Proceedings of the American Physical Society

MINUTES OF THE NEW YORK MEETING, FEBRUARY 21–22, 1936

THE 204th regular meeting of the American Physical Society was held in New York on Friday and Saturday, February 21–22, 1936, as a joint meeting with the Optical Society of America. The presiding officers at the sessions of the Physical Society were Professor F. K. Richtmyer, President of the Society, Professor H. M. Randall, Vice President, Professor E. U. Condon, Dr. Karl K. Darrow, Dean Henry G. Gale, Professor F. W. Loomis, and Professor John Zeleny. All sessions were held in the Pupin Physics Laboratories of Columbia University.

The joint session with the Optical Society of America was held on Friday morning at ten o'clock. This session was a symposium on *The Diffraction Grating*. The President of the Physical Society, Professor F. K. Richtmyer, presided. The invited papers were as follows: *Early History of the Diffraction Grating* by Karl K. Darrow, Bell Telephone Laboratories, Inc.; *On the Ruling and Testing of Diffraction Gratings* by R. W. Wood, The Johns Hopkins University; *Developments in the Rulings of Gratings at the University of Chicago* by Henry G. Gale, University of Chicago; and *Diffraction Grating Supply and Demand* by R. C. Gibbs, Cornell University. The attendance at this symposium was about 300.

On Friday evening the Society joined with the Optical Society for dinner at the Columbia University Faculty Club. This dinner was attended by one hundred and thirty-five guests. The President of the Physical Society, Professor F. K. Richtmyer, presided and called upon President Hardy of the Optical Society to speak.

Meeting of the Council. At its meeting on Friday, February 21, 1936, the Council transferred thirteen candidates from membership to fellowship, reinstated two to fellowship and three to membership, and elected thirty-seven candidates to membership. *Transferred from membership to fellowship:* Mildred Allen, William Phelps Allis, Gladys A. Anslow, Robley D. Evans, Alfred B. Focke, Nathaniel H. Frank, Hans Mueller, Jenny E. Rosenthal, Donald C. Stockbarger, Julius A. Stratton, John A. Wheeler, Ernest O. Wollan, and John C. G. Wulff. *Reinstated to fellowship:* George Glockler and John P. Minton. *Reinstated to membership:* Francis J. Altman, Neal D. Newby, and Leland J. Stacy. *Elected to membership:* F. L. Biship, Jr., Carl L. Bryan, Samuel D. Cornell, Jack N. Ferguson, Willis A. Gibbons, Clark Goodman, Wayne C. Hall, Robert A. Harrington, Dunham Jackson, Myron A. Jeppesen, Ralph P. Johnson, Creighton C. Jones, Hirosi Kamogawa, Max Knobel, Maurice K. Laufer, Clayton R. Lewis, W. James Lyons, Steven R. Meadows, Kiyoshi Murakawa, Robert G. Nugent, Kyujiro Oshima, Richard D. Present, Edward M. Purcell, S. J. Richards, Jacob A. Rinker, George D. Rochester, Raymund Sänger, George S. Sperti, Chauncey Starr, Donald W. Stoner, Hans Thirring, Jean-Francois Thovert, Charles H. Townes, John C. Turnbull, Johan H. van der Veen, Harold Walke, and Matthew Zaret.

The regular scientific program of the American Physical Society consisted of sixty-nine contributed papers; numbers 53 and 57 were read by title. The abstracts of the contributed papers are given in the following pages. An *Author Index* will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. **Early History of the Diffraction Grating.** KARL K. DARROW, *Bell Telephone Laboratories, Inc.*
2. **On the Ruling and Testing of Diffraction Gratings.** R. W. WOOD, *The Johns Hopkins University.*
3. **Developments in the Rulings of Gratings at the University of Chicago.** HENRY G. GALE, *University of Chicago.*
4. **Diffraction Grating Supply and Demand.** R. C. GIBBS *Cornell University.*

5. **Statistics of Geiger-Müller Tube Counters.** L. I. SCHIFF, *Massachusetts Institute of Technology.*—A general relation is derived for the number of counts registered by a Geiger-Müller tube counter exposed to a source whose

strength varies arbitrarily with the time, when the counter has a finite, constant resolving time. This is applied specifically to the case of an exponentially decaying source superposed on a uniform background. The resulting expression is too complicated to solve analytically, and approximations good enough to cover the whole field of usefulness of the formula are of little value, so the solution is expressed in nomographic form. A relation is found for the number of spurious coincidences in a set of N counters used coincidentally, when exposed to backgrounds that are uniform for each but not necessarily the same for all, and when the resolving time of the individual counters is neglected in comparison with the resolving time of the combining circuit for coincidences. The coincidence theory is applied also to the magnetic beta-ray coincidence spectrometer of the type used by Henderson, Alichanow and others, and an expression for the number of spurious coincidences observed in this instrument is obtained.

6. Theoretical Analysis of Amplification of Pulses from an Ionization Chamber. E. A. JOHNSON, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—A Fourier integral analysis of the frequency spectrum of a pulse from an ionization chamber has been made and the shape of the output pulse calculated as a function of the pass band of the amplifier. An optimum value for the pass band is found as a function of collection time of the ionization chamber. The signal-to-noise ratio is then calculated and the optimum value of collection time for a given input tube is determined. The advantages of a fixed-bias method over a floating-grid method are pointed out and the design of the input stage discussed.

7. Design and Operation of the Counter Controlled Cloud Chamber. J. C. STREET AND E. C. STEVENSON, *Harvard University.*—The pneumatic rubber diaphragm-type of cloud chamber suggested by C. T. R. Wilson is especially suited to large sizes. Rigid front and back stops of wire gauze or perforated metal allow just the correct expansion without excessive care in controlling air pressure. An adjustment of the separation of the gauzes controls the expansion ratio. The use of alcohol vapor in argon, for which the expansion ratio is less than 1.10, results in lower excess pressures in the chamber and permits large chambers of light construction to be used. The latter are especially useful in cosmic-ray studies. Two such chambers have been constructed and have proved very satisfactory. The design and operation of these chambers will be discussed in detail. A description of the light source and of the auxiliary apparatus for counter control will be given.

8. Cloud Chamber Photographs of Counter Selected Cosmic-Ray Showers. E. C. STEVENSON AND J. C. STREET, *Harvard University.*—A detailed discussion is given of the appearance of cosmic-ray showers from a lead plate 1.3 cm thick in a large cloud chamber controlled by three G–M counters, one above and two below the chamber. Showers of photons were responsible for about half the triple coincident counts, but sprays of electrons from the lead accounted for the tripping of the lower counters in most of the other cases. Three-quarters of the single-centered electron shower sprays were due to an electron which traversed the upper counter and struck the lead from above. The remainder were due to nonionizing rays, presumably photons. Twenty-three photographs out of a total of a hundred seventy-four showed complex phenomena. The distributions of the showers according to size and the shower electrons according to angular spread are given.

9. The Variation of Cosmic-Ray Showers with Altitude from Counter Measurements. R. H. WOODWARD, *Harvard University.*—In order to determine the relative intensity and quality of the shower producing radiation as a function of the altitude, curves for the production of cosmic-ray showers in lead have been obtained at four elevations: sea level, 1620 m (64 cm mercury), 3250 m (51 cm), and 4300 m (44 cm). Care has been taken to make the four sets of data directly comparable. The same counters and geometrical arrangement were used for all measurements. The recovery times of the counters were measured at each station and corrections were made for the change of efficiency of the counters with altitude and with thickness of lead. Within experimental error the shape of the curve is the same at each of the four elevations. The rate of shower production increases very nearly exponentially with decreasing barometric pressure, attaining at 44 cm of mercury a value 8.5 times that at sea level.

10. Frequency of Occurrence of Cosmic-Ray Bursts as a Function of Altitude and Size of Burst. R. T. YOUNG, JR.,* *Harvard University.*—Measurements of bursts produced in a small ionization chamber (230 cc volume) have been carried out at different stations. A comparison is made between frequencies of different sized bursts for various shielding conditions at Cambridge, Mass. (Bar. 76) and Mt. Evans, Colo. (Bar. 45). The table gives the ratios of frequency between Mt. Evans and Cambridge for six thicknesses of lead above the chamber. The bursts were divided into three groups of sizes shown in the left-hand column. The size of burst is expressed in number of rays, based on 80 ions per cm path of ray in air under standard conditions. The data show an increasing ratio with increasing burst size. Measurements by C. G. and C. D. Montgomery[1] give the ratio 26.6 between comparable stations for all bursts greater than 40 rays. Counter measurements[2] give the ratio 8.5 for frequency of occurrence of showers. Since the size of the average shower recorded by counter apparatus is 3–4 rays,[3] the data given in the table cover the range between showers as recorded by counters and large bursts recorded in chambers. One may conclude that counter and ionization chamber measurements are in agreement when the size of shower is considered.

* Now at Worcester Polytechnic Institute.
[1] C. G. and C. D. Montgomery, Phys. Rev. **47**, 429 (1935).
[2] R. H. Woodward, Abstract 9, present meeting.
[3] J. C. Street and E. C. Stevenson, Abstract 7, present meeting.

SIZE OF BURST IN RAYS	0	0.66	1.27	3.18	6.66	19.4	AVERAGE FOR ALL THICKNESSES
10–15	10.0	11.7	7.5	8.8	7.9	8.2	9.0
15–30	17.5	20.0	15.0	21.0	18.7	15.0	18.0
Greater than 30	16	19	21	26	34	17	22

11. Automatic Coincidence Counter Measurements on Shipboard of the Cosmic-Ray Latitude Effect. THOMAS H. JOHNSON AND DONALD N. READ, *Bartol Research Foundaiion of the Franklin Institute.*—In order to investigate latitude effects of cosmic rays from single directions and thus to bring out details of the phenomenon remaining obscure in the directionally averaged results of the ionization chamber, coincidence counters have been adapted for automatic recording of cosmic-ray intensities on shipboard. Power, supplied from the ship's dynamo, is stabilized as to voltage; the apparatus is leveled on gimbals; coincidence recording dials, barometer, compass, thermometer, voltmeters, and clock are photographed automatically at hourly intervals. The length of an unattended voyage, limited by the size of the film casette, is 67 days. A recent voyage on the sun deck of the S.S. Santa Barbara from New York to Valparaiso showed a latitude effect of 20 percent for vertical rays with the minimum occurring somewhat north of the geomagnetic equator. Counter trains inclined 45° from the vertical showed a greater latitude effect on the eastern than on the western side of the meridian, the difference agreeing with the equatorial asymmetry of 10 to 15 percent. Shower intensities recorded with an out-of-line arrangement surmounted by a lead plate showed a latitude effect of about 7 percent with the high "plateau" persisting to lower latitudes than in the case of the vertical intensities. Present results are preliminary to a more thorough investigation. This work is supported by the Carnegie Institution of Washington.

12. Characteristic Alpha-Ray Tracks in Infected Photographic Emulsions. T. R. WILKINS, *University of Rochester.*—Special photographic emulsions have been "infected" with drops of solutions of radium and its products and others with the thorium active deposit. The alpha-rays corresponding to the remaining members of the two series then leave tracks which in the developed plates appear as rows of grains proportional in number to the air ranges of the various alpha-rays. A method of stereomicrophotography and a special stereoscope have been developed which make it possible to examine these tracks stereoscopically and to measure the angle between any two of the rays ejected by the products of a single atom. The over-all magnifications of the microscope and stereoscope are easily arranged to equal the stopping power of the emulsion (about 1200). In the radium plates the radium C′ track, easily recognized by its length (30 grains), has not been observed alone but seems to be accompanied by a track of about 20 grains in length making a characteristic angle of 110° with it. A pair (each track of 13 grains with an angle of about 170°) seems to occur fairly frequently and in the thorium plates characteristic groups have also been found. The difficulties of interpretation will be discussed.

13. A Model of Motion. JOHN Q. STEWART, *Princeton University.*—Preliminary applications of general statistical method of "controlled loading" (described at the Christmas meeting Am. Astron. Soc.).—From the classical equation $m\ddot{x}=F$—force F an assigned function of t, x, $\dot{x}$, with arbitrary initial values—find, stepwise, $\ddot{x}$ at constant intervals $\bar{t}$ of time. At each step, chance selection of an indicator from among $r+s$ (constant number equally, probable indicators—r (variable) "plus," s (variable) "minus"—determines displacement Δx *restricted to)* $\pm\bar{x}$ another constant: and $\bar{x}/\bar{t}=c$. Expectation $(r-x)/(r+s)=p-q=\dot{x}/c$. Let $\ddot{x}\bar{t}$ determine sign changes for indicators. Identify $r+s$ with "rest mass" m divided by m, a third constant. Path, x a function of t, so found for $t/\bar{t}$ steps is for only one "element" $\bar{m}$. A particle's path is $m/\bar{m}$ such, averaged. (Further study necessary of the averaging, and role of $(1-\dot{x}^2/c^2)=1/k^2=4pq$). Standard deviation in x after $t/\bar{t}$ steps for a swarm of $m/\bar{m}$ elements is $2[pq(t/\bar{t})\bar{x}^2/(m/\bar{m})]^{\frac{1}{2}}$, or $(4pqht/m)^{\frac{1}{2}}$: $h=\bar{m}\bar{x}^2/t$. With velocity small p, $q=\frac{1}{2}$ nearly, and *de Broglie wave-length*, $h/m\dot{x}$, evidently develops as that expectation $\dot{x}t$ of advance which just exceeds the deviation. *Classical motion* is limit when m is large. *Velocity addition theorem of special relativity*, $u=(v+u')/(1+vu'/c^2)$ develops when two independent motions, $u/c=p-q$, $u'/c=p'-q'$, drive a third, $u/c=P-Q$ (p, q, etc., being probabilities of advance, recession, respectively, by $\bar{x}$ at every $\bar{t}$; $p+q=1$). Then, plausibly, $P=pp'/(pp'+qq')$, $Q=qq'/(pp'+qq')$. If u, v are independent and u' driven, *subtraction theorem* is $p'=qP/(pQ+qP)$, $q'=pQ/(pQ+qP)$. When particle is *charged*, classical term $-2(e^2/3c^3)\dddot{x}$ is added to $m\ddot{x}$ above, corresponding to use also, at each step, of a second analogous random selection; with $r_2+s_2=(e/\bar{e})^2$, and $\ddot{x}$ related to $(r_2-s_2)/(r_2+s_2)$.

14. Quantum Electrodynamics of Crystals. W. SHOCKLEY, *Massachusetts Institute of Technology.*—It is found that a good solution to the problem of the interaction of quantized radiation and a crystal can be obtained. The electronic states of the crystal are represented by determinantal wave functions in which the one-electron wave functions are the solutions of a Schrödinger equation in a periodic field. Both the electronic wave functions and the expansion functions of the electromagnetic field are taken to satisfy periodic boundary conditions on the surface of a large box. If the excited states are represented by suitable linear combinations, rather than by single determinants, the matrix of the Hamiltonian for the combined systems is just that of a system of coupled oscillators, each band to band transition of the electrons furnishing a continuum of oscillators. The eigenvalues are readily found (by solving the classical problem) and the questions of coherence and index of refraction can be discussed after the manner of Wentzel.[1] The value of ϵ is that given by Wilson.[2]

[1] G. Wentzel, Helv. Phys. Acta **6**, 89 (1933).
[2] A. H. Wilson, Proc. Roy. Soc. **A151**, 274 (1935).

15. On the Quantum Theoretical Treatment of Ionic Crystals. DOUGLAS H. EWING AND FREDERICK SEITZ, *University of Rochester.*—Up to this time, there has been no attempt made to solve the Hartree or the Fock-Slater system of equations self-consistently for ionic crystals. A start on this is now being made for the case of LiF, following the general plan of the work of Wigner and Seitz. It is found that none of the electrons, aside from the $1s$, retain the form possessed in the free atoms of either Li or F, so that the eight additional electrons per LiF molecule must be handled alike in the self-consistent equations of the solid. A second-approximation solution of these,

which is to be improved later, indicates that at least forty percent of the charge of one electron remains about the Li ion, so that the classical picture of complete ionization seems to be appreciably in error.

16. Tabulation and Study of the Energy Levels of the Asymmetrical Rotator. ENOS E. WITMER, *University of Pennsylvania.*—In a previous abstract[1] the writer gave the following formula for the energy levels of the asymmetrical rotator:

$$E=(h^2/8\pi^2)J(J+1)\{a+(c-a)\tau(s:n,J)\}.$$

Here $s=(b-c)/(a-c)$ and a, b and c are the reciprocals of the principal moments of inertia with $a>b>c$. J is the total angular momentum in Bohr units and n is the second quantum number. The ranges of s and τ are between 0 and 1. The values of τ have been computed to eight decimal places for the values of s given by $s=0.1m$ where m is any permissible integer and for all possible values of n and J for $J\leq 8$. It is intended to carry the table up to $J=15$ and to use all values of s given by the formula $s=0.05m$ where m is any integer. The computed values of τ have been studied in the light of the correspondence principle and certain empirical formulas obtained.

[1] Enos E. Witmer, Phys. Rev. **47**, 340 (1935).

17. Potential Curves of LiH and LiD. F. H. CRAWFORD AND T. JORGENSEN, JR., *Harvard University.*—A re-examination of the wave equation for a diatomic molecule by Van Vleck[1] has indicated four types of energy terms usually neglected. These are due to interaction of (1) vibration and rotation, (2) electronic and nuclear motions, electronic levels whose Λ-values (3) differ by ± 1 and (4) are the same. Now unfortunately effects (3) and (4) require a more or less complete knowledge of the electronic structure of the molecule in question for their estimation while effect (2) has not thus far been evaluated in sufficient detail for purposes of computation. On the assumption that these effects are approximately independent we have discussed effect (1) in detail. Using the 15 equations given by Dunham it is possible by successive approximations to deduce values of the coefficients a_1, a_2, etc., in the expression for the potential energy of a diatomic molecule:

$$V=a_0\xi^2(1+a_1\xi+a_2\xi^2+a_3\xi^3+a_4\xi^4+\cdots).$$

The results for LiH and LiD are practically identical. For LiD we have

STATE	a_1	a_2	a_3	a_4	a_5	a_6
Ground $^1\Sigma$	-1.858	$+2.58$	-3.45	$+5.79$	-12.2	20.7
Excited $^1\Sigma$	-0.869	$+6.74$	-11.23	$+28.6$	≈ -60.0	—

Potential curves of LiH and LiD. The constants in the ground state increase almost linearly in absolute magnitude with the subscript while the rather striking variation from this for the excited state represents quite satisfactorily the well-known anomalies in the molecular constants of the LiH and LiD molecules.

[1] Van Vleck, Bull. Am. Phys. Soc. **10**, No. 7 (1935).

18. The Image Force in Quantum Mechanics. JOHN BARDEEN, *Harvard University.*—According to classical theory, an electron at a distance x from the surface of a plane conductor is attracted toward the surface by the image force, $e^2/4x^2$. It is shown that the same result follows from quantum theory as a consequence of the interaction of the given electron with the electrons of the conductor if the following conditions are fulfilled: (1) The electrostatic potential in the interior of the conductor is constant; (2) x is large compared with atomic dimensions; (3) exchange forces and (4) effects connected with the finite size of the conductor may be neglected.

19. An Upper Limit to Electron-Neutron Interaction. E. U. CONDON, *Princeton University.*—Phenomenologically there is always the possibility of there being an interaction energy between electrons and neutrons. If we assume short range (compared with 10^{-12} cm) forces, this will give rise to a large cross section for scattering of thermal energy neutrons by the electron cloud of an atom, unless the forces are extremely weak. For such low neutron energies there will be no possibility of excitation of electronic levels of the atoms so the electron cloud will behave like a rigid distribution giving a weak long range force between electron and atom because of the smearing out of the electron distribution. However, if such an effect contributed in large measure to the slow neutron scattering cross sections, the effect would be the same for different isotopes of the same element and would go roughly as Z^2 where Z is the atomic number. This is contrary to the facts so if we assume that the contribution of electron-neutron interaction to the slow neutron scattering cross section is less than 10^{-24} cm^2 in hydrogen we may conclude that $K<30mc^2(e^2/mc^2)^3$ where the interaction law is assumed to be of the form $K\delta(x_1-x_2)\delta(y_1-y_2)\delta(z_1-z_2)$, where the neutron's coordinates are x_1, y_1, z_1 and those of an electron are x_2, y_2, z_2.

20. Must Neutron-Neutron Forces Exist in the H_1^3 Nucleus? R. D. PRESENT, *Purdue University. (Introduced by K. Lark-Horovitz.)*—In order to answer this question a precise calculation has been made with a Wigner potential for neutron-proton interaction of explicit form $Ae^{-\alpha r}$, which solves the two-body problem exactly. The wave function for H_1^3 is expanded in terms of an exponential times a power series in the interparticle distances with coefficients to be determined by the Ritz-Hylleraas method. When $1/\alpha$ is chosen as 10^{-13} cm an energy of $-9.5mc^2$ is obtained with an eight term function; the convergence is rapid and the eigenvalue may be estimated to occur at $-9.6\pm 0.1mc^2$. If a and b refer to two calculations made on H_1^3 with the same potential but different wave functions and if E_a and E_b are close to the eigenvalue E, then it follows simply that $E=(E_a+E_b)/2\int\psi_a\psi_b d\tau$. Taking Massey and Mohr's calculations (a), which give about $-9mc^2$, and our own (b), we obtain another estimate for the lower limit. A saturation-type operator must give a higher energy; also our potential well is probably too narrow and our energy therefore too low. We have thus found an upper limit for the binding energy of H_1^3 using only proton-neutron forces, and a lower limit for direct neutron-neutron interaction ($6.5mc^2$).

21. On Neutron-Proton Exchange Interaction. MILTON S. PLESSET, *University of Rochester.*—In the Majorana coordinate exchange interaction the difficulties with the incorrect behavior of the center of mass and the lack of invariance for Galilean transformations are very clearly brought out by considering the interaction in terms of momentum variables. It is apparent in the momentum representation that these difficulties all arise from the fact that the matrix elements of the Majorana interaction depend explicitly on the total momentum of a neutron-proton pair; these matrix elements have in general the form $f(\mathbf{p}+\mathbf{p}'+\mathbf{P}(m_1-m_2)/(m_1+m_2))\delta(\mathbf{P}-\mathbf{P}')$, where $\mathbf{P}$ is the total momentum of a neutron and a proton, and $\mathbf{p}$ is their relative momentum. The flaw in the Majorana interaction may readily be eliminated by modifying the interaction. Although, as Breit and Wigner have remarked, such a modification leads to a complicated result when expressed in terms of positional coordinates, it is of interest to note that the modified interaction (with m_1 not necessarily equal to m_2) has essentially the same degree of simplicity in the momentum representation as the original Majorana interaction (with $m_1=m_2$).

22. The Sign of the Magnetic Moment of the Deuteron. J. M. B. KELLOGG, I. I. RABI AND J. R. ZACHARIAS, *Columbia University.*—We have applied to deuterium the method of nonadiabatic transitions in an atomic beam which was previously (reported at the St. Louis meeting last December) utilized to ascertain that the sign of the magnetic moment of the proton is positive. The experimental results show that the h.f.s. doublet of the lowest state of the deuterium atom is normal. The magnetic moment of the deuteron is therefore positive. We wish to acknowledge the aid given these researches by a grant from the Carnegie Institution of Washington.

23. A Cyclotron Electromagnet. M. C. HENDERSON AND M. G. WHITE (National Research Fellow), *Princeton University.*—A brief description will be given of the electromagnet being built at Princeton for use as a "Magnetic Resonance Ion Accelerator" as developed by Lawrence and Livingston. A small model (1/10 scale) enabled many variations of pole shape and of yoke to be tried. As shown by the model, the final design should produce a field of 19,000 gauss in a four-inch gap between 35-inch poles, with an excitation of 30,000 ampere turns per cm of gap. The total weight of steel is 42 tons, a considerable saving over the amount used in converted Poulsen arc magnets. The poles are tapered slightly, following a rough ogive curve, from a core of 40 inches to a pole tip diameter of 35 inches. Fields in the gap up to the saturation point of the steel may thus be attained. Since this magnet is to be used for ions of mass 2 and 3 as well as for protons, the high field will be useful. Using electrodes with a 15-inch radius, this magnet should furnish 11,000,000-volt deuterons at 17,800 gauss. Enough copper has been used in the windings (over 8 tons) to keep the power bill low and to simplify the cooling problem. 40 kw should give 19,000 gauss; 10 kw, 15,000 gauss.

24. Mass Spectrograph Analysis of Bromine. J. P. BLEWETT, *Princeton University.*—The observation by B. and I. Kourtchatow, Myssowsky and Roussinow[1] of three periods of radioactive decay for the products of disintegration of bromine by slow neutrons suggests the presence of an isotope of mass 77 or 83 in addition to the known isotopes of masses 79 and 81. A mass spectrograph analysis shows that neither isotope is present to more than one part in 2000. Assuming that no other isotope is present, the isotopic constitution of bromine was observed to be 50.6 ± 0.6 percent of mass 79 to 49.4 ± 0.6 percent of mass 81, giving an atomic weight of 79.90 ± 0.02, to be compared with the accepted value of 79.916. Appearance potentials of the ions Br^+, Br_2^+, and Br^{++} were observed at 13.7 ± 0.5, 13.0 ± 0.5, and 39.5 ± 1.0 volts, respectively. With the known ionization potential of atomic bromine, this appearance potential of Br^+ gives a heat of dissociation of 1.9 volts for Br_2, in good agreement with the value of 1.96 deduced from the molecular spectrum. Large negative ion peaks appeared, both of Br^- and Br_2^-. The curve of height of Br^- peak *vs.* electron energy shows a sharp maximum at 2.8 volts. A measurement of the kinetic energy of these ions gave 2.3 volts, whence the electron affinity of Br^- may be calculated to be 3.8 volts.

[1] Comptes rendus **200**, 1201 (1935).

25. Magnetic Spectrum of Positrons Generated in Silver and Lead by Gamma-Rays from Ra C. G. L. LOCHER AND C. L. HAINES, *Bartol Research Foundation of the Franklin Institute.*—Comparison of four spectrograms, made with silver and lead as positron-generating elements, and gamma-ray sources of (a) 80 percent Ms-Th_1+20 percent Ra, and (b) Ra, only, show that: (1) The upper energy limit of the positrons is the same for both sources, and is between 1.11 and 1.115 MEV, showing that the limit previously ascribed to Th C″ gamma-rays[1] is due to the radium contamination of the Ms-Th_1 source; (2) the energy limit is the same for lead as for silver, with either gamma-ray source, but different distributions of density of blackening with energy are found for lead and silver; (3) with lead as the generating element, no intermediate lines appeared; with silver as the generating element, about five faint lines appear at energies between 0.069 and 0.598 MEV, with source (a), and about four faint lines, with energies between 0.315 and 1.09 MEV, with source (b). Assuming the simple transformation process $h\nu\rightarrow e_+ + e_- +$K.E., the observed upper energy limit of the positrons is lower than that expected, by an amount somewhat greater than the error of measurement, if we assume that the reputed wave-lengths of Ra C gamma-rays are correct. No reasonable correlation between the positron lines from silver and known gamma-ray lines from Ra C is found. The results of an exposure being made with a Ta generator and Ra C gamma-rays will be available for the meeting. This should show whether the positron lines found are characteristic of the gamma-ray source only, or involve the nuclear constitution of the positron generator.

[1] Phys. Rev. **49**, 198A (1936).

26. Disintegration of Sulphur by Thorium C′ Alpha-Particles. C. J. BRASEFIELD AND E. POLLARD, *Yale University.*—We have detected protons when sulphur was bombarded with alpha-particles from Thorium C′. These are

probably due to the reaction: ${}_2He^4+{}_{16}S^{32}\rightarrow{}_{17}Cl^{35}+{}_1H^1+Q$. The protons which are ejected at right angles to the incident alpha-particles appear in three groups at ranges of 24, 32 and 38-cm air equivalent. The relative yields in the groups are respectively 5 : 4 : 1. The values of the transmutation energy change Q corresponding to each range are -3.6, -2.85 and -2.35 MEV, respectively. These Q values are in good agreement with similar values reported recently by Haxel. The ranges of protons ejected in the same direction as the incident alpha-particles were also measured. Only the longest range group appears unmasked by natural protons. This has a range of 46 cm of air permitting a more accurate determination of the corresponding Q value, namely, -2.4 ± 0.2 MEV. When this is converted to mass units and substituted in the above equation, the resulting mass of ${}_{16}S^{32}$ is 31.9817 ± 0.0016.

27. Scattering of Slow Neutrons. ALLAN C. G. MITCHELL AND EDGAR J. MURPHY, *New York University, University Heights.*—By using the method previously described,[1] the scattering of slow neutrons from sixteen different metals has been investigated. Employing the radioactivity induced in silver as a detector, it was found that the scattering cross section exhibited by most of the metals examined, with the exception of Ag, Hg, and Cd, is approximately the same as that found in absorption measurements. This indicates that the absorption coefficient of these metals is due largely to scattering rather than to capture. With the metals Ag, Hg, and Cd, the total scattering is small while from absorption data large cross sections were found. The present results indicate that the large cross sections are due to capture and that no anomalously large scattering cross sections exist for these elements. Measurements on the scattering by the same series of elements using, however, indium and rhodium detectors showed differences in the percent scattering attributable to the detector used.

[1] A. C. G. Mitchell and E. J. Murphy, Phys. Rev. **48**, 653 (1935).

28. Temperature Effect with Selected Groups of Slow Neutrons. F. RASETTI AND GEORGE A. FINK, *Columbia University.*—Fermi and Amaldi, and Szilard, have shown that slow neutrons filtered through cadmium are still strongly absorbed in silver, rhodium, indium, iridium and other elements. We have investigated how the number of neutrons in certain groups depends upon the temperature of the paraffin through which the neutrons come, using an arrangement like that of Moon and Tillman, the cold paraffin layer being 1 cm thick. The results are given in the table. The three facts, that silver activation by unfiltered slow neutrons shows a temperature effect, that with Cd filtered neutrons there is practically no such effect, and that cadmium absorbs strongly throughout the thermal velocity range, indicate that silver absorbs strongly in two velocity regions, one at low thermal velocities and another in the Cd residual region above thermal velocities. Similarly for rhodium.

Detector	Filter	Activity at 90°K / Activity at 300°K	Fermi-Amaldi group
	(g/cm²)		
Mn (150 min.)	0.47 —	1.26	mainly group C
Cu (5 min.)	0.37 —	1.38	mainly group C
Ag (22 sec.)	0.06 —	1.25	mainly group C
Ag (22 sec.)	0.06 Cd 0.4	1.04	mainly group A
Ag (22 sec.)	0.25 Ag 0.56	1.05	
Rh (44 sec.)	0.33 Cd 0.4	1.08	mainly group D

29. Slow Neutron Production and Absorption. G. A. FINK, J. R. DUNNING AND G. B. PEGRAM, *Columbia University.*—The slowing down and absorption of neutrons in successive cylindrical layers of water has been studied. The rate of absorption is found to be about 0.3 cm^{-1}. Estimates of the total neutron yield from Rn-Be sources based on the rates of production at different radii and a Li ion chamber detection efficiency of about 1 percent give about 10,000/sec./cm, or one neutron for about 10,000 alpha-particles. To determine whether the absorption in paraffin (or water) is due to capture by H or C (or O) a bare source, and then the same source inside of a 12 cm diameter paraffin sphere, was surrounded by carbon in cylinders of 22 and 30 cm in diameter. The results show that, at least at room temperature, any absorption in carbon is more than compensated for by slow neutrons produced in the carbon. The slowing down of neutrons was further investigated by surrounding a Rn-Be source with Al, Pb, SiO_2 and Cu. These materials reduce by 15 to 40 percent the number of fast neutrons (velocities high enough to be detected by projected protons).[1] The number of neutrons of intermediate velocities is increased and some of the neutrons are slowed down to thermal velocities.

[1] J. R. Dunning, G. B. Pegram, G. A. Fink and D. P. Mitchell, Phys. Rev. **48**, 265 (1935).

30. Capture of Slow Neutrons. E. WIGNER AND G. BREIT, *Princeton University and Institute for Advanced Study.*—Current theories of the large cross sections of slow neutrons are contradicted by frequent absence of strong scattering in good absorbers as well as the existence of resonance bands. These facts can be accounted for by supposing that in addition to the usual effect there exist transitions to virtual excitation states of the nucleus. Radiation damping due to the emission of γ-rays broadens resonance and reduces scattering in comparison with absorption by a large factor. Interaction with the nucleus is most probable through the S part of the incident wave. The higher the resonance region the smaller will be the absorption. For a resonance region at 50 volts the cross section at resonance may be as high as 10^{-19} cm² and 0.5×10^{-20} cm² at thermal energy. The estimated probability of having a nuclear level in the low energy region is sufficiently high to make the explanation reasonable. Temperature effects and absorption of filtered radiation point to an energy order of bands from Cd to I which can be reconciled with the observed capture cross sections.

31. The Effect of Absorbed Hydrogen on the Magnetic Susceptibility of Manganese. MARY A. WHEELER, *Vassar College.*—Manganese which had been purified by distillation was heated in hydrogen at various temperatures. The susceptibility at room temperature was decreased to 9.28 $(10)^{-6}$ from a normal value of 9.60 $(10)^{-6}$ when the absorption took place at 400°C, a temperature at which the alpha form is stable. When the hydrogen was absorbed in

the beta form at 850°C the susceptibility became 9.36 $(10)^{-6}$. The decreased susceptibility can be due to the adsorption of diamagnetic hydrogen. However, when the hydrogen was absorbed by the gamma form at 1220°C or by melted manganese the susceptibility was increased to 10.42 $(10)^{-6}$ and 10.00 $(10)^{-6}$. While alpha- and beta-manganese are complicated cubic structures, gamma is a simple face-centered tetragonal form. Thus in gamma-manganese the hydrogen is probably inserted interstitially and increases the lattice constant. This could cause a narrowing of the energy bands of the collective electrons and an increase of the susceptibility. No trace of ferromagnetism was found.

32. A Flux Balance for the Measurement of Magnetic Susceptibilities in Alternating Fields of Low Intensity. L. G. HECTOR AND G. R. ECKSTEIN, *University of Buffalo.*—This magnetic flux balance consists of two primary and one secondary coils arranged along a common axis. The two primary coils are identical but are connected so that their fields are opposed to one another. The secondary coil is placed between the two primary coils. When it is located symmetrically no resultant e.m.f. will be developed between its terminals when alternating current exists in the primaries. The magnetic specimen to be measured is inserted into the system so that it changes unequally the mutual inductances of the secondary with respect to the two primary sections. The e.m.f. developed across the secondary is measured with the aid of an amplifier having a voltage gain of approximately 10^6. Susceptibilities of a number of paramagnetic substances have been measured at frequencies ranging from 60 to 5000 cycles per second in fields of 16 oersteds and less. The sensitivity of the balance is comparable to that ordinarily obtained with intense fields by classical methods. A second balance similar in appearance and operation to the flux balance just described but depending on opposed windings in the secondary coil with aiding fields from the primary sections has also been developed for similar types of measurement.

33. Measurement of Transition Points of Electrolytic Iron by Hydrogen Diffusion. W. R. HAM, *Pennsylvania State College.*—The diffusion of hydrogen through iron is modified at the transition points. In the regions where the iron may be regarded as homogeneous, i.e., between 400° and 700°, the diffusion follows the usual formula found by many observers, $R=Ap_0^y\epsilon^{-b/T}/X$, where $b=3750$ and $y=0.5$, and the other symbols have their usual significance.* Between 770° and 840°C a similar relation holds but with different constants, as is also the case between 848° and 900°, and 900° and 954°C. In other words, the α-β and β-γ transitions seem to be members of a system, converging with rising temperature. The transition at 900° from body-centered to face-centered results in a large change in diffusion rate. This break is very abrupt and independent of hydrogen concentrations corresponding to impressed pressures of H_2 between 73 cm and 10 cm of Hg. This independence of hydrogen concentration has previously been found to be the case for the magnetic transformation regions of iron and nickel. Consequently, hydrogen diffusion furnishes a very sensitive and accurate means of determination of such points or regions.

* Ham and Sauter, Phys. Rev. **49**, 195A (1936).

34. Dependence of Young's Modulus for Nickel Upon Temperature and Magnetization. SIDNEY SIEGEL, *Columbia University.*—Using the method of the composite piezo-electric oscillator,[1] Young's modulus and the logarithmic decrement for a polycrystalline specimen of 99.7 percent pure nickel, annealed at 1100°C, were determined as functions of temperature and intensity of magnetization. Approximately uniform magnetization in the specimen, a cylinder 7 cm long, 0.477 cm diameter, was obtained by the use of specially designed coils. Heat resistant insulation was used throughout to enable the entire set-up to be placed in an oven and raised to 400°C. A simple recording galvanometer system recorded a complete resonance curve for the composite oscillator in four seconds. For magnetizations up to $J/J_{sat}=0.5$, the change of Young's modulus ΔE was found to obey a law of the form given by $\Delta E/E=k(J/J_{sat})^2$, in agreement with a theory of Akulov.[2] The total change of the modulus from the demagnetized state to the saturated state is 6.7 percent at 23°, reaches a maximum of 18.7 percent at 185°, and decreases to zero at the Curie point, 353°. The curve for Young's modulus *vs.* temperature, in the saturated state, is smooth except for a change in slope at 353°. The decrement decreases with magnetization at all temperatures below 353°. The value of the decrement in the saturated state below the Curie point, and its value above 353°, is 1.5×10^{-3}. In the demagnetized state, the decrement is 5×10^{-2} at room temperature, reaches a maximum of 10×10^{-2} at 180°, and decreases to 1.5×10^{-3} at 353°.

[1] Zacharias, Phys. Rev. **44**, 116 (1933).
[2] Akulov and Kondorsky, Zeits. f. Physik **85**, 661 (1933).

35. Further Experiments on Metallic Conduction. ERNST WEBER, *Polytechnic Institute of Brooklyn.*—The experiments previously described[1] have been continued. The distribution of large d.c. currents in a flat copper conductor in a strong magnetic field perpendicular to the flow of current is investigated, and its relation sought with the experiments of Kapitza on the increase of resistance in a magnetic field.

[1] Phys. Rev. **44**, 318 (1933); **45**, 740 (1934).

36. The Electro-Optical Kerr Effect in Methane, Ethylene and Ethane. WILLIAM M. BREAZEALE,* *Vanderbilt University.*—In continuation of the work previously reported by the author[1] the Kerr effect has been measured in three hydrocarbons, methane, ethylene and ethane, under pressure. The pressures used ranged from 30 to 100 atmospheres and the temperatures from 15° to 55°C. The wave-length in all cases was 6500A. With the aid of the Lorentz-Lorenz relation the measurements were reduced to N. P. T. and 6500A. The absolute values for the Kerr constant B thus obtained are, for methane 3.66×10^{-12}, for ethylene 16.3×10^{-12}, and for ethane 10.9×10^{-12}.

* The experimental work for this paper was performed at the Rouss Physical Laboratory, University of Virginia.
[1] Phys. Rev. **48**, 237 (1935).

37. The Use of Light Metal Rotors for the Ultracentrifuge. J. BISCOE, *Rockefeller Institute for Medical Research.*—The existing ultracentrifuges[1] use rotors of heat-treated steels. Steel rotors of large size (diameter = *ca.* 7 inches)

such as are needed for accurate measurements are costly and very destructive to the rest of the apparatus when they fail. Experiments have consequently been made to find out whether any light metal alloys could be used. The driving mechanism for the rotors turning in vacuum was essentially that of Beams and Pickels.[2] Calculations and experimental determinations have been made of the bursting speeds of rotors of various sizes and shapes made from alloys obtained from the Aluminum Company of America and the Dow Chemical Company. In all experiments the rotors were drilled for ultracentrifuge cells of standard size; dummy cells of equal weight were used in all runs. On the basis of the observed bursting speeds other rotors were run for several hours at 100 r.p.s. and for longer times at 150 and 200 r.p.s. below bursting speed to ascertain the amount of permanent stretch under such conditions. On the basis of these results a practical light metal rotor seven inches in diameter has been designed. It can be used apparently indefinitely at 50,000 r.p.m. and for a limited period at *ca.* 54,000 r.p.m. At the lower speed the gravitational field at the center of the cell (6.50 cm from the axis) is 180,000, at the higher speed it is 210,000 times the earth's field. For greater fields with so large a rotor steel must be employed.

[1] T. Svedberg, Naturwiss. **22**, 225 (1934); J. W. McBain and C. M O'Sullivan, J. Am. Chem. Soc. **57**, 2631 (1935).
[2] J. W. Beams and E. G. Pickels, Rev. Sci. Inst. **6**, 299 (1935).

38. An Ultracentrifuge for Gases and Vapors. J. W. BEAMS AND F. B. HAYNES, *University of Virginia.*—The method[1] of spinning rotors at high speed in a vacuum or in gases at various pressures has been utilized in the development of a gas centrifuge. The rotor, which has a triangular horizontal cross section, spins in a chamber at reduced pressure. Gas enters the spinning rotor through openings in its periphery and is pumped out of its center through a tube fastened to the rotor. This tube extends down along the axis of the rotor through a vacuum tight seal so that the lighter fractions of the gas are collected in a separate chamber. The holes in the periphery of the rotor are so directed that only molecules with speeds greater than that of the periphery can enter. Since the peripheral speed is well above the average molecular velocity of most gases or vapors at ordinary temperatures, the rotor serves as a velocity selector. This separation due to velocity selection and the separation due to centrifuging are additive. Preliminary results on the separation of nitrogen from carbon dioxide roughly verify the theory of separation and indicate that the apparatus may be successfully used for the separation of isotopes.

[1] R. S. I. **6**, 299 (1935).

39. The Structure of Ice III. RONALD L. MCFARLAN, *Harvard University.**—The stability of the high pressure ice forms discovered by Tammann and Bridgman at very low temperatures and atmospheric pressure has made it possible to obtain x-ray diffraction photographs of these forms. Since ice III is extracted from the press by taking it through the ice II region the precautions taken to avoid consequent misinterpretation of the ice III films are given. The analysis of the ice III diffraction patterns leads to a body-centered orthorhombic structure, and a unit cell of dimensions $a=10.20$A, $b=5.87$A, and $c=7.17$A. The unit cell contains sixteen molecules, has the symmetry of space group V_h^{26}–Ibam, and leads to a value for the density of 1.105 g per cc. Each oxygen is surrounded by a distorted tetrahedron of oxygen ions in a manner similar to that of ice I. An arrangement of the hydrogen atoms is proposed which makes the ice III lattice ionic. The volume decrease in the ice I–ice III transition is shown to be the result of a rearrangement of the oxygen ions. A simple transition mechanism is described, which is used to interpret some of the phenomena observed by Bridgman.

* Now at The United Drug Company.

40. The Widths of the *L* Series X-Ray Lines and Limit of Pb(82). ROSS E. SHRADER, *Cornell University.* (*Introduced by F. K. Richtmyer.*)—By means of a precision, two-crystal spectrometer of high resolving power, the widths of certain L series x-ray lines and the L absorption limits of Pb(82) have been measured. Calculations of the widths of the M, N, and O levels have been made by a method similar to that used by Richtmyer, Barnes and Ramberg,[1] on the basis of the theory of Weisskopf and Wigner[2] on natural line breadths. These calculated widths in electron volts are as follows:

L_{I}	11.0	M_{IV}	4.7	N_{V}	6.7
L_{II}	4.6	M_{V}	3.8	O_{I}	9.6
L_{III}	5.1	N_{I}	12.5	O_{II}	—
M_{I}	10.5	N_{II}	8.9	O_{III}	—
M_{II}	10.8	N_{III}	8.4	O_{IV}	3.1
M_{III}	7.3	N_{IV}	6.7	O_{V}	2.8

(These values compare favorably with those obtained for Au(79).[1]) The corrected line widths range from 0.41 X.U. (for $L\gamma_6$) to 2.26 X.U. (for Ll).

[1] Richtmyer, Barnes and Ramberg, Phys. Rev. **46**, 843 (1934).
[2] Weisskopf and Wigner, Zeits. f. Physik **63**, 54 (1930).

41. Wave-Lengths of $K\alpha$ X-Ray Satellite Lines for Elements S(16) to Ge(32). F. K. RICHTMYER AND L. G. PARRATT, *Cornell University.*—Utilizing the high resolving power of the two-crystal spectrometer, ionization curves of the diagram lines $K\alpha_{1,2}$ and of the four $K\alpha$ satellite lines α', α_3, α_3' and α_4 have been recorded for elements S(16) to Ge(32). A new component, α_3'', between α' and α_3, is present for elements S(16) to Ni(28). For elements S(16) to V(23) another line α'' is observed very close to and on the short wave-length side of the α_1 line. Elements of atomic numbers lower than S(16) and higher than Ge(32) have not yet been studied. The wave-length positions of the resolved satellite components referred to the wave-lengths of the $K\alpha_{1,2}$ lines for each element are reported in the present paper. The line α_3' is observed to move progressively relative to the α_3 and α_4 lines as the atomic number changes. This suggests the possibility that the α_3' satellite may be of a type different from that of the $\alpha_{3,4}$ satellites. In general no simple relation with atomic number is observed for the $\Delta\nu$ intervals between the satellites and the $\alpha_{1,2}$ lines. The question of which, if either, of the doublet lines should be taken as the "parent" line in calculating the $\Delta\nu$ intervals is discussed.

42. Widths of $K\alpha$ X-Ray Satellite Lines. L. G. PARRATT AND F. K. RICHTMYER, *Cornell University.*—In the empirical description of x-ray satellite lines several factors

may be considered: (1) The excitation potential, (2) wave-length positions, (3) relative intensities, and (4) widths and shapes of the various satellite lines. The authors have recently reported the excitation potential,[1] wave-lengths (preceding abstract) and relative intensities[2] of the $K\alpha$ satellites for elements S(16) to Ge(32). In the present paper are discussed the widths of the $K\alpha$ satellite lines. The observed satellite contours are resolved somewhat arbitrarily into the structural components. Partly because of this arbitrary resolution and partly because of uncertainties in the observed contour, chief of which is the unknown α_1 shape which comprises the satellite background, an error of 5 to 20 percent may be present in the widths of the satellite lines. The $K\alpha$ satellite lines are from one to three times as wide at half-maximum intensity as are the $K\alpha_1$ or α_2 lines. In general the widths of these $K\alpha$ satellites vary with atomic number in a manner similar to the variation in the widths of the $K\alpha_2$ lines. The theories of satellites have not been developed to the point of predicting line widths.

[1] L. G. Parratt, Phys. Rev. **49**, 132 (1936). See abstract in supplementary program.
[2] L. G. Parratt and F. K. Richtmyer, Bull. Am. Phys. Soc. **10**, No. 7 (1935), Abstract 57.

43. A Simple Method for Decreasing Skin Damage in High Voltage X-Ray Therapy. G. FAILLA, *Memorial Hospital, N. Y. C.*—Since biological changes result from the ionization produced in living tissue, and since the ionization is due to the secondary electrons liberated by the x-rays, it follows that the elimination of secondary electrons, were it possible, would prevent the biological changes. Secondary electrons may be removed from a beam of high voltage x-rays in air by means of a magnet and suitable diaphragms. The effectiveness of this scheme depends, of course, on the range of the secondary electrons. For, if the range is very small, the electrons provide their full quota of ions before they can be deflected out of the x-ray beam. With gamma-rays the problem is relatively simple. If we remember that secondary electrons are deflected through large angles in traversing matter, it is evident that by suitable canalization of the radiation beam and diaphragming, it is possible to remove most of the electrons originating in the walls of the x-ray tube or filter, without the use of a magnet. The advantage of the use of x-ray beams stripped of secondary electrons in x-ray therapy is apparent, since the ionization in the skin and consequent damage are materially reduced. The details of the scheme applicable to x-rays produced at voltages above a million volts will be presented.

44. Experimental Corroboration of the Lower Biological Activity of Gamma-Ray Beams Partially Freed of Secondary Electrons. G. H. TWOMBLY, L. MARINELLI AND G. FAILLA, *Memorial Hospital, N. Y. C.*—In the treatment of cancer with x-rays, the dose of radiation which can be delivered to a deep seated tumor is limited by the tolerance of the skin. There is reason to believe that the acute erythema which limits the possible dose is the result of changes occurring within 2 mm or less of the skin surface. Since biological changes result from the ionization produced in the living tissues by secondary electrons, the removal of such electrons from the primary beam at the surface of the skin should lessen the ionization produced by the beam to a varying degree depending on the depth and the amount of penetration of the skin by the secondary electrons. Experiments performed with ionization chambers and drosophila eggs show that, by the removal of a fair proportion of the beta-particles from a gamma-ray beam either by canalization or a magnetic field, the ionization at 1 mm below the surface of a substance such as celluloid is materially reduced.

45. Electric Impedance of Marine Eggs. KENNETH S. AND ROBERT H. COLE, *Columbia University.*—The alternating current resistance and capacity of sea-water suspensions of the eggs of the sea-urchins, Hipponöe and Arbacia, and the common star fish, have been measured at frequencies from one thousand to sixteen million cycles per second. On the basis of a generalization of the Maxwell equation for the resistance of a suspension of spheres, the electrical characteristics of several parts of the egg cells may be calculated from the data. It is found (1) that the capacity of the unfertilized egg membrane is from 0.75 to 1.1$\mu f/cm^2$, (2) that the egg interior is not electrically homogeneous, about five percent of the volume being membrane covered material, while the balance has a specific resistance of 6–8 times that of sea-water, (3) that on fertilization, a membrane having a capacity of 2–3$\mu f/cm^2$ is laid down over the egg surface and separated from it by a space a few micra thick which has approximately the specific resistance of sea-water.

46. Some Research on the Adaptation of Physics Experiments in Mechanics for the Visually Handicapped. P. C. MITCHELL, *New York Institute for the Education of the Blind.*—A method for increasing the degree of accuracy of the screw micrometer, by adding a metal disk or a spiral scale, to make possible the use of Braille figures and enlarged divisions for the touch method of taking readings. A similar problem met in the use of the vernier caliper by means of a triangular scale. Some typical adaptations of such experiments as the composition and resolution of forces, elasticity and Hooke's law, the laws of the pendulum, and simple harmonic motion. One outstanding problem presented in an attempt to find a suitable method for reading the position of a column of mercury in glass. Some possible solutions, by means of the photoelectric cell and other devices, applied to Boyle's law experiment. The same problem to be met in developing a convenient mercury-in-glass thermometer for experiments in heat.

47. Electron Motion in a Plasma. E. G. LINDER, *RCA Manufacturing Co. Inc., Camden, N. J.*—An equation for electron motion in a plasma is developed which is more general than previous ones, in that electron pressure is not neglected. The resulting expression is

$$d^2\xi/dt^2+4\pi ne^2/m\xi=(kT/m)(d^2\xi/dx^2),$$

where ξ is electron displacement, n electron density, T electron gas temperature, and x the equilibrium electron position. From this it is found that the possible frequencies of free vibration form a series given by $f_i=(kT/\lambda_i^2m+ne^2/\pi m)^{\frac{1}{2}}$. The lower limit corresponds to the Tonks-Langmuir value $(ne^2/\pi m)^{\frac{1}{2}}$, while the other frequencies depend upon the possible standing waves

which may exist. If $T=0$ the equation reduces to the Tonks-Langmuir equation; if $e=0$ (uncharged particles) we get the equation for sound wave propagation; and if $d\xi/dt=0$, the equation yields the Debye-Hückel expression for the variation of potential near a charged plane in a plasma under equilibrium conditions. If it is assumed that the shortest possible wave-length is $\alpha\lambda_D$, where $\lambda_D=(kT/4\pi ne^2)^{\frac{1}{2}}$, the "Debye distance," and α is a small numerical factor, which according to Langmuir is 3.31, the above theory is found to agree better with the experimentally found relation between f and n than the simpler theory, which neglects electron pressure.

48. Secondary Electron Emission from a Hot Nickel Target Due to Bombardment by Hydrogen Ions. MONICA HEALEA, *Radcliffe College*, AND E. L. CHAFFEE, *Harvard University*.—A hot nickel target was bombarded by hydrogen molecular ions to determine the number of secondary electrons emitted per positive ion at various voltages. The method used was that of Oliphant.[1] The ions were drawn from a discharge, collimated by a narrow canal, bent by an electric field, and allowed to impinge on the hot target. The latter was surrounded by a platinized bulb which served as the collector for the electrons. After the target had been kept hot for six weeks values consistent among themselves could be obtained. The number of electrons elicited from the target per positive ion varied from 0.046 at 303 electron volts to 0.223 at 1539 electron volts ion energy.

[1] M. L. E. Oliphant and P. B. Moon, Proc. Roy. Soc. **A127**, 373 (1930).

49. Influence of Electron Reflection on Photoelectric Emission. W. B. NOTTINGHAM, *Massachusetts Institute of Technology*.—Electrons emitted thermionically from tungsten and thoriated tungsten filaments are distributed in energy as though they suffered a reflection at the barrier given by $R(p_x)=\exp(-p_x^2/2m\omega)$ where $\omega=3.05\times10^{-13}$ erg and $p_x=$momentum in excess of that required to go over the barrier.[1] DuBridge and others have shown that Fowler's photoelectric theory which assumes reflection constant (or zero) fits the experimental data. The above reflection may be incorporated into the theory. The new function is nearly identical in form with the Fowler curve over the experimental range. If we assume the reflection hypothesis to be correct, all previous determinations of photoelectric work functions are too high by an amount given approximately by $\Delta\phi=8+0.138T-5\times10^{-5}T^2$ millivolts. Whereas the Fowler analysis gives work functions for clean surfaces practically independent of the temperature, the new method when applied to DuBridge's data on palladium yields a *negative* temperature coefficient of the work function of $(4.5\pm1)\times10^{-5}$ volt per degree. This is consistent with a thermionic constant A of 60 amp. per cm^2 per deg.^{2}, if we assume that only 40 percent of the apparent surface emits, as is thought to be the case for pure tungsten, and include the effect of reflection.

[1] W. B. Nottingham, Phys. Rev. **49**. 78 (1936).

50. Concentration of Arc Current in a Thyratron. K. H. KINGDON AND E. J. LAWTON, *General Electric Company*.—In most mercury thyratrons the arc glow appears to fill the space between the electrodes uniformly. If, however, the glow be examined with a slit and rotating mirror whose axes are perpendicular to the direction of current flow, it will be found that the apparently uniform discharge really consists of a concentrated current streamer which is in very rapid motion around the outer portions of the electrodes. The velocity of the streamer perpendicular to the direction of current flow usually lies between 10^4 and 10^5 cm per sec. This velocity increases with the arc current (15 to 150 amperes) and decreases as the mercury pressure is raised (1 to 25 microns). Streamers may occur whenever the arc passes through a constriction such as a grid hole, or a hole in the cathode heat shield. The arc apparently finds it easier to concentrate in one or two holes at any instant than to use all the holes simultaneously. After leaving the hole, the streamer is probably held together by the electrostatic force due to a slight excess positive space charge. The motion of the streamer is due to the expulsion of gas molecules and ions from the streamer.

51. Statistical Fluctuations in Multiple Space Charge. E. W. THATCHER AND H. S. HOWE, *Union College*.—A double grid vacuum tube may be operated in such a manner that the plate current-emission characteristic shows two horizontal tangents and a region of negative slope. This behavior has been interpreted as a consequence of multiple space charge.[1] Statistical fluctuations in the anode current have been studied with a view to testing the applicability of Llewellyn's equation,[2] $\overline{V_s^2}=(\partial I_p/\partial I_e)^2\overline{V_i^2}$, to these conditions. The two regions of zero mean square shot voltage predicted by static characteristics have not been observed. A peak value correlated with the maximum negative slope is in general larger than indicated by the relation given. Another peak consistently recorded is under conditions approaching temperature limitation and is in essential agreement with theory. We are forced to the conclusion that fluctuations other than cathode shot effect are operating within the electron stream. Noise measurements on the grid currents have supported this view. A study of mechanisms for the generation of these fluctuations is in progress.

[1] E. W. Thatcher, Physics 6, 81 (1935).
[2] F. B. Llewellyn, Proc. Inst. Rad. Eng. **18**, 243 (1930).

52. A Universal Ion Source. LLOYD P. SMITH AND H. A. CARLOCK, *Cornell University*.—A dense electron beam arising from a large ring shaped disk indirectly heated cathode is focused by means of electrostatic lenses on a cup shaped target into which gas flows or solid material is placed which in turn is vaporized and ionized by the electron beam. The ions thus formed stream in a direction opposite to that of the electrons and are focused into a beam passing through the hole in the electron emitter by the same electrostatic lens system which focuses the electron. Since the focusing is independent of the mass of the ions formed no further adjustments are required after the proper potentials have once been applied to the electrostatic lenses.

53. New Type of Pressure Control and Indicator. T. J. KILLIAN, *Luminous Tube Lighting Corporation, Seattle.*—A simple new type of electronic vacuum gauge has been developed which is extremely sensitive in any desired range either to indicate or control pressure. The device has no moving parts but consists of the element, for which the name baratron is proposed, sealed to the system, a variable impedance and a grid controlled tube. Two concentric glass cylinders with the inside of the inner tube and the outside of the outer tube coated with electrically conducting material make a simple and at the same time sensitive baratron element. A study has been made of the operation of the device by means of probe electrodes and a cathode-ray oscillograph. Various uses are illustrated such as controlling the pressure within two percent for many thousands of hours in gaseous discharge lamps using an active gas such as carbon dioxide.

54. New Materials for Glass-Metal Seals. A. W. HULL, E. E. BURGER AND L. NAVIAS, *Research Laboratory, General Electric Co.*—A careful study has been made of the thermal expansion of iron-nickel alloys, and a successful search for a glass to match one of these alloys. This new combination has certain advantages over the iron-nickel-cobalt combination previously described[1] in that the alloy is less oxidizable, less difficult to make, and less expensive; and the glass is softer and more easily sealed, while maintaining an equally low coefficient of expansion. A new glass is described which can be sealed directly to iron. The match is not perfect, but is better than that of most materials now in use; and the glass, though of very high expansion, appears to have good qualities.

[1] Hull and Burger, Physics **5**, 384 (1934).

55. The Michelson-Morley Experiment in the Case of an Ideal Interferometer. W. B. CARTMEL, *Université de Montréal.*—In a preliminary report presented a year ago at Pittsburgh, it was shown that there is no fringe shift so great as v^2/c^2 to be expected from this experiment, but only a shift proportional to v^3/c^3. On further investigation it was found that with an ideal interferometer v^3/c^3 is still too much, and finally the expected fringe shift vanished altogether. This is in agreement with what was found by Righi and by Hedrick. In 1920 Righi[1] proved from Huyghens' principle that the effect in the arm of the interferometer at right angles to the ether-drift is exactly the same as that in the arm that lies along the direction of the drift, and in 1927 Hedrick[2] and Epstein deduced an equation showing that any shift of the fringes is independent of the orientation of the interferometer. The present report covers a proof relating to the time of passage of a ray of light back and forth in the arm of the interferometer, which, when along the direction of the drift, is easily shown to be

$$t=\frac{2l}{c}\left[1+\frac{v^2}{c^2}+\frac{v^4}{c^4}\cdots\right].$$

I shall show by direct calculation that the time of passage of a ray of light back and forth in the arm at right angles to the drift is also given by the sum of the above series, and that therefore the effect being the same in both arms, no shift of the fringes whatever is to be expected.

[1] A. Righi, Comptes rendus **170**, 1550 (1920).
[2] E. R. Hedrick, Astrophys. J. **68**, 374 (1928).

56. The Vacuum-Cell Luminescence Microscope and Its Use in the Study of Luminescent Materials. JOHN GALLUP, *RCA Manufacturing Co.* (*Introduced by L. B. Headrick.*)—A new type of luminescence microscope is described. Its use in the examination and comparison of materials luminescing under electron bombardment in vacuum is explained. Fields of self-luminous particles are obtained of sufficient brightness to permit of satisfactory visual observation at magnifications up to 500×. Good photomicrographs can be made at 100× magnification with an exposure time of 2 minutes and ordinary film. In the study of manganese-activated calcium silicates, this microscope has made possible the determination of some of the relationships which exist between color of luminescence, intensity of luminescence, and crystal form in the calcia-silica system. It has been determined that the low-temperature form of calcium metasilicate, characterized by lath-shaped crystals, luminesces more brightly than any other manganese-activated calcium silicate studied. The need for a thorough, wet mixing of ingredients in preparing luminescent materials is strikingly indicated when uniformity in color and intensity of luminescence is required.

57. The Spectra of Phosphorus P V–P XII.* HOWARD A. ROBINSON (Irving Langmuir Fellow), *American-Scandinavian Foundation, Physical Insiitute, Uppsala, Sweden.*—Spectrograms using red phosphorus in a hot spark discharge have resulted in the determination of many new lines in the higher spectra of this element. Two Siegbahn grazing incidence spectrographs have been available. From 1000A–100A a one-meter speculum metal grating having an approximate dispersion of 4A/mm in the first order has been used. A high resolving power five-meter glass grating ruled at this Institute has been used in the region from 100A–33A. The dispersion of this grating is approximately 0.35A/mm in the first order. Over 250 of the new lines in P VI–P XII have been determined by the use of this latter instrument, lines appearing as low as 35A. Preliminary classifications have resulted in a substantiation and extension of Bowen and Millikan's[1] data for P V (Na I-like). The *s*, *p*, *d* term sequences have been followed to $n=7$ and the *f* sequences to $n=6$. The ground state separations are now known—by means of easily located ground state to low primed state multiplets or in some cases by certain of the ground state to 3*d* transitions—for the higher stages of ionization. The results are in good agreement with predictions of the irregular doublet law (where applicable) or with predictions based on the method of constant second differences.

* To be read by title.
[1] Phys. Rev. **25**, 295 (1925).

58. The Third Spectrum of Xenon. C. J. HUMPHREYS, *National Bureau of Standards.*—The spectrum, Xe III, characteristic of Xe^{++}, has been selected from the xenon spectra excited in a Geissler tube, on the basis of the suppression of lines originating in ions of higher stage than

the first by the insertion of varying amounts of inductance in the discharge circuit. Wave-length measurements based mainly on observations with the Rowland grating at the National Bureau of Standards extend from λ2200 to λ8900. About 250 lines have been classified arising from 76 levels of Xe III. The low states of Xe^{++} are ^3P, ^1D, and ^1S, due to the $5s^25p^4$ configuration. The higher excited states are built upon the ^4S, ^2D, and ^2P states of Xe^{+++} by the addition of ns, np, or nd to the normal $5s^25p^3$ configuration. The identification of the experimental terms is nearly complete. In all cases permitted by the j selection rule, the odd levels are connected with the low $5s^25p^4$ terms by combinations occurring in the range covered by J. C. Boyce's extreme ultraviolet data. Numerous interlimit combinations permit precise determination of the relative term values. The absolute term values are arrived at from the estimation of the limit of the $5s^25p^3$ $(^4S)nd$ $^5D^0$ series. The lowest $4s^24p^4$ $^3P_2$ level comes out accordingly 259,089 cm^{-1} equivalent to an I. P. of 32.0 volts for Xe^{++}.

59. Spectroscopic Investigation of Discharges at High Gas Pressure. WILLIAM W. WATSON AND G. F. HULL, JR., *Yale University.*—Spectra of capacity discharges between electrodes of various metals in H_2, N_2 and He at pressures up to 15 atmospheres have been examined at high dispersion. A continuous spectrum which becomes in all cases very intense at pressures above 4 atmospheres serves as a background for absorption bands due to AlH, MgH, BeO, etc. The lines of the AlH $^1\Pi\rightarrow{}^1\Sigma$ band at 4260A which are not affected by predissociation ($J<15$) are all uniformly shifted to the red (0.05 cm^{-1} per atmos.) and symmetrically broadened (half-width 0.24 cm^{-1} per atmos.) by about the same amount as for the pressure broadening of S–P resonance lines by H_2 gas. Lines of $\Sigma\rightarrow\Sigma$ bands exhibit but slight pressure shifts; BeO $^1\Sigma\rightarrow{}^1\Sigma$ band lines are shifted 0.04 cm^{-1} to the red per atmosphere of O_2, with no dependence on K. Details of the pressure broadening of the Al resonance lines are presented. The great breadths and shifts of the maxima of these emission lines (largest for N_2) are attributed principally to interatomic Stark effect and interactions with near-lying excited states, while the contours and pressure shifts of the self-reversals are about those expected if due to van der Waals forces between Al atoms and gas molecules.

60. Pressure Effects of Foreign Gases upon Band Lines. HENRY MARGENAU, *Yale University.*—Widths and shifts of molecular absorption lines, if caused by foreign gas pressures, are a measure of the strength of the interaction between the excited molecule and the normal foreign perturber. When the latter has a symmetrical charge distribution, the energy of interaction can be calculated with fair approximation; it is of the van der Waals type. Closer inspection then leads to the following conclusions: (a) Anomalously large broadening and correspondingly strong shifts occur when the excited molecule is capable of a downward (dipole) transition involving an energy which is nearly equal to that of a higher state of the perturbing molecule. (Quasi resonance.) (b) The usual effect produces a breadth and a shift only slightly larger than those found in atomic lines. Both are nearly independent of vibrational and rotational quantum numbers; they are practically the same as would be expected for that atomic line to which a given band corresponds in type and energy. Theory predicts a slight but hardly measurable increase in line width with increasing vibrational and rotational quantum number. The preceding qualitative conclusions are partially confirmed in the experiments described in the foregoing abstract.

61. The Population of the Higher Excited States in a Cesium Discharge. F. L. MOHLER, *National Bureau of Standards.*—The reversal temperatures of the principal series lines of cesium were measured by projecting the image of a strip lamp through a columnar discharge onto the slit of a spectrograph and measuring the lamp temperature at which the lines match the background. This could be measured to the sixth doublet of the principal series for pressures between 76 and 350 microns and currents from 0.5 to 2 amperes. The temperatures are in the range 2400 to 1800°K. The temperature drops appreciably from the first to the third line but beyond is nearly constant. It increases with increasing current and decreasing pressure. The number of atoms N_n in the excited state is $N_n=N_1g_n/g_1\exp(-E_{n,1}/kT)$ where T is the reversal temperature, g's are the weights and E the energy of the state. N_n approaches a constant value for large values of n which ranges between 10^6 and 10^7 per cm^3 for the above conditions. The variation of T with pressure keeps N_n nearly constant in the range studied. Measurements of the intensity of higher series lines in the diffuse series lead to values of N_n for D states if it is assumed that the transition probability is proportional to n^{-3}. The results are not entirely consistent with the reversal temperature measurements.

62. Optical Properties of LiF Crystals in the Near Infrared. R. BOWLING BARNES AND LYMAN G. BONNER (National Research Fellow), *Princeton University.*—The transmissions of various samples of LiF crystals have been determined in the region from 1μ to 15μ by means of a rocksalt spectrometer. These results are compared with reflection measurements previously made by Korth from 10μ to 33μ, and with transmission measurements of the characteristic vibration at 32.6μ made by Barnes. Indications of a complex absorption structure are given by the existence of many secondary maxima. This is in accordance with theoretical expectations. A single crystal of LiF 2.0 mm thick is shown to be 75 percent transparent at 7μ and opaque at 10μ.

63. Properties of Crystal Powders in the Far Infrared. LYMAN G. BONNER (National Research Fellow) AND R. BOWLING BARNES, *Princeton University.*—The optical properties of a number of powdered cubic crystals have been investigated in the far infrared, between 34 and 126μ. The Christiansen transmission peaks, corresponding to the wave-length at which the refractive index of the crystal equals that of air, have been located for several crystals. In addition the region of the fundamental has been reexamined for each crystal and secondary maxima found on both sides of ν_0.

64. Optical Investigation of Thin Gold Foils. R. SMOLUCHOWSKI, *The Institute for Advanced Study, Princeton.*—Measuring the light absorption in thin metal foils Smakula found consecutive maxima and minima of absorption coefficient which he indicated as connected with electronic levels (bands) in the metal lattice. Since this point of view does not seem to be satisfactory, new measurements have been made on thin gold foils in order to find another possible explanation of the effect. Special care has been taken to obtain reproducible foils which were made by condensing gold vapor on thin glass plates. A special arrangement permitted the estimation of the obtained thickness. The measurements have been carried out on a series of foils, varying from "colloidal" foils to good developed crystal layers, the different structures of the foils appearing in the shape of the absorption curve. The dependence of the observed maxima and minima of absorption of light in the wave-length region 4800–6800A upon the thickness of the foils and the angle of transmission of the light beam seems to indicate that the origin of this effect is to be looked for in the grain structure of the surface of the foils, the grains themselves however being very different from uniform spheres as it was supposed in Mie's theory of optical effects in colloids.

65. Excitation Potential, Relative Intensity and Wave-Length of the $K\alpha''$ X-Ray Satellite Line.* LYMAN G. PARRATT, *Cornell University.*—With a two-crystal vacuum spectrometer, ionization curves of the $K\alpha''$ satellite line have been recorded for elements S(16) to V(23). This satellite line, on the short wave-length side of and very close to the $K\alpha_1$ line, was observed in 1922 by Dolejsek and has been until now a forgotten line. The excitation potential of this satellite has been determined: The initial atomic state for its emission appears to be one of KM ionization. The $K\alpha''$ intensity relative to the $K\alpha_1$ intensity varies with atomic number, reaching a maximum of 2.3 percent at Ca(20). The $K\alpha''$ wave-length positions have also been determined for each element. The observed data are compatible with both the Wentzel-Druyvesteyn and the Richtmyer theories for the origin of this satellite line.

* To be called for after Paper No. 45.

66. Hypotheses for Photoelectric Emission Analysis.* W. B. NOTTINGHAM, *Massachusetts Institute of Technology.*—Fowler's hypothesis for photoelectric sensitivity is "that the number of electrons emitted per quantum of light absorbed is . . . proportional to the *number of electrons per unit volume* of the metal whose kinetic energy normal to the surface augmented by $h\nu$ is sufficient to overcome the potential step at the surface." This results in Fowler's universal function multiplied by $(W_a-h\nu)^{-\frac{1}{2}}$. With DuBridge's hypothesis, which differs from Fowler's by the introduction of "*the number of electrons striking unit area of the surface per second*" in place of the italics above, Fowler's function is obtained without the factor $(W_a-h\nu)^{-\frac{1}{2}}$ but this is questionable dimensionally. A new hypothesis agreeing quite well with energy distribution data is that the number of electrons emitted per second per quanta absorbed per second is proportional to the number of electrons striking the surface per second, whose kinetic energy normal to the surface augmented by $h\nu$ is sufficient to overcome the potential step at the surface, *multiplied by the time electrons of a given kinetic energy are "bound" in a mirror image potential barrier.* The transmission of these electrons over the barrier is assumed to be governed by the factor $\{1-\exp(-p_x^2/2m\omega)\}$. (See abstract 49.)

* To be called for after Paper No. 54.

67. A Formula for the Michelson-Morley Experiment.* W. B. CARTMEL, *Université de Montréal.*—Having arrived at an *exact* solution of our problem in the case in which the mirrors and rays are arranged with mathematical precision, it is a fairly simple matter to deduce the effect that would be produced when the mirrors only deviate by a small amount from this assumed disposition, because in a well-arranged interferometer the departure from mathematically exact adjustment is only slight. Using a simple geometrical construction I have deduced the following formula for the fringe shift:

$$\delta F=\frac{2l}{\lambda}\left[(M\phi+N\alpha)(\alpha-\beta)\frac{v}{c}\cos\theta+2(\phi+\alpha)\frac{v^2}{c^2}\cos 2\theta\right],$$

in which α and β are angles between the normals to end mirrors A and B, and lines drawn at an angle of 45° with the plate, and ϕ is the angle of incidence. The fringe width is given by $F=\lambda/2(\alpha-\beta)$. If $\phi=\alpha=\beta=0$, we have an ideal interferometer in which case there is no fringe shift. If $(\phi+\alpha)$ equals zero, the ray meets the end mirror normally, the coefficient of the double frequency term is zero and there is no v^2/c^2 effect. If $(\alpha-\beta)$ equals zero, the fringes are infinitely wide, also the single frequency term is zero. It may be shown that the above formula completely accounts for the results obtained by all those who have tried this experiment, from Michelson and Morley[1] down to Kennedy and Thorndike.[2] It accounts particularly well for the results obtained by Dayton C. Miller,[3] because he has given his results in greater detail than anyone else. The coefficient $2(\phi+\alpha)$ can be shown to be equal to 1/400 in Miller's case, which accounts for his finding 1/400 of the expected fringe shift and 1/20 of the expected velocity.

* To be called for after Paper No. 64.
[1] Phil. Mag. (5) **24**, 449 (1887).
[2] Phys. Rev. **42**, 400 (1932).
[3] Rev. Mod. Phys. **5**, 203 (1933).

68. Tracks of Atomic Cosmic-Ray Corpuscles in Photographic Emulsions. T. R. WILKINS AND H. ST. HELENS, *University of Rochester.*—On the photographic plates sent in the recent United States Army-National Geographic Stratosphere balloon a number of tracks have been found similar to those made by alpha-rays in photographic emulsions but of much greater length. The longest track so far found has about 350 grains in the track compared with about 33 produced by a 7.8 million electron volt Ra C′ alpha-ray in the emulsion used. In some cases there are ejected proton tracks branching from the main track. Studies of the temperature coefficient of the response of a photographic emulsion to alpha-rays[1] and of the relative responses of an emulsion to alpha-rays and protons make it possible to distinguish between the tracks of these two particles and to estimate the energy of a particle even if

the whole track is not recorded. Since it is impossible to make this distinction from cloud chamber photographs it will be seen that the emulsion method offers a very important new tool for the study of cosmic rays. A special stereoscope has been developed for viewing the tracks in three dimensions so that correct measurements can be made on the average grain spacing which is about 1.5μ for alpha-rays and 2.2μ for protons for 5–10 MEV energies. The increase of these separations with the energies of the particles and with a lowering of temperature have to be considered in the interpretation of the tracks. The long track (350 grains) is interpreted as due to an alpha-particle of about 100 MEV energy. The track was horizontal.

[1] S. E. Sheppard, T. R. Wilkins, E. P. Wightman and R. N. Wolfe, in press.

69. Protons As Primary Cosmic Rays. W. F. G. SWANN, *The Bartol Research Foundation of the Franklin Institute.*—It has been suggested that the primary cosmic rays found at sea level are almost exclusively protons. Now a charged particle is characterized by the fact that its ionization increases enormously towards the end of its range, so that, in the case of protons and alpha-particles large and measurable spurts of ionization should be produced in relatively short distances by those rays which are ending their journeys. If r is the distance from the end of the range to the point where the ionization per centimeter of path is σ, then, the fraction of the rays which, passing through a length L of a vessel containing gas at pressure p, produced therein spurts of ions greater in number than $Lp\sigma$, is $(1-e^{-\mu r})$. The assignment of a lower limit to the spurts which can be measured determines σ, and so r, through the aid of Bethe's theory; and, it becomes possible to calculate how many such spurts should be observed if the primary rays are protons. With the lower limit of measurement taken as 54,000 ions it is calculated that about one spurt per hour equal to or greater than this amount should be observed in a vertical cylinder of length 15.2 cm, and cross section of the area 45.6 cm^2. Measurements later to be reported have been made by C. G. and D. D. Montgomery, W. E. Ramsey and the writer, with the result that less than ten percent of the calculated number of spurts have been observed. The conclusion is that the primary cosmic rays cannot be protons, and that if protons are to be admitted at all, they must function in some such manner as that implied in a former theory by the writer, *viz.*, through the production of secondary rays which then become the entities actually observed by our counters.

70. A Quantitative Study of the Improvement of Speculum Gratings by the Application of Aluminum. ALFRED B. FOCKE, *Brown University.*—Tests made on a clean concave speculum metal grating show that if the surface is coated with aluminum by evaporation, the time required to obtain a photograph of a spectrum is reduced by a factor which is the ratio of the reflection coefficient of aluminum to that of the speculum metal. The speed of the original grating was increased for the given wave-lengths by the following amounts: 4077A—45 percent, 3341A—80 percent, and 2536A—170 percent. In preliminary tests the observed increase in speed was very much greater than indicated by these values, since the initial tests were made before the grating had been sufficiently cleaned.

71. On the Dual Nature of Instruments. EUGENE W. PIKE, *Scott Paper Co., Chester, Pa.*—In applied physics instruments have a dual function. They serve as a means of identifying identical materials or structures, and of correlating similar structures; they also serve to define the forms of the concepts in terms of which one may think about the material under consideration. The requirements made by these two functions on the construction of an instrument are usually antithetical. As a result instruments defining simple concepts are often physically unrealizable, while the simple instruments of the empirical technical man define incredibly complex concepts. The examples given include a preliminary analysis of tensile rupture testing into somewhat simpler concepts.

72. The Absorption of Neutrons Slowed Down by Paraffin at Different Temperatures. P. N. POWERS, G. A. FINK AND G. B. PEGRAM, *Columbia University.*—Several attempts have been made to detect experimentally the difference between the velocity distribution of neutrons traversing cold paraffin from that with the paraffin at room temperature.[1-4] We place a Rn-Be source in a howitzer-shaped block of paraffin with a central plug to scatter fast neutrons out of the direct beam to the Li-lined ionization chamber used as a detector. Measurements were made of the absorptions of various materials with the paraffin at room temperature and at liquid-air temperature, but with the source kept near room temperature. The results expressed in terms of "nuclear cross section" are given in Table I. The increase in cross section may be most easily

TABLE I.

MATERIAL	CROSS SECTION ($\times 10^{-24}$ cm^2) 300°K	95°K	PERCENT CHANGE
Cd	2800	3000	7
B	540	690	26
Rh	125	175	40
HgO	445	605	36
Ag	55	75	35
Paraffin	42	45	7
LiF	69	91	34
Gd	22200	27700	25
Sm	4300	4400	3

explained by the fact that the neutrons stay longer in the vicinity of the nuclei. The magnitude of the change is in agreement with the results of other investigators on temperature effects, and, in the cases of Cd and Ag, with the results of experiments with revolving disks.[5]

[1] Amaldi, d'Agostino, Fermi, Pontecorvo, Rasetti, Segrè. Proc. Roy. Soc. **A149**, 522 (1935).
[2] Moon and Tillman, Nature **136**, 904 (1935).
[3] Westcott and Niewodniczanski, Proc. Camb. Phil. Soc. **31**, 617 (1935).
[4] Fink, Dunning, Pegram and Mitchell, Phys. Rev. **49**, 103 (1936).
[5] Rasetti, Segrè, Fink, Dunning and Pegram, Phys. Rev. **49**, 104 (1936).