBERG AND SAM LEVY. (*Introduced by L. B. Tuckerman.*)—The natural flexural modes of vibration of propeller blades are important in designing propellers against fatigue failure. The present paper discusses the effect of centrifugal force on these modes by extending a solution for nonrotating blades[1] to blades that rotate as in actual flight. The resulting equations were solved numerically for two aluminum alloy propeller blades of typical design, vibrating with the fundamental mode and with the second harmonic mode and rotating at speeds covering the range of service speeds. Rotation was found to increase the maximum stress per unit tip deflection less than 13 percent and was found to shift the maximum toward the hub. For engineering calculations it is probably sufficient to calculate the resulting stress in the rotating blade by superimposing the stress for no rotation on the steady centrifugal force stress. A convenient and accurate approximation to the natural frequencies is given by Lord Rayleigh's method by making use of the solutions for no rotation. Both the stress distribution and the natural frequencies of a given propeller blade may be derived from those measured on an affine model blade by applying two simple model rules due to Theodorsen.[2]

[1] Nat. Bur. Stand. J. Research 14, 189–215 (1935).
[2] N. A. C. A. Tech. Note No. 516, Feb. 1935.

161. Relation of Camera Error to Photogrammetric Mapping. IRVINE C. GARDNER, *National Bureau of Standards.*—In connection with the work of the different agencies of the Department of Agriculture large areas of the United States are being photographed from the air. The primary purpose of this photographic work is the checking of crop control and of projects for the prevention of soil erosion. In view of the lack of precise topographic maps for much of this country it is considered desirable to have these photographs so made that they will also serve for the construction of maps. The demands for these two purposes are somewhat conflicting and a careful study of the relation between the errors in the photograph and the resulting errors in the finished map is necessary if the photographs are to serve the dual purpose. Some of the errors in a map constructed from airplane photographs are the results of differences between the actual performance of the camera and the postulated performance based upon the camera calibration. These differences are inevitable and any reduction in their value is always accompanied by increased cost and more elaborate construction of the camera. Consequently it is necessary to know the extent to which they affect the map in order that the design of the camera may proceed on a sound engineering basis. The different sources of error in the camera have been investigated and equations have been derived showing the extent to which they introduce errors in the map. This information will serve as a basis for establishing tolerances for the precision airplane camera.

162. Heat Effects of Tridymite Inversions. A. Q. TOOL, *National Bureau of Standards.*—Tridymite was developed from commercial silica gel by a heat treatment of six months at 950°C. To hasten the formation of cristobalite and its transformation into tridymite, about 1 percent of borax was added to the gel. After treatment the sample consisted of about 5 percent isotropic material and almost 95 percent of small wedge-shaped twins of tridymite. Cooling curves procured on this tridymite showed one small and two comparatively large and very definite exothermic effects of high low inversions with maxima

near 115°, 99°, and 86°C. One large definite endothermic effect and a small one with minima near 116° and 146°C in the heating curves indicated low high inversions. The low high effect near 116° was found to correspond to the high low effect near 86°C. The effect near 146° and the one near 115°C were likewise related. The effect near 99°C had no corresponding detectable low high effect, but it was gradually reversed by increasing the temperature. This reversal began near 120°C but was not completed until 450°C was exceeded. Heterogeneity of the crystals is a possible cause for such behavior.

163. The Heat of Combustion of Tetramethylmethane. JOHN W. KNOWLTON AND FREDERICK D. ROSSINI, *National Bureau of Standards.*—Calorimetric measurements of the heat of combustion of tetramethylmethane, in a "flame" calorimeter at constant pressure, are described. The new data yield for the reaction

$$C(CH_3)_4\ (gas)+8\ O_2\ (gas)=5\ CO_2\ (gas)+6\ H_2O\ (liq.)$$

$\Delta H=-3516.41\pm0.94$ NBS international kilojoules per mole, at 25°C and 1 atmosphere.

164. A Long Period Activity Induced in Cu. S. W. BARNES AND GEORGE VALLEY, *University of Rochester.*—Copper parts of a cyclotron chamber in which only protons have been accelerated have been found to show a long-lived radioactivity ($\backsim$7 mo.). Both positrons and electrons are emitted, in the ratio of 2 : 1. The maximum range of the β-particles in Al is 0.03 inches. Strong γ-radiation is present. Preliminary measurements indicate a γ/β ratio of 60 ± 10. γ-ray absorption curves have been obtained in Cu and Pb. The energy distribution of the positive and negative electrons, from cloud chamber photographs, will be discussed and the results of a chemical separation will be given.

165. Artificial Radioactivity Produced by Proton Bombardment. R. SHERR, M. C. HENDERSON, M. G. WHITE, L. A. DELSASSO, AND L. N. RIDENOUR, *Princeton University.*—The radioactivities produced by about 1 microampere of approximately 4.1 Mev protons accelerated in the Princeton cyclotron are under investigation. To date the following elements have been bombarded: Al, S, Cr, Co, Ni, Cu, Se, Mo, Ag, Bi. All except S and Bi have displayed activities which do not seem to be attributable to impurities. The targets have been bombarded in the main accelerating chamber vacuum, to make use of the maximum available energy and to avoid so far as possible the chance of oxygen contamination. Full details will be reported at the meeting.

166. Efficiency of Disintegration of Beryllium Under Proton Bombardment. L. S. SKAGGS, G. T. HATCH, AND S. K. ALLISON, *University of Chicago.*—The two reactions studied are $_4Be^9(p,\alpha)_3Li^6$ and $_4Be^9(p,d)_4Be^8$. If the air equivalent of the material in the path of the particles between the target and the ionization chamber is not more than about 3 mm, the two types of particles may be distinguished by the strengths of the pulses from the linear amplifier. The yield of alpha-particles has been measured from 200 to 400 kv bombarding energy by biasing the counting circuit so that only the stronger pulses are recorded. By heating the beryllium target before bombardment begins (by means of a built-in heater filament) formation of carbon deposit may be completely prevented and targets with polished surfaces remain bright indefinitely. The yield of alpha-particles rises monotonically from 9.7×10^{-8} alphas per proton at 204 kv to 3.0×10^{-6} at 392 kv. At 212 kv it is 1.3×10^{-7} which is consistent with 4×10^{-7} reported for the total yield of particles (α's plus d's) at this voltage by Williams, Haxby, and Shepherd. The yield of deuterons has been investigated by running bias curves and by photographing oscilloscope fluctuations and counting. In the region 200–300 kv the d/α ratio is about 1.2. The data are being extended to higher voltages.

167. Energy Spectra of Particles from Nuclear Disintegrations. SAMUEL K. ALLISON AND NICHOLAS M. SMITH, JR., *University of Chicago.*—A device for the deflection of disintegration particles in an electrostatic field has been constructed. The plates of the deflector are 90° sections of two concentric cylinders of average radius 25.40 cm and distance 0.635 cm apart. Slits are placed at the conjugate foci (8.76 cm from the ends of the plates) and the whole mounted in a vacuum chamber. The device has been used to analyze the values of $\frac{1}{2}mv^2/z$ (where z is the charge of the particle) for the disintegration particles arising from bombardment of beryllium by protons. With 1.6 microamperes of protons at 320.0 kv striking the target at 45° to its clean, polished surface, the beam of disintegration particles at right angles to the proton beam showed on analysis a narrow band of particles, sharp on the high energy edge, which were deflected around the condenser at a voltage of 36.02 ± 0.3 kv. This gives $\frac{1}{2}mv^2/z=0.726\pm0.007$ Mev. Assuming these are alpha's with $z=2$, the energy balance in the reaction $_4Be^9(p,\alpha)_3Li^6$ is 2.153 ± 0.05 Mev or 0.002312 ± 0.00005 mass units. Using Livingston and Bethe's masses, this gives 6.01697 for $_3Li^6$. No sharp peak for the deuterons from $_4Be^9(p,d)_4Be^8$ was found, which is consistent with some theories of the breadth of the normal state of $_4Be^8$.

168. Relative Probability of the Loss of Neutron and Alpha-Particle in Iron. J. M. CORK AND B. R. CURTIS, *University of Michigan.*—When iron is bombarded by energetic deuterons, radioactive isotopes of both cobalt and manganese are formed. It has been shown that both of these isotopes come from the same parent isotopes in iron, namely, mass 54 whose abundance is 6.8 percent. The radio-cobalt of mass 55 and half-life 18 hr. is formed by an (H^2, n) reaction while the manganese of mass 51 and half-life 21 min. is due to an (H^2, α) process. This is then a particularly favorable case to compare the probability of emission of neutron and alpha-particles. Excitation curves of the two activities have been determined at energies up to 5.5 Mev. While the threshold energies for the two reactions cannot be precisely determined due to a high order of contact of the excitation curve with the energy axis the probability of the neutron ejection is vanishingly small at 1.8 Mev and of the alpha-ejection at 2.5 Mev.

At 5.4 Mev, for a thick target, the relative activity indicates that to eject a neutron and an alpha-particle, respectively, 4×10^6 and 6×10^7 striking particles are required.

169. Dependence of Neutron Interaction with Nuclei on Neutron Energy. P. N. POWERS, H. H. GOLDSMITH, H. G. BEYER, AND J. R. DUNNING, *Columbia University.*—The dependence of neutron interaction on energy for a number of elements has been investigated by using a well collimated beam of neutrons from a paraffin "howitzer," which could be kept at room temperature, ~295°K, or at ~105°K, by circulating liquid air. The test samples were introduced into the mid-point of the neutron beam, which was about 70 cm long from source to BF_3 ion-chamber (see Table I). Using the $1/v$ law for boron the effective

TABLE I. *Total cross sections (scattering and capture)*

ELEMENT	CROSS SECTION AT ~295°K $\times10^{24}$ CM^{-2}	CROSS SECTION AT ~105°K $\times10^{24}$ CM^{-2}	PERCENTAGE INCREASE
B (B_4C)	550±10	895±90	63
B (Pyrex)	559±9	837±22	50
H (~$C_{16}H_{34}$)	42.5±0.9	55.0±1.4	29
D (D_2O)	5.3±0.2	6.5±0.3	12
Fe	12.0±0.4	12.0±1.0	0
Au	79.7±5.1	134.2±7.7	69
Ir	324±7	418±11	29

temperature of the neutrons corresponds to ~120°K. The *n-p* interaction for the proton in paraffin has already increased by at least the theoretical factor of 4, due to molecular binding, i.e., using 12 to 14×10^{-24} cm² as the value for ~2 ev neutrons. The *n-d* interaction is not as sensitive to molecular forces. The non-dependence of the iron cross section on temperature shows that the purely magnetic scattering can only be a small fraction of the total cross section.

170. Dependence of Magnetic Scattering of Neutrons on Magnetization of Iron. H. G. BEYER, H. CARROLL, C. WITCHER, AND J. R. DUNNING, *Columbia University.*—The variation in the magnetic scattering of neutrons with the intensity of magnetization of the iron has been investigated. A well-collimated slow neutron beam was passed through three ¼-inch Armco iron plates, spaced 6 cm apart, and placed between the pole pieces of a large electromagnet. The BF_3 pressure ion-chamber used as a detector was magnetically shielded, and tests showed that there was definitely no change in the sensitivity of the detector system to within ±0.3 percent, due to the stray field. The magnetization curve of the iron plates was measured as a function of the magnet current and correlated with the amount of neutron polarization observed. The results show that the increase in number of neutrons transmitted through the iron when magnetized, as compared to demagnetized, does not follow the magnetization curve of the iron. The change in intensity is very small until a current approximately five times that corresponding to the "knee" of the magnetization curve is reached. A steep threshold then occurs; the magnetic scattering increases rapidly to above 3 percent, and then remains constant. Hence, under these conditions, appreciable magnetic scattering does not occur until a threshold corresponding to a high degree of saturation of the iron is reached.

171. Scattering of Neutrons by Gases. H. CARROLL, H. G. BEYER, K. WILHELM, AND J. R. DUNNING, *Columbia University.*—The scattering of neutrons by gases has been further investigated by introducing cells containing the gases at appropriate pressures into a neutron beam, about 1 meter long, from paraffin "howitzer" to BF_3 pressure ion-chamber. The neutron beam, about 4 cm in diameter, was very accurately collimated by means of cadmium and B_4C shielding. A calibrated vacuum dummy cell was used as a comparison standard. The neutron-proton interaction has been measured, using H_2, methane, ethane, propane and butane. The effects of molecular binding for neutrons of ~300°K are clearly shown by the results. H_2 has a *n-p* cross section, per proton, of 31.5×10^{-24}, methane 45×10^{-24}, while ethane, propane and butane have approximately the same value as methane. Argon and helium have the smallest cross sections for slow neutrons yet measured, approximately 1.0 and 1.5×10^{-24} cm². A number of other gases have also been measured.

172. Spin of the Neutron. H. H. GOLDSMITH AND LLOYD MOTZ, *Columbia University.*—Schwinger[1] has shown that the experimental results on the scattering of neutrons by ortho- and parahydrogen may be used to distinguish between the possible neutron spin values $\frac{1}{2}\hbar$ or $\frac{3}{2}\hbar$, and that these results decisively favor the former value. We reach a similar conclusion by considering the variation of the *n-p* scattering cross section with neutron energy on both spin assumptions and comparing the predicted and experimental cross sections at 2.5−3.0 Mev. Using 14×10^{-24} cm² for σ_{np} at $E_n=0$, and introducing the weight factors appropriate to the assumption $S_n=\frac{3}{2}\hbar$, we find from

$$\sigma_{np}=\frac{4\pi\hbar^2}{M}\left(\frac{3}{8}\frac{1+\alpha r}{\epsilon+\frac{1}{2}E_n}+\frac{5}{8}\frac{1+\beta r}{\epsilon'+\frac{1}{2}E_n}\right)$$

that ϵ', the binding energy of the excited (quintet) state, is ~240 kv. The equation then leads to values of σ_{np} which are appreciably higher in the region of $E_n=0.1$ Mev −5 Mev than those obtained on the usual assumption $S_n=\frac{1}{2}\hbar$. For $E_n=2.5-3.0$ Mev the cross section values are $\sigma\sim3.5\times10^{-24}$ cm² for $S_n=\frac{3}{2}\hbar$, and $\sigma\sim2.4\times10^{-24}$ cm² for $S_n=\frac{1}{2}\hbar$. The experimental value[2] is $\sim2.0\times10^{-24}$ cm². Possible explanations of the discrepancy between the $S_n=\frac{1}{2}\hbar$ value and the experimental values will be discussed. Feenberg has pointed out that additional confirmation of the correctness of $S_n=\frac{1}{2}\hbar$ may be found in the evidence for the shell structure of light nuclei.

[1] Schwinger, Phys. Rev. **52**, 1250 (1937).
[2] Ladenburg and Kanner, Phys. Rev. **52**, 1255 (1937). Zinn, Seely, and Cohen, see abstracts of this meeting.

173. The Free Fall of Molecules. I. ESTERMANN, O. C. SIMPSON AND O. STERN, *Carnegie Institute of Technology.*—The free fall of molecules was studied as a preliminary experiment for the exact measurement of the Bohr magneton by the "molecular balance" (compensation of the

magnetic force by gravity).[1] By using a molecular beam of two meters length, the deflection of the molecules by gravity was observed. The intensity distribution was in agreement with Maxwell's law of velocity distribution. A vacuum of about 10^{-7} mm was necessary in order to avoid too much scattering of the slow molecules.

[1] Phys. Rev. 51, 852 (1937).

174. Lattice Vibrations in Polar Crystals. R. H. Lyddane, *Johns Hopkins University* and K. F. Herzfeld, *Catholic University.*—The calculation of frequencies for vibrations of a polar cubic crystal of the NaCl type is made by an extension of the Madelung method. The calculation is principally concerned with the Coulomb field at a point in the vibrating lattice. The results are used to obtain a better insight into the behavior of long waves, and values of the frequencies for certain of the short waves. The effect of the polarizability of the ions is considered.

175. An Important λT Relation for Black-Body Radiation. Frank Benford, *General Electric Company* and A. G. Worthing, *University of Pittsburgh.*—A study of the efficiency of a black-body source as a producer of radiation within a narrow wave-length band shows that, for a given wave-length, the temperature of maximum efficiency is given by $\lambda T_m = 3652\mu\text{K}°$. The constant is about 5/4 that, namely $2884\mu\text{K}°$, occurring in a similar relation for the wave-length at which, for a given temperature, the spectral radiancy is a maximum. There are also three other λT equations containing the same constant, namely: $\lambda_m' T = \lambda T_m' = \lambda_e T = 3652\mu\text{K}°$. The interpretations for the subscripted symbols are: λ_m' is the wave-length at which, for a given temperature, the spectral rate of emission of photons is a maximum; T_m' is the temperature at which, for a given wave-length, the efficiency of production of photons is a maximum; and λ_e is the wave-length, appropriately called the effective wave-length for total black-body radiation, at which the percentage rate of change of spectral radiancy with percentage change of temperature is exactly that for the total radiation, namely 4. That the relations involving T_m, T_m', and λ_e have the same constant is readily comprehended but that this is true for the λ_m' case is not so apparent.

176. Čerenkov Radiation. George Collins and Victor G. Reiling, *University of Notre Dame.*—The authors have continued[1] their investigation of the asymmetric radiation originally reported by Čerenkov[2] which is produced when very fast electrons pass through matter. A well collimated beam of 1.8 Mev electrons was passed through sheets of mica, glass, and Cellophane about 0.002 cm thick and the light produced was photographed after reflection from a conical mirror surrounding the source. The theoretical relationship $\cos\theta = 1/\beta n$ which expresses the direction of emission of light was accurately verified for these substances. By passing the electron beam into a thick liquid target a sufficiently intense source of Čerenkov radiation was obtained to photograph its spectrum. The radiation was found to be perfectly continuous, in agreement with the theory of Frank and Tamn,[3] and in every case investigated extended from the red to the beginning of the ultraviolet absorption of the liquid used.

[1] Collins and Reiling, Phys. Rev. 53, 205 (1938).
[2] Čerenkov, Comptes rendus Acad. Sci. USSR 14, 3 (1937); Phys. Rev. 52, 378 (1937).
[3] Frank and Tamn, Comptes rendus Acad. Sci. USSR 14, 3 (1937).

177. Factors Affecting the Measurement of Solar Radiation by Pyrheliometers. L. F. Miller, *University of Minnesota.*—A comparison of flat and spherical absorbers in a pyrheliometer for the measurement of sun's radiation direct plus sky radiation shows that the spherical has a geometrical, thermal, and optical symmetry not exhibited by the flat disk absorber. The spherical absorber possesses the same sensitivity for all angles at which radiations are received. The flat disk absorber in its measurement of radiation involves the angle of incidence in such a manner in relation to the cosine of the angle that there are discrepancies of 58 percent at 85°; 35 percent at 75°; 13 percent at 60°, etc. The flat black surface does not operate as a simple black-body absorber at the different angles of incidence. This was determined by the differential absorption of a pair of blackened flat disks arranged within exhausted quartz bulbs which could be adjusted at various angles of incidence from zero to ninety degrees. The spherical absorber with its uniform sensitivity integrates the entire hemispherical firmament at once so that by calibration it gives a more nearly correct measure of sky radiation. This is an important feature where there is a constantly shifting sky radiation. Any two like pyrheliometers placed side by side to measure the same solar radiation should, if they are uniform and symmetrical in their geometrical and physical properties, give a one to one correspondence for observations at each instant throughout the day. Ratio values of these observations plotted against time should result in a horizontal straight line. Tests with two such arranged pyrheliometers having spherical absorbers enclosed in quartz bulbs showed this not to be the case. The above-mentioned symmetries of this type of pyrheliometer equalize this redistribution so that the correct measurement of total calories for the day is not affected.

178. The Density and Temperature of the Atmosphere to About 60 km from Twilight Sky Brightness Measurements. E. O. Hulburt, *Naval Research Laboratory.*—With a calibrated Macbeth illuminometer measurements were made of i_z the brightness of the zenith sky and of i_θ the energy flux across a vertical plane from the twilight horizon for the depression θ of the sun below the horizon from 0° to 13°. For clear sky conditions the i_z, θ and i_θ, θ curves did not change with the season from October, 1937, to March, 1938, and were the same for evening and morning twilight. Calculation from the Rayleigh theory of molecular scattering and the observed i_z and i_θ data showed that within ±30 percent the densities of the atmosphere from sea level to about 60 km were those of the density-height relation known to 20 km and extrapolated for a temperature of 218°K. It follows that the temperature of the twilight temperate zone atmosphere is 218°±15°K from 20

to 60 km. The influence of secondary scattering, determined from i_a, although small for small values of θ increased rapidly with θ to such an extent that the twilight zenith sky brightness measures gave no indication of the distribution of density above about 60 km.

179. A Photomechanical Method for the Determination of Atmospheric Ozone. BRIAN O'BRIEN AND HAROLD S. STEWART, JR., *Institute of Optics, University of Rochester.*—A photographic method has been developed for continuous determination of atmospheric ozone from ultraviolet solar spectra of wedge form recorded serially on film. A contact print is made to very high contrast film (Eastman Kodalith) as previously described.[1] This positive is in turn projection printed through an optical system which isolates any desired pair of wave-lengths from the spectrum photograph and images them closely spaced and magnified upon Kodalith recording paper. Although derived from a wedge spectrum, the two lines, of different length, terminate abruptly, the difference in length being directly proportional to the logarithm of the intensity ratio of the two selected wave-lengths. This quantity together with the zenith angle of the sun and the known extinction coefficients of ozone determine directly the quantity of ozone in a zenith atmosphere above the observer. The accuracy approaches that of the photoelectric method, and in comparison to it the photographic procedure permits much greater simplification in field station equipment which is made completely automatic. Moreover the method is self-checking since a number of pairs of wave-lengths may be selected from the original film record, each pair providing an independent determination of ozone.

[1] O'Brien and Stewart, J. O. S. A. **28**, 50 (1938).

180. An Automatic Spectrograph and Accessory Equipment for Solar Spectrum Photography. HAROLD S. STEWART, JR. AND BRIAN O'BRIEN, *Institute of Optics, University of Rochester.*—An automatic quartz spectrograph recording the ultraviolet solar spectrum on 35 mm film has been developed to carry out the procedure outlined in the preceding abstract. The duration and frequency of exposures may be adjusted over wide limits, three spectra per hour being adequate for determination of total zenith ozone, more being required for vertical distribution of ozone. The hour and minute at which each exposure is made are recorded directly on the film. The spectrograph camera carries sufficient film for one month of normal operation. Automatic printing equipment is used to produce, from the original spectrograph film, the final paper record from which the spectral intensities may be read directly. The first positive is contact printed to assure very uniform illumination. Illumination is less critical in the second projection printing to paper, but quite uniform field brightness is secured by means of a composite absorbing element following the projection condenser.

181. Preliminary Measurements with an Oblique Ether-Drift Interferometer. W. B. CARTMEL, *Université de Montréal.*—With the 45° interferometer previously described,[1] some thousands of measurements were made morning, noon and night in the month of February, resulting in extremely small fringe shifts. However, a study of Professor Miller's results[2] (which has been approved by him) showed that the epoch apex on Feb. 8 is on the meridian at 9 hours (which is midnight), and sets on the horizon at 14 hours, at which time sin z is a maximum, and equal to unity. The declination seems to be about $-40°$, so that in Montreal (lat. 45°) the noon value of sin z being sin $(\delta+\phi)$ would be very small. However, on April 1, the epoch apex appears to be on the meridian some hours later, so that at 9 A.M. late in March one should expect fairly large fringe shifts. The total second order shift expected for a velocity of 30 km/sec. is 0.024. Results of about this magnitude have been obtained consistently by myself and others, at 9 A.M. in March. This preliminary study seems to indicate an approximate value of 35 to 40 km/sec. for the earth's velocity. The re-analysis of Professor Miller's results brings his seasonal variations into agreement with those of Kennedy and Thorndike as given in Table II, p. 415, of their paper.[3]

[1] W. B. Cartmel, Phys. Rev. **53**, 108 (1938).
[2] Dayton C. Miller, Rev. Mod. Phys. **5**, 203 (1933).
[3] Roy J. Kennedy and Edward M. Thorndike, Phys. Rev. **42**, 400 (1932).

182. The Theory of the Ether-Drift Interferometer in Brief. W. B. CARTMEL, *Université de Montréal.**—It was shown by Voigt[1] in 1887 that the second order effect is the same in a direction at right angles to the earth's motion as in the direction of the motion, and in a second paper[2] he showed that no second order fringe shift is to be expected with a rectangular interferometer. If $t \propto 1/(1-v^2/c^2 \cdot \cos^2\theta)$, we must consider the function $w=1/z$ which leads to wave surfaces corresponding to a source at the origin and a sink at infinity, as shown in Webster's *Dynamics*,[3] Fig. 165, p. 526, in which the maximum variation is at 45°. For an interferometer of obliquity Ω we have $\cos^2\theta$ in one arm and $\sin^2(90-\Omega-\theta)$ in the other, and

$$\delta t = 2l/c \cdot v^2/c^2[\cos^2\theta - \cos^2(\Omega+\theta)],$$

which reduces to

$$\delta t = 2l/c \cdot v^2/c^2 \cdot \sin\Omega \cdot \sin 2(\theta+\tfrac{1}{2}\Omega), \qquad (1)$$

a formula which may also be derived by the method previously given.[4] From (1) it follows that for a 45° interferometer, the fringe shift amplitude is given by

$$\delta F = l/\lambda \cdot v^2/c^2, \qquad (2)$$

a formula which also applies to a rectangular interferometer with one arm vertical and the other laid flat, or to an unequal armed interferometer, l being the difference in length of the two arms. A rectangular interferometer with one arm vertical is suitable for use at the time of rising or setting of the apex. Its efficiency is equal to that of a 45° interferometer, but it lacks certain advantages of the latter.

* To be called for after paper No. 181.
[1] W. Voigt, Göttingen Nachrichten **1–21**, 41 (1887).
[2] W. Voigt, Göttingen Nachrichten **1–21**, 233 (1887).
[3] A. G. Webster, *Dynamics* (Teubner, Leipzig, 1904).
[4] W. B. Cartmel, Phys. Rev. **49**, 649 (1936).

183. A Vacuum Tube Frequency Meter.* HAROLD LIFSCHUTZ, *University of Michigan.*—A high speed electronic frequency meter has been developed which combines the advantages of the thyratron type introduced by Hunt[1] and the vacuum tube type of Gingrich, Evans and Edgerton.[2] This employs the triode vacuum tube scale-of-two recently described.[3] The triode scale-of-two is a direct coupled multivibrator with two equilibrium states. The incoming signals cause transitions from one equilibrium state to the other. During these transitions uniform pulses are developed at the plates of the scaling tubes. The regenerative coupling which secures this uniformity also makes these pulses independent of the amplitude and waveform of the input signals. Each scaling tube drives a tube at cut-off to run a milliammeter, the reading of which is then proportional to the number of input pulses per second. The scale-of-two principle allows each tube to work at half speed. Tripping speeds of 155,000 per second have been demonstrated for this circuit.[3] Both transformer input and RC input have been used. The circuit is independent of the polarity of the input pulse. The reading of the meter is very insensitive to variations in the plate supply to the scaling tubes. Good linearity and sensitivity in microamps per cycle is obtained. A complete frequency meter with tank circuit[2] has been built for nuclear work and the taking of Geiger-Müller counter characteristics.

* To be called for after paper No. 142.
[1] F. V. Hunt, R. S. I. **6**, 43 (1935).
[2] Gingrich, Evans and Edgerton, R. S. I. **7**, 450 (1936).
[3] H. Lifschutz and J. L. Lawson, R. S. I. **9**, 83 (1938).

184. Isophot Contours of Polarized Light Photographs of the Solar Corona. BRIAN O'BRIEN, D. H. MENZEL, H. S. STEWART, JR. AND C. J. ARONSON, *University of Rochester and Harvard Observatory.**—Isodensity contours have been produced from corona negatives of the eclipse of June 8, 1937, made with a camera of 240 cm focal length provided with a polarizing screen. The method has been described.[1] These contours, together with the characteristic curve for the original photographic negatives, permit the determination of percent polarization at any point in the corona, as well as the brightness distribution for each polarized component. The original negatives were made with polarizer settings at 45° intervals, and one comparison negative was made with polarizer removed. The forms of the isophot contours in polarized and unpolarized light are similar, although the former are elongated in the plane perpendicular to the electric vector. As with unpolarized light the coronal streamers do not appear, as such, in the isophot contours, since, as has been shown (reference above), the streamers consist of sharply bounded but only slightly brighter regions of the corona.

* To be called for after paper No. 179.
[1] O'Brien, Stewart, and Aronson, J. O. S. A. **28**, 50 (1938).

Erratum

In the published abstract* of the paper by Marshak and Bethe presented at the New York Meeting of the American Physical Society the author's corrections were inadvertently omitted. The corrected abstract appears below.

10. Electron Pair Theory of Nuclear Forces and Electron-Proton Interaction. R. E. MARSHAK AND H. A. BETHE, *Cornell University.*—Rabi's atomic beam determination of the magnetic moment of the proton gave a value about 15 percent larger than Stern's, this discrepancy apparently lying outside the limits of experimental error. Young[1] suggested that an additional spin-spin interaction between proton and electron could account for the discrepancy. By coupling the heavy particles with the electron-positron field to get nuclear forces (Gamow-Teller[2] theory) one has at the same time the physical mechanism for the desired proton-electron interaction. The Hamiltonian (nonrelativistic approximation for heavy particles) was taken as

$$H=G\{C_1\Psi^*\Psi\psi^*\beta\psi+C_2\Psi^*\Psi\psi^*\psi+C_3\Psi^*\boldsymbol{\sigma}\Psi\psi^*\beta\boldsymbol{\sigma}\psi + C_4\Psi^*\boldsymbol{\sigma}\Psi\psi^*\boldsymbol{\sigma}\psi\}$$

where Ψ is the quantized wave function of the heavy particle and ψ that of the electron. The diagonal element of this interaction with the electron eigenfunction in the hydrogen atom was calculated. The constants were deduced from the best values for heavy particle interaction, *viz.* ${}^3V_{NP}=75\ mc^2$, ${}^1V_{NP}=40\ mc^2$, range $=2.25\times10^{-13}$ cm. Assuming $C_3=C_4$, one finds $G=1.25\times10^{-6}\ (mc^2)(\hbar/mc)^3$ and $C_3=C_4=0.25$. With these values one obtains $V_{Pe}=0.0052\ \text{cm}^{-1}$, which is 12 percent of the h.f.s. splitting. This is just what is required to explain Rabi's result although the exact quantitative agreement is of course accidental. The effect being of first order in G is not equivalent to the hyperfine structure caused by the magnetic moment of the proton which is $\sim G^2$.

* Phys. Rev. **53**, 677 (1938).
[1] L. A. Young, Phys. Rev. **52**, 138 (1937).
[2] G. Gamow and E. Teller, Phys. Rev. **51**, 289 (1937).