Proceedings of the American Physical Society

MINUTES OF THE ST. LOUIS MEETING, DECEMBER 31, 1935–JANUARY 2, 1936

THE 37th Annual Meeting (the 203rd regular meeting) of the American Physical Society was held at Washington University, St. Louis, Missouri, on Tuesday, Wednesday, and Thursday, December 31, 1935 and January 1 and 2, 1936 in affiliation with Section B—Physics—of the American Association for the Advancement of Science and the American Association of Physics Teachers. The presiding officers were Professor R. W. Wood, President of the Society, Dean F. K. Richtmyer, Vice President, and Professor L. A. DuBridge, Dr. W. E. Forsythe, Professor A. L. Hughes, Professor L. R. Ingersoll, Professor D. C. Miller, Professor H. M. Reese, Professor Alpheus W. Smith, and Professor D. L. Webster. There were about three hundred physicists in attendance at the meeting. All sessions were held in the Wayman Crow Hall of Physics of Washington University.

The joint session with the American Association of Physics Teachers was held on Tuesday afternoon at two o'clock in Crow Hall in a symposium on *Photoelectricity* at which Professor D. L. Webster, President of the American Association of Physics Teachers presided. The invited papers were as follows: (1) *The New Physics and the Undergraduate* by Professor A. A. Knowlton, Reed College; (2) *Photoconductivity in Crystals* by Professor A. L. Hughes of Washington University; and (3) *The Copper-Copper Oxide Barrier Layer* by Dr. L. O. Grondahl of the Union Switch & Signal Company.

On Tuesday evening the Physical Society and the American Association of Physics Teachers held a dinner at the Gatesworth Hotel. Professor R. W. Wood, President of the Physical Society, presided. Brief speeches were made by President Wood, President D. L. Webster of the Association of Physics Teachers, and Professor A. L. Hughes, Chairman of the Local Committee for the Physical Society, the Association of Physics Teachers, and Section B of the A.A.A.S. Dr. Thomas C. Poulter, second in command of the recent Byrd Antarctic Expedition, spoke on *The Byrd Expedition in the Field*, with special reference to its scientific work, and showed motion pictures of the life and work of the expedition. There were two hundred and twelve present at the dinner.

Annual Business Meeting. The regular annual business meeting of the American Physical Society was held on Wednesday morning, January 1, 1936, at nine-thirty o'clock, President Wood presiding. The President had appointed Messrs. K. K. Darrow and F. S. Goucher tellers to canvass the ballots for the officers of the Society. In accordance with the report of the tellers the following elections were declared made for the year 1936:

President	F. K. Richtmyer
Vice President	H. M. Randall
Secretary	W. L. Severinghaus
Treasurer	G. B. Pegram
Members of the Council—four-year term	J. W. Beams
	E. C. Crittenden
Members of the Board of Editors—three-year term	H. A. Bethe
	L. A. DuBridge
	M. A. Tuve

The Secretary reported that during the year there have been 148 elections to membership. The deaths of 13 members have been reported; 19 have resigned, and 54 have been dropped. The membership of the Society as of December 29, 1935 was as follows: 2146 members; 694 fellows; 6 honorary members; total 2846.

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

The Managing Editor reported that a preliminary estimate of the cost of publishing the *Physical Review*, *Physics*, and the *Reviews of Modern Physics* for 1935 would probably be under $5.00 per member; that the relatively low

cost for this year was due to the following: (1) The subscription income was greater than anticipated partly because of the putting into effect of the policy of charging for the additional postage for foreign subscribers and partly because the number of subscribers showed a healthy increase, and (2) the volume of publication remained practically the same as in 1934. It was emphasized that this fortunate state of affairs might not continue for long and that it would require only a relatively small increase in the number of pages to be published to run the cost above the resources of the Society.

The joint session with Section B of the A.A.A.S. and the American Association of Physics Teachers was held on Wednesday morning at ten o'clock. The presiding officer was Professor John T. Tate, Vice President of Section B. The Retiring Vice President of Section B, Dean Henry G. Gale, presented a paper on *The Diffraction Grating*. Professor R. W. Wood, President of the Physical Society delivered an address on *Optical and Physical Effects of High Explosives* and Professor Arthur H. Compton spoke on *Recent Developments in Cosmic Rays*.

On Thursday afternoon at four-thirty o'clock the Physical Society joined with the American Mathematical Society in the Municipal Auditorium at the Josiah Willard Gibbs Lecture which was delivered by Professor Vannevar Bush of the Massachusetts Institute of Technology on *Mechanical Analysis*. On the same afternoon Dr. V. K. Zworykin of the Radio Corporation of America gave a lecture on *Electron Optical Systems and Their Applications*.

Meeting of the Council. At the meeting of the Council held on Wednesday afternoon, January 1, 1936 one candidate was elected to fellowship and ten candidates were transferred from membership to fellowship. Forty candidates were elected to membership. *Elected to fellowship:* Edward Teller. *Transferred from membership to fellowship:* Norman I. Adams Jr., A. B. Cardwell, Floyd A. Firestone, George M. Murphy, Lothar Nordheim, Leland B. Snoddy, E. C. Stevenson, James D. Stranathan, J. C. Street, and E. J. Workman. *Elected to membership:* Lewis G. Abernathy, C. J. Bakker, Alfred Boch, William M. Breazeale, John H. Buck, Glen D. Camp, C. Fred Clarke, A. W. Dicus, Charles O. Duevel, Jr., Douglas H. Ewing, G. M. Giannini, Walter Gordy, Armin Helz, Robert A. Howard, Harry R. James, Martin Katzin, William G. Keck, Richard C. Keen, Chris. P. Keim, Harry C. Kelly, Philip G. Koontz, Elbert P. Little, Robert J. Maurer, Frederic D. Merrill, Jr., Robert D. Miller, Yukihiko Miyagawa, Keron C. Morrical, Wilson C. Morris, Richard G. Nuckolls, Kinnosuke Ogura, Hidesuke Ohmata, Anna L. Peckham, James A. Peoples, Jr., Paschal H. Pretz, P. Scherrer, Edward J. Schremp, Francis W. Sears, J. W. Smith, Harris M. Sullivan, and D. H. Tomboulian.

The regular scientific program of the Society consisted of seventy-five contributed papers. Numbers 7, 10, 17, 36, 39, 42, 43, 64, and 65 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.

G. B. PEGRAM, *Secretary pro tempore*

ABSTRACTS

1. Dia- and Paramagnetic Susceptibilities at Two to Ten Oersteds. WILLIAM SCHRIEVER AND R. E. SMITH, *University of Oklahoma.*—Specimens of three pure diamagnetic elements and three pure paramagnetic salts were investigated by measuring the force on a spherical specimen when it was placed in an axially symmetrical field whose strength, and space rate of change of strength along the axis of symmetry, could be calculated. The forces varied from 6 to 25×10^{-6} dyne and the sensitivity of the apparatus was 10^{-6} dyne per millimeter deflection at a scale distance of 317 cm. The small deflections were reproducible to within 6 percent, the large to within 1 percent. The necessary variation of the field over the specimen was less than 5 percent of the mean value of the field strength. The observed variations are greater than the experimental errors. At one oersted $FeCl_3$ had a susceptibility of 159.

Substance	Volume of Substance (cm^3)	Volume Susceptibility (e.m.u.) $H=2.5$	$H=5$	$H=10$	Int. Crit. Tab.
Bismuth	1.32	−10.9	−11.2	−10.7	−13.78
Antimony	1.55	−4.45	−3.89	−3.10	−5.75
Cadmium	1.59	——	−0.895	−0.63	−1.56
Bismuth (Powder)	0.992	−9.78	−7.65	−7.13	——
(Powders)		$H=2$	$H=3$	$H=5$	
$FeCl_3$	0.43	153.	148.	140.	79.
$FeSO_4+7H_2O$	0.505	78.5	77.7	75.	72.5
$Co_2(SO_4)_3+7H_2O$	0.435	69.5	79.8	75.	240.

2. Magnetic Viscosity. C. W. HEAPS, *The Rice Institute.*—Barkhausen jumps of magnetization in nickel and iron may continue to occur for 20 or 30 seconds after the magnetizing force has become constant. This phenomenon appears to be a type of magnetic viscosity which cannot be caused directly by eddy currents. A possible explanation may lie in highly localized regions of high temperature, these high temperatures being produced by the localized eddy currents associated with single Barkhausen reversals. The flow of heat from these small regions would cause a redistribution of local strains and thus allow other regions which are not very stable magnetically to make a Barkhausen jump. A wave of magnetic reversal may be assumed to penetrate an elementary domain of volume 10^{-8} cm^3 according to the same laws observed by Sixtus and Tonks for very large Barkhausen discontinuities. It appears that on this assumption sufficiently high local temperatures will not be produced to explain the phenomenon in the manner indicated. However, by making the reversal time of the elementary domain extremely small a local high temperature of sufficient magnitude might be produced. A second factor to be considered is the uneven distribution of the large scale eddy currents produced by the change of magnetic force. These large scale currents will warm the outside layers of the wire more than the inner layers and thus some time will be required for the attainment of a uniform temperature. There are reasons for believing that the large scale eddy currents do not by their heating effect have much influence on magnetic viscosity.

3. A Prerecording Oscillograph and Its Use in Studying Rectifier Operation. A. W. HULL AND HANS LAUB, *General Electric Company.*—By utilizing the phosphorescence of the screen of a cathode-ray oscillograph it is possible to record electrical conditions just prior to, as well as during and after, an unpredictable event, such as arc-back of a rectifier. The oscillograph is allowed to write continuously on its screen, and the image fades as fast as it is written, except for a slight time lag due to the decay period of the phosphorescence. This time lag constitutes a memory of what happened just prior to any given instant. A camera whose shutter is operated, with the help of a Thyratron, by the event being studied, sees and records this "memory" as well as the trace that is written while the shutter is open. We have called these records *memory oscillograms.* With the help of these oscillograms we have obtained, for the first time, reliable information on the question: "At what part of the cycle does a rectifier arc-back?" With Phanotrons and Thyratrons, all the arc-backs that we have observed occur at the middle of the inverse cycle, i.e., when the voltage is maximum.

4. The "Effective" Capacity of an Intermittent Glow Discharge Tube. DANIEL E. CLARK AND LESTER I. BOCKSTAHLER, *Northwestern University.*—When the electrodes of a discharge tube are joined in parallel with a capacity and supplied with a constant current, a regular periodic discharge takes place. The phenomena may be explained in terms of the charging and discharging of a condenser. The magnitude of the capacity which must be assigned to the condenser in order to calculate the period of the discharge is greater than the value of the external capacity plus the circuit capacity computed from its dimensions. The additional "effective" capacity was found for tubes with half-inch aluminum electrodes, 2 cm separation, by using, in turn, H_2, He, N_2, O_2, A and air as residual gas. The magnitude of the "effective" capacity ranged from 120 micromicrofarads for H_2 to 600 for N_2. For H_2, O_2, A and air the "effective" capacity was independent of the current while for He and N_2 there was a slight increase with current. The period is a linear function of the external capacity. No simple relation exists between the gas pressure and frequency save that the latter increases as the former decreases. The frequency was found by means of a Duddell oscillograph which recorded the amplified output of a photoelectric cell which responded to the light flashes in the discharge.

5. Sensitivity of Photon Counters. S. W. BARNES AND L. A. DUBRIDGE, *University of Rochester.*—It is well known that Geiger-Müller tube counters with cylinders of Ni, Mo, Au, etc., are sensitive to ultraviolet light, counts being produced by the release of electrons from the metal surface. There have been few satisfactory measurements of the sensitivity, however, and almost no attempt to realize the greatest possible sensitivity. It is probable that no counters have been used capable of giving a measurable response to ultraviolet light intensities less than about 3000 quanta/cm^2 sec. Claims for higher sensitivity appear to be open to question. In the study of the supposed mitogenetic rays there is a demand for counters responding to 2–5 quanta/cm^2 sec. The sensitivity limit is set (1) by the presence of background counts and (2) by the photoelectric yield of the surface. Because of (1) it will be difficult to measure radiation which yields less than 2 electrons/min. The photoelectric yield for most metals at 2536A is of the order of 10^{-5} electron/quantum or less, giving the sensitivity limit of 3000. However, a distilled Mg surface in vacuum may have a yield of 10^{-2} which should give a counter sensitivity of 3 quanta/cm^2 sec. Unfortunately most counting gases destroy the active surface. A mixture of pure He and Ne does not affect the surface but gives rather poor counts. A counter of this type will be described.

6. The Geiger-Müller Photon Counter—Quantitative Aspects, Detection of Small Intensities, Use in Absorption Spectroscopy. WALTER D. CLAUS AND ALEXANDER HOLLAENDER, *University of Wisconsin.*—The authors have recently discussed[1] some of the uncertainties involved in the calibration of the Geiger-Müller photon counter. An approximate solution to the problem is obtained through the intermediary of the counter tube used as a calibrated vacuum photo-cell. The photoelectric yield of the sensitive surface of the counter is definitely less than the yield of the same surface (Zn, Cu, Al, sensitized, not outgassed) in vacuum, so that $10^3 h\nu$/cm^2/sec. is the lower limit of intensity in the ultraviolet (2300A) which can be detected with the counters thus far investigated. Attempts to detect mitogenetic radiation from a number of sources

with these counters have been made. The quantitative response of the photon counter to incident radiation suggests the use of the device in absorption spectroscopy, while its response to extremely small intensities permits the use of very pure light from readily available, constant sources of continuous radiation. The instrument should thus be of great value in the study of fine structure in absorption spectra.

[1] Claus and Hollaender, J. Opt. Soc. Am. **25**, 270 (1935).

7. Fowler's Photoelectric Theory, Assuming Quantum Absorption Probability a Function of Electronic Energy. ALAN T. WATERMAN, *Yale University*.—It is assumed in Fowler's theory that the photoelectric current is proportional to the number of "available" electrons, i.e., those with energies normal to the surface which exceed a given value. This implies that the chance of an electron absorbing a quantum is independent of its energy. Recent theoretical progress following quantum-mechanical lines does not justify this assumption but indicates that this chance depends upon the electron's momentum normal to the surface. Therefore this feature is incorporated into Fowler's treatment by including a factor proportional to the normal kinetic energy in the expression for the number of "available" electrons. On integrating it is found that the form of the Fowler function, $F(x)$, used in evaluating the work function, remains unaltered and leads to the same value of the work function, computed by horizontal displacement of the experimental curve. The vertical shift alone is affected. The same result is obtained on assuming a quantum absorption probability proportional to the first power of the normal velocity instead of the second. One may conclude therefore (1) that there is no inconsistency between the Fowler analysis (as used hitherto) and recent quantum-mechanical theory in the respect mentioned, and (2) that apparently the Fowler theory can give no evidence as to the probability of absorption of a quantum unless vertical shifts are analyzed. The form of the Fowler function $F(x)$ is determined only by the form of the statistical partition function.

8. On the Nature of the Barrier Layer in the Cuprous Oxide Photovoltaic Cell. II. J. W. BALLARD AND E. HUTCHISSON, *University of Pittsburgh*.—In the course of extended study of cuprous-oxide photo-cells many data were obtained which bear on the behavior of such cells. While some of these results are merely confirmation of the work of previous investigators, many of them are new and significant in the explanation of the action of barrier-layer cells. The following conclusions were drawn from the experimental results: (1) Sensitization of cuprous-oxide surface occurs on bombarding the oxide surface with positive ions, negative ions, or electrons. (2) Sensitization has not been obtained by heating the cuprous-oxide disk as a whole. (3) The positions of maximum spectral responses and of limiting wave-length in the near infrared are independent of the kind of gas used in bombardment. (4) Electrical resistance and total response of a cell depend upon the kind of gas used in bombardment. (5) The maximum sensitization depends upon an optimum time of bombardment. (6) The electrical resistance seems to increase with time of bombardment. (7) The position of maximum spectral response is independent of the time of bombardment. (8) The position of maximum spectral response is probably independent of the kind of metallic film. (9) Spectral transmission of the oxide seems related to the spectral response maxima in the near infrared.

9. Photoelectric Properties of Sodium Films on Aluminum. JAMES J. BRADY AND VINCENT P. JACOBSMEYER, S.J., *Saint Louis University*.—Previous work[1] has shown that thin films of potassium, rubidium, and caesium deposited on a silver surface give a maximum sensitivity when the calculated film thickness is in the order of 10 molecular layers or less. For thicker films, the sensitivity is less. Sodium films are deposited on aluminum, and it is found that the maximum sensitivity is not attained until the film thickness is in the order of 100 molecular layers. The sensitivity is constant for greater thicknesses. No detectable photo-current is observed until the film thickness is in the order of 6 molecular layers. A difference of this kind is expected on the basis of the adion field theory for the work function of the underlying metal is less than the ionization potential of the alkali atom. The reverse is true in the previous work. The photoelectric cell is of the concentric sphere type like that previously reported by Brady.[2] Current-voltage curves are observed for different film thicknesses. These indicate that the work function remains the same for all the film thicknesses investigated. A spectral distribution curve is obtained for the thick film (100 molecular layers). Surface changes after deposition of the sodium are discussed.

[1] Brady, Phys. Rev. **41**, 613 (1932).
[2] Brady, Phys. Rev. **46**, 768 (1934).

10. A Hydrodynamical Theory of Piston Ring Lubrication.* R. A. CASTLEMAN, JR., *East Falls Church, Virginia*.—While a satisfactory hydrodynamical theory of journal bearing lubrication was advanced some 50 years ago by Osborne Reynolds, and has since been considerably extended and applied with gratifying results by Sommerfeld, Kingsbury, Michell and others, much haziness still persists as to the lubrication of the so-called "packing rings" which reciprocate with the pistons of engines. If we assume that the cross section of the ring, no matter how "straight" initially, is soon worn down to some gently rounded form, with the thick part in the middle (e.g., circular, *with very large radius of curvature*) and further assume that oils as used in engine lubrication cannot stand absolute tension, we find that, while the piston is moving at ordinary speeds, the ring will be separated from the wall by a film of lubricant a few ten-thousandths of a centimeter thick, and therefore large compared to the molecular size, so that boundary conditions need not be considered. It also follows that a "small rounding" of the edge of the ring, so often assumed, will not result in the maintenance of a sufficiently thick film. Results from this theory are in qualitative agreement with observations of ring wear by C. G. Williams, and with measurements of ring clearance by F. Salzmann.

* To be read by title.

11. An Analytical Treatment of the Horn-Diaphragm Coupling Chamber for Receiver Measurements. C. K. STEDMAN, *Purdue University.* (*Introduced by K. Lark-Horovitz.*)—A telephone receiver may be tested by removing its horn and loading it acoustically with an air column of variable length in a closed tube.[1] In this way one can measure the acoustic impedance of the horn and the sound power output of the receiver, under the assumption that the air chamber in front of the diaphragm can be regarded as an addition to the tube of an equivalent length r determined by experiment. Under this assumption the acoustic impedance Z_A at the diaphragm is given by

$$Z_A = -j\left(\frac{A_1}{A_2}\right)^2 A_2\rho c \cot kx \qquad (1)$$

where A_1 is the diaphragm area, A_2 the cross section of the tube, and x the total length, i.e., actual length plus r. A complete analytical treatment leads to the formula

$$Z_A = -j\cos^2 kr\left[\left(\frac{A_1}{A_2}\right)^2 A_2\rho c \cot kx\right] - j\left(\frac{A_1}{A_2}\right)^2 A_2\rho c \sin kr \cos kr. \qquad (2)$$

Eq. (1) leads to correct results for the measurement of acoustic impedance of the horn and sound power output, but it leads to quite erroneous results when extended to determine the acoustic impedance at the diaphragm and the mechanical impedance of the diaphragm itself. Eq. (2) covers all cases. Furthermore it is expressed in terms of a single parameter r which can be calculated theoretically at low frequencies, or determined empirically at higher frequencies. The theory has been verified experimentally.

[1] Fay and Hall, J. Acous. Soc. Am. **5**, 46 (1933).

12. Sound Propagation. D. A. BOURGIN, *University of Illinois.*—For a wide class of mixtures marked simplification is possible in the author's earlier formulae for sound propagation in gases. Double transitions and multiple collision effects have been included as required by recent experimental findings. The Knudsen-Kneser expression for gas contamination absorption is shown to be a very special case under the general result, and the implied approximations are brought into evidence. For pure gases the Kneser-Ruttger's method as generalized by Richards is shown to be equivalent in principle with the writer's developments (though the ωi dependence is implicit). C_∞ or $3k/2$ may be introduced by either method.

13. The Direct Detection and Measurement of the Angular Momentum of Light. RICHARD A. BETH, *Worcester Polytechnic Institute and Palmer Physical Laboratory.*—As was first pointed out by A. Sadowsky,[1] Maxwell's theory predicts that a beam of polarized light must, in general, exert a torque on a doubly refracting medium which changes its state of polarization. The predicted value of the effect is quantitatively the same as that obtained by assigning an angular momentum of $\pm h/2\pi$ to left and right circularly polarized photons, respectively, and assuming the conservation of angular momentum. During the past year it was possible to detect and measure this effect.[2] The experiment consists essentially in determining, by mirror and scale, the deflection of a quartz half-wave plate hung from a quartz fiber between two fixed quartz quarter wave plates, the *top* side of the top one being coated with a reflecting layer of aluminum. All plates are horizontal, and the axes of the two fixed plates are 90° in azimuth from those of the hanging plate between them. Light from a tungsten ribbon filament passes through a large Nicol and up into the plate system. The *change* in torque on the half-wave plate was measured when the lower plate was turned back and forth through a fixed angle in resonance and in antiresonance with the natural period of the torsional pendulum. Experimental curves show that the effect varies as required by the theory for different filament temperatures, for different azimuths of the plane of polarization of the Nicol, and for different values of the angle through which the lower plate was turned. The torques obtained were in the region 0.5 to 4×10^{-9} dyne-cm.

[1] A. Sadowsky, Acta et Commentationes Imp. Universitatis Jurievensis **7**, No. 1–3 (1899); **8**, No. 1–2 (1900).

[2] I wish to thank the National Research Council for a grant-in-aid and Professor A. W. Duff, of the Worcester Polytechnic Institute, who originally brought the problem to my attention.

14. Mean Free Paths for Gas Beams in Mercury Vapor. JOHN A. ELDRIDGE, *State University of Iowa.*—The decrease in intensity of a molecular beam as it passes through mercury vapor has been observed and the mean free path (for beams) determined for several gases. The values (in centimeters) at one bar mercury vapor pressure are as follows: He 12.5; H_2 6.85; N_2 5.8; CO_2 5.3; C_2H_6 5.2. These values are slightly smaller than would be predicted from viscosity data on classical lines (using a rigid sphere model). A difference in this direction follows from the wave mechanics.

15. An Attempt to a Purely Theoretical Derivation of the Mass of the Universe. ARTHUR HAAS, *University of Vienna* (now Visiting Professor at Bowdoin College). (*Introduced by W. L. Severinghaus.*)—If a universe of finite mass M consists of N protons+neutrons and R is the radius of the approximately spherical volume, over which the astronomical objects are distributed, we arrive at the relation

$$MRc = 2N^{\frac{1}{2}}h \quad \text{or} \quad N^{\frac{1}{2}} = Rm_H c/2h \qquad (1)$$

(m_H the mass of the H-atom).[1] If, on the other hand, we make the assumption that the gravitational energy of the universe is equal, with opposite sign, to the sum of the proper energies of all the material particles contained in the universe, we arrive at the formula

$$N = 5Rc^2/3fm_H, \qquad (2)$$

f denoting the gravitational constant. Combination of (1) and (2) yields

$$N^{\frac{1}{2}} = (10/3)(hc/m_H{}^2 f) \qquad (3)$$

and hence

$$N = 1.2\times10^{79}, \quad M = 2.0\times10^{55}\ \text{g}, \quad (R = 9.3\times10^{26}\ \text{cm}) \qquad (4)$$

in agreement with the values derived by Eddington in an entirely different way. No reference, however, to the

ideas of general relativity, of an expansion of the universe, or of a curvature of space and no astronomical data are necessary for the derivation and evaluation of (3). From a comparison with Eddington's theory the relation seems to follow:

$$(e^2/c)\gamma = 2(6/5)^{\frac{1}{2}}h \qquad (5)$$

γ denoting the mass ratio between H-atom and electron. Calculation of e from (5) gives a value which only differs by about one percent from the accepted value.

[1] Cf. A. Haas, Anz. Akad. Wiss. Vienna No. 11, 1932; and another theoretical deduction by K. Sitte and W. Glaser, Zeits. f. Physik **88**, 103 (1934).

16. On the Probability of Radiative Processes for Very High Energies. L. W. NORDHEIM, *Purdue University.*—The present theory of radiative processes (radiation of electrons and pair production by photons) ceases to be valid for fields above the critical limit: potential difference mc^2/e over h/mc. The available formulae (Bethe-Heitler) give accordingly wrong results if applied to cosmic rays. By a method of v. Weizsäcker and Williams the total cross sections can be obtained by summing the contributions of passages at various distances from the atomic nuclei. If the regions are left out, for which the applicability of the ordinary theory is doubtful according to the above criterion, new formulae are obtained which seem to satisfy the observations. They give quantitatively the specific energy losses of electrons in lead (as measured by Neddermeyer and Anderson). In agreement with Compton's analysis only electrons with an initial energy of above 8000 MV have a fair chance to traverse the atmosphere. As at a critical energy (decreasing with the nuclear charge) the cross sections for radiative processes approach zero, the transition effect for showers (greater intensity in air than in lead of the photon radiation accompanying primary electrons) is readily explained, the values of the various absorption coefficients being again at least in qualitative agreement with the experimental data.

17. Mathematical Expression of Charge Distribution in a Space Lattice. VIVIAN JOHNSON, *Purdue University. (Introduced by K. Lark-Horovitz.)*—The assumption that the forces holding a solid body together are of an electrical nature has been used with great success by Born, Ewald, and others in the theory of the dynamics of crystal lattices. However, the expression for the potential functions used has never been proved to be convergent. Following a suggestion of W. E. O. Maier, the problem has been treated in a way similar to Riemann's treatment of the Green's function of a rectangular parallelopiped.[1] Thus we prove the convergence of the sum:

$$S = \sum_{-\infty}^{\infty} k \sum_{-\infty}^{\infty} m \sum_{-\infty}^{\infty} n \frac{e^{\pi i q(k+m+n)}}{(k^2+m^2+n^2)^{\frac{1}{2}}},$$

where $q = l/2^p$; p being any integer and l any odd integer. l and p may be chosen so as to approximate any real number. By squaring the denominator of each term the convergence is improved, and therefore also the sum:

$$S' = \sum_{-\infty}^{\infty} k \sum_{-\infty}^{\infty} m \sum_{-\infty}^{\infty} n \frac{e^{\pi i q(k+m+n)}}{k^2+m^2+n^2}$$

is convergent. The electrostatic potential of a lattice distribution can be written as the sum of eight terms, each of the type S', and therefore also is proved to be convergent.

[1] Courant and Hilbert, *Meth. der Math. Phys. I*, pp. 327–330.

18. Energy Distribution of Slow Neutrons. E. U. CONDON AND G. BREIT, *Princeton University.*—The problem of finding the distribution in energy of particles of mass m, initially of the same energy, which have made n impacts with particles of mass M all initially at rest, is solved. It is supposed the impacts are elastic and the distribution in angle isotropic in a coordinate system in which the center of mass is at rest. If x is the ratio of the energy after n impacts to the initial energy then the chance that x lie in dx at x is $(\log 1/x)^{n-1}/(n-1)!$ for $m = M$. For unequal masses the expression is more complicated but easy to calculate. The results have some interest in connection with the slowing of neutrons by elastic impacts with other nuclei, especially with hydrogen nuclei.

19. Does the Alpha-Particle Possess Excited States? EUGENE FEENBERG, *University of Wisconsin.*—Two Hamiltonian operators have been investigated in an attempt to answer the above question. In the first only neutron-proton interactions are considered. These are represented by a potential function of the ordinary (Wigner) type with the explicit form $Ae^{-\alpha\pi^2}$. In the second the neutron-proton interaction operator depends on spin orientation as suggested by Wigner to explain the large scattering cross section of slow neutrons in hydrogen.[1] The interaction between like particles is represented by the potential $A_v e^{-\alpha\pi^2}$. Both A and A_v are determined as functions of α by requiring that the computed normal state energy, using a Gaussian-type wave function, equals the experimental binding energy of the alpha-particle. The function

$$\psi_{2p} = N(x_1+x_2-x_3-x_4)\exp\left[-\tfrac{1}{2}\nu(\pi_{13}^2+\pi_{14}^2+\pi_{23}^2+\pi_{24}^2) - \tfrac{1}{2}\mu(\pi_{12}^2+\pi_{34}^2)\right]$$

appears to be suitable for the study of the singlet $2p$ state of the alpha-particle with about the same degree of accuracy as the simple Gaussian-type function for the $1s$ state. With this wave function and the second Hamiltonian the $2p$ energy eigenvalue is $-18mc^2(1/\alpha^{\frac{1}{2}} = 2.4\times10^{-13}$ cm), $-13mc^2(1/\alpha^{\frac{1}{2}} = 2.2\times10^{-13}$ cm), $-8mc^2(1/\alpha^{\frac{1}{2}} = 2.0\times10^{-13}$ cm). With the first Hamiltonian the energies run about $7mc^2$ higher. The second Hamiltonian yields a singlet $2p$ state which is stable against spontaneous disintegration into H^3 and H^1 for $1/\alpha^{\frac{1}{2}} \geqq 2.3\times10^{-13}$ cm. Similar calculations on the triplet $2p$ state indicate that the triplet level lies below the singlet.

[1] Feenberg and Knipp, Phys. Rev. **48**, 906 (1935).

20. A Generalization of the Uncertainty Principle. BORIS PODOLSKY, *University of Cincinnati.*—The paper considers the knowledge of system α that may be obtained as a result of measurements performed upon another system β. A synthesis is proposed preserving the best aspects of the various points of view. It preserves the criterion of reality of Einstein, Podolsky and Rosen, but permits the conclu-

sion that quantum-mechanical description of physical reality is complete. In achieving this synthesis one is led to a generalization of the uncertainty principle which may be stated as follows: *If ΔQ and ΔP are the uncertainties in the values at any moment of time of a coordinate and its conjugate momentum respectively, which may be obtained by processes* (not necessarily simultaneous or even compatible) *each of which does not disturb the system under consideration, then $\Delta P \Delta Q > h$,* in the same way as in Heisenberg's uncertainty relation.

21. Ultraviolet Absorption Spectrum of Carbon Disulphide Vapor. J. RUD NIELSEN, F. W. CRAWFORD AND L. D. HUFF, *University of Oklahoma.*—A large number of absorption bands have been measured between 2300A and 1900A, and the bands between 3800A and 2900A have been remeasured. The variation of the intensities with temperature has been studied for both band systems by the method described by Clements.[1] Applying the results obtained from the Raman and the infrared absorption spectra, we have made some progress in the analysis of the band systems, although the intensity data have not yet been fully utilized.

[1] Clements, Phys. Rev. **47**, 220 (1934).

22. Haze and Smoke Visibility—Theory and Measurement. G. D. SHALLENBERGER AND E. M. LITTLE, *State University of Montana, Missoula.*—The present workers in collaboration with the U. S. Forest Service made a study of the visibility of smokes and of distant mountain ridges. This study included a mathematical treatment, based on the scattering of light by particles producing haze, Fechner's law of stimulus-sensation for vision, and visual resolving power. It also included measurements made in the field with a visibility meter that was originated in the course of the study, and which can be used also in aviation, etc. The visibility of a smoke is the distance it is from an observer when it can just be seen. A similar definition was used for ridge visibility. The visibility of a smoke in sunlight differs from that of a smoke in the shade. The azimuthal curves for the former are circles except on extremely clear days, while those of the latter have depressions in the direction of the sun when the sky is clear. With an overcast sky the shade smoke azimuthal curves are also circles. Under some conditions it was found that adding haze to the air *increases* the visibility. Binoculars increase visibility but not proportional to their power. Also, field and laboratory measurements were taken.

23. Simultaneous Sets of Interference Fringes. I. WALERSTEIN AND R. A. WOODSON, *Purdue University.*—In the usual arrangement of the Michelson interferometer a set of circular fringes is obtained if the dividing plate is half-silvered and the planes of the two mirrors are exactly perpendicular to each other. If the half-silvering is removed from the dividing plate it is possible to obtain, because of internal reflections, two nearly equally intense reflected beams and two transmitted beams, one much stronger than the other. A similar division of each incident beam takes place at the compensating plate. The various beams upon recombining at the dividing plate give rise simultaneously to at least three sets of visible fringes of different forms. Calculations of the path difference for any two interfering rays due to one ray passing through a number of glass plates and the other one passing through a lesser number of plates lead to a conic section form of the fringes. The shapes of the simultaneous sets of fringes change continuously as the difference in distances of the mirrors from the dividing plate, the angle between the dividing and compensating plate, and the angles between plates and mirrors is varied. They are circles, ellipses, straight lines, and double sets of hyperbolas, one with a horizontal and the other with a vertical axis but with common asymptotes.

24. Low Intensity Solarization for Three Emulsions. HENRY P. GRIGGS, S.J., *Saint Louis University.* (*Introduced by F. E. Poindexter.*)—The work of Reardon and Griggs[1] on Hammer Extra-Fast emulsions has been repeated (at Spring Hill College, Mobile, Alabama) for the Extra-Fast emulsions and also carried out with Hammer Ultra-Rapid Press and Special-Ortho Plates. The numbers of reversals obtained for a maximum exposure time of 11,854 minutes for the different emulsions were as follows: for the Extra-Fast, four; for the Ultra-Rapid, six; and the Special-Ortho, seven. The density increases at successive maxima in all cases except for the last maximum of the Special-Ortho emulsion which is slightly less than the preceding maximum density. With the exception of this one maximum, there is no damping down of the swings in the density *vs.* log E graphs, and hence the results do not agree with those of Lubovich on exposures at high intensities.[2]

[1] Reardon and Griggs, J. Opt. Soc. Am. **24**, 331 (1934).
[2] Lubovich, J. Opt. Soc. Am. **14**, 309 (1927) and Rev. Sci. Inst.

25. Pressure Effect and Physical Development. ANNA JOYCE REARDON, *Saint Louis University.* (*Introduced by F. E. Poindexter.*)—The effect of pressure on the latent photographic image was investigated with reference to three methods of physical development. These methods were: (1) Physical development before fixation, as described by Odell;[1] (2) pre-fixing with acid hypo and then development of the pressure-affected latent image in Odell's silver-nitrate-amidol developer; (3) pre-fixing of latent image in 30 percent plain hypo and development in Odell's developer. All three types of physical development show a reduction in latent image density. The amount of reduction depends upon the pressure applied and the type of development employed. The actual density obtained with physical development was in each case less than that obtained with chemical development, although the exposure time, for physical development, was twice as great. The density-log E graphs obtained when the underlying Br was dissolved out with 30 percent plain hypo were straight lines. The percent of density reduction for an exposure-time of 256 minutes and a pressure of 1357 kg/cm^2 was 13 percent for chemical development; 28 percent for physical development method (1); 41 percent for physical development method (2); and 68 percent for physical development method (3).

[1] Odell, Ind. Eng. Chem. **25**, 877–879 (1933).

26. A New Pressure Effect in Photography. FRANKLIN E. POINDEXTER, ANNA JOYCE REARDON AND ONA K. DEFOE, *Saint Louis University.*—We find that the application of hydrostatic pressure to a photographic film after exposure but before development lowers the developable image density. Eastman's Par-speed nitrate Portrait films were used. After exposure, the films were cut into two parts. One of these portions was placed in water at room temperature, the other part was sealed into a hard rubber vessel in water and placed in a high pressure apparatus. The two parts were chemically developed simultaneously. The pressures varied from 26,000 to 36,000 lbs./sq. in., and were applied from 20 to 30 minutes. We find that the density is lowered some 4 or 5 percent for an image density in the region of 0.7.

27. The Optical Constants of Liquid Sodium Amalgams. A. P. FRIESEN, *University of Kansas.*—The optical constants of liquid sodium and of 44 liquid sodium amalgams, between the limits of 0 and 40 atomic percent mercury, were determined. Large changes in n^2-k^2 and in $2nk$ with change in concentration occurred in the neighborhood of those concentrations where so-called intermetallic compounds exist. Incidentally more or less periodic small changes in n^2-k^2 and in $2nk$ were discovered at those concentrations where compounds are not known to exist. Work is in progress to obtain further experimental data that may be useful in the interpretation of these small periodic changes or "ripples."

28. A Mercury Manometer with High Multiplication Factor for Differential Pressure Measurements. RICHARD M. SUTTON, *Haverford College, Haverford, Pa.*—The maximum gain of deflection of liquid in one tube of an ordinary U-tube manometer approaches a limiting factor 2 obtained by making the ratio of areas of the side arms large. However, by using two liquids of different densities and by making a simple modification of design, it is possible to secure a real multiplication factor much greater. An ordinary U-tube of large bore is constricted in one arm at some point *above* the bend in the U. Mercury is inserted in the U to a level somewhat below this constriction. A light liquid is inserted above the mercury to fill the remaining volume of large tube and to extend into the smaller tube. For a given pressure difference, the light liquid in the smaller tube is now deflected farther than the mercury in a simple manometer by a factor $[2\rho_2 a/b]/[2\rho_2+(a/b-1)\rho_1]$ where a and b are the areas of the larger and smaller tubes, ρ_1 and ρ_2 are the densities of the light and heavy liquids, respectively. For maximum multiplication the two side arms containing mercury are made equal in area and *all* of the reduction in area occurs above the interface of the two liquids. This manometer combines the compactness of a mercury manometer with the sensitivity over any chosen pressure range of a light-liquid manometer. Application of the design to a sensitive acceleration meter and to a xylene-mercury barometer giving large deflections for normal atmospheric variations is described.

29. Surface Tension of Mercury in the Presence of Nitrogen, Hydrogen, and Carbon Dioxide. MARIE KERNAGHAN, R.S.C.J., *Maryville College of Saint Louis University.*—The apparatus and the method are those previously described by the author.[1] The combination of drying tubes and pressure gauge dispenses with stopcocks and is so constructed as to admit any gas in any quantity and to hold the pressure constant through any length of time. Nitrogen was obtained directly by passing air through pyrogallic acid solution; hydrogen and carbon dioxide were each prepared in a Kipp generator. The surface tension of mercury in a vacuum was again checked and found to be 476.5 dynes per centimeter at 20°C. The results obtained in the presence of the gases may be summarized as follows:

P (mm)	H_2	N_2	CO_2
<0.00001	475.5	476.5	476.5
.5	474.0	470.6	469.3
1	473.3	470.0	468.8
3	472.3	469.4	467.3
5	471.5	469.0	465.8
7	471.0	469.0	465.2
300	471.0	469.0	465.2

[1] Kernaghan, Phys. Rev. **47**, 202A (1935).

30. Variation with Altitude of the Optimum Thickness of Lead for the Production of Cosmic-Ray Showers.—J. C. STEARNS, *University of Denver,* AND DAROL K. FROMAN, *Macdonald College, McGill University.*—The number of showers obtained per minute from various thicknesses of lead scattering blocks were counted by a triple-coincidence Geiger counter system at altitudes ranging from sea level to 14,120 ft. Two methods were used. In the first the three counters were arranged in the form of a triangle and counts were taken with various thicknesses of lead above the top counter. In agreement with B. Rossi,[1] the thickness of lead giving the maximum number of showers is found to be 1.7 cm and within experimental error, to be independent of altitude. In the second method the three counters were placed in a vertical line and the difference in counting rate, with the lead scatterer placed firstly above the top counter, and secondly between the two lower counters, was taken to be a measure of the number of showers produced. This method gave a much sharper maximum at 1 cm of lead.

[1] Rossi, Report of International Conference on Physics, Vol. I, p. 245.

31. The Variation with Altitude of the Absorption of Cosmic and Shower Radiation. DAROL K. FROMAN, *Macdonald College, McGill University,* AND J. C. STEARNS, *University of Denver.*—The absorption in lead, zinc and aluminium of primary cosmic rays has been measured by a triple Geiger counter at altitudes ranging from sea level to 14,120 ft. The absorbing material was placed between the counters, a lead block two inches thick was kept between the counters to absorb any extremely soft radiation. For thicknesses of material less than 16 cm some of the average absorption coefficients are given in the table. The absorption

ALTITUDE (ft.)						
120	5,300	10,800	5,300	10,800	5,300	10,800
MATERIAL						
Pb	Pb	Pb	Zn	Zn	Al	Al
ABSORPTION COEFFICIENT (cm^{-1})						
0.014	0.018	0.023	0.012	0.018	0.006	0.010

of the shower radiation was measured by using three counters in triangle formation. A scattering block of lead was placed above the system and the absorption measured in lead sheets placed just above the lowest counter. The apparent absorption coefficient of the showers from lead varies from about 0.5 cm^{-1} Pb at sea level to about 0.4 cm^{-1} Pb at 14,120 ft. elevation. The absorption in lead is not quite exponential and the shape of the absorption curves indicates the possibility that shower particles may have the ability to excite new showers.

32. Fluctuations in Cosmic-Ray Ionization as Given by Several Recording Meters Located at the Same Station. RICHARD L. DOAN, *University of Chicago.*—A graphical comparison will be given of the intensity variations of cosmic rays as registered on several different recording meters during a period of ten weeks. As one might expect, the agreement is statistical rather than coincident. The barometer effect as calculated from the data of the individual meters ranges from 1 to 2 percent per cm of mercury. A diurnal analysis carried out for a ten-day period during which barometric changes were small indicates a maximum of intensity at about 9:00 A.M. having a magnitude 0.19 percent greater than the average. The average number of cosmic-ray ionizing particles traversing unit area of the ionization chamber per unit time, as estimated from statistical fluctuation data, is shown to compare favorably with counter observations. As regards ionization bursts: Analysis of distribution-in-time of the bursts shows that they occur in a purely random manner. Size-frequency distributions can be represented for the most part by a single exponential function. Analysis of nearly 700 bursts $>15(10)^6$ ions occurring over a 25 mm Hg range of atmospheric pressure yields no evidence for a barometer effect on burst frequency although the consistency of the data is not sufficient to rule out the possibility of an effect as large as 8 percent per cm Hg.

33. Heavy Particles Produced by Cosmic-Ray Encounters. CARL D. ANDERSON AND SETH H. NEDDERMEYER, *California Institute of Technology.*—Our preceding measurements on the energies of cosmic-ray tracks made at sea level have revealed but a few cases in which heavy particles appear as a result of cosmic-ray encounters. Similar measurements made this summer on top of Pike's Peak bring to light unambiguously a considerable number of such particles—approximately 100 out of 7000 successful counter-tripped exposures. These tracks possess the following properties: (1) In the great majority of cases these tracks seem to be made by protons. (2) They appear to be ejected in all directions and to have little relation to the direction of the incoming beam. (3) In several cases protons and electrons originate in the same center, the energies of the latter being sometimes more than 100 MEV. (4) These proton tracks appear as the result of disintegrations produced both by ionizing and nonionizing rays. (5) The high values of the energies of the disintegration particles preclude the possibility that the disintegrating nucleus could have supplied this energy. The foregoing results, on the other hand, show that both ionizing and nonionizing rays may be so absorbed as to appear in part in the ejection of heavy particles from a nucleus. (6) Practically all the heavy tracks can be interpreted only as secondaries produced within the atmosphere or the material above the chamber. (7) Certain types of disintegrations, heretofore unobserved at sea level, indicate the presence of neutrons at high altitudes. It is a pleasure to acknowledge the aid given to these researches by the Carnegie Institution of Washington and the Union Oil Company of California.

34. Gamma-Ray Ionization Currents in Air. JAMES W. BROXON AND GEORGE T. MERIDETH, *University of Colorado.*—An ionization chamber particularly adapted to measurements over rather wide ranges of temperature, pressure, intensity of the collecting field, and intensity of ionizing radiation has been constructed. Entire uniformity of collecting field has not been provided, but in the main volume of the ionized gas there is not great variation from uniformity. Measurements of currents due to ionization by a weak gamma-ray source combined with natural ionization have been made in air at room temperature. With gradients extending to about 4000 volts/cm, currents have been measured at a few pressures between local atmospheric pressure and 170 atmospheres. At the higher pressures, the current continues to increase with the strength of the collecting field throughout the range employed. Except with very low gradients, the rate of accumulation of negative ions is greater than that of positives (see recent observations of Clay and Van Tijn[1]). With the high gradients, the current-pressure relations appear roughly to resemble those observed by one[2] of us with only the natural ionization and much lower gradients. It is expected that further data will be available for the meeting.

[1] Clay and Van Tijn, Physica **2**, 8, 825 (1935).
[2] James W. Broxon, Phys. Rev. **37**, 1325 (1931).

35. The Yield of Alpha-Particles from Li^7 Bombarded by Slow Protons. H. D. DOOLITTLE, *University of Chicago. (Introduced by A. J. Dempster.)*—The absolute yield of alpha-particles from a thick target of lithium bombarded by protons of energies from 23 to 72 electron kilovolts has been determined. The logarithm of the number of disintegrations per proton has been plotted against $V^{-\frac{1}{2}}$ where V is the energy of the proton in electron volts. The results of Herb, Parkinson and Kerst as well as those of Oliphant and Rutherford have been included in the graph to extend it over the range from 23 to 400 kilovolts. This curve is not a straight line as expected by the theory but is slightly concave upwards. No indications of resonance nor of a minimum voltage required for disintegration were observed. An FP-54 Pliotron in a modified form of the DuBridge-Brown balanced circuit was used in photographic recording of the alpha-particles.

36. The Energy Levels of the Nuclei of Light Elements. H. A. WILSON, *Rice Institute.*—Regarding atomic nuclei as combinations of neutrons and protons their energies of

formation may be supposed due to the formation of bonds analogous to the chemical bonds in for example hydrocarbons. The energies of formation may then be explained by assuming suitable constitutions and bond energies. It is found that the energies of formation and the nuclear reaction energies of several of the light elements may be explained in this way. In this paper it is shown that the energy levels of several light elements may be explained by supposing some of the bonds normally present to be missing.

37. Theory and Operation of an "Achromatic" Mass Spectrograph. A. J. DEMPSTER, *University of Chicago.*—A mass spectrograph has been constructed which brings a divergent bundle of charged atoms to a focus even when different velocities are present. This analog to the achromatic doublet lens first separates the various velocities by an electrostatic field, and reunites them by means of a magnetic field. Even with comparatively wide slits an increased resolving power is obtained. With a high frequency spark as a source the isotopes of elements not obtainable by other methods have been observed. Mass spectra of gold, palladium, rhodium, platinum, uranium, and iridium have been made. Preliminary results with nickel, cadmium, tin, cerium, and lead will be reported, and the behavior of the instrument illustrated by reproductions of spectra.

38. The Existence of Isobares of Adjacent Elements and the Mass of the Neutrino. KENNETH T. BAINBRIDGE AND EDWARD B. JORDAN, National Research Fellow, *Harvard University.*—Mattauch and Sitte have suggested that isobares differing by one unit in atomic number either are unstable or do not exist at all. Beck, Bethe and Heisenberg have shown that isobares of this class may be accounted for on the neutrino hypothesis for a neutrino mass $m_n > 0$. Germanium, cadmium, indium, tin, tellurium, mercury, lead, and bismuth have been analyzed with a linear scale mass spectrograph which combines high sensitivity, resolving power, and dispersion. Spectra of singly and doubly ionized isotopes from hydrogen free sources give definite proof of the existence of three isobaric pairs, Cd^{113} In^{113}, In^{115} Sn^{115}, and Sb^{123} Te^{123}, which apparently are stable. Both members of each of these pairs could be stable for $m_n > 0$. Alternatively the members of higher atomic number could change by K-electron capture with or without benefit of a neutrino, these transmutations being beyond the possibility of detection by the experimental tests applied to these elements. β-instability is manifest for all other definitely attested cases of adjacent isobares with the exception of the proton-neutron, H^3He^3 pairs. The isotopes Cd^{115}, Sn^{121}, Hg^{197}, and Pb^{209}, which are members of isobaric pairs, cannot be present to greater than 1/8, 1/60, 1/2, 1/10, respectively, of the abundance claimed.

39. The Spectrum of Th IV.* R. J. LANG, *University of Alberta, Edmonton.*—The spectrum of thorium has been photographed from 3000A to 350A with the vacuum spark and the spark in air and in nitrogen as sources. The following multiplets have been located for the trebly-ionized atom: $7S-7P$, $6D-7P$, $7P-7D$, $7P-8S$, $7P-8D$, $7P-9S$, $6D-5F$, $5F-8D$, $5F-5G$.

* To be read by title.

40. Fine Structure of α-Lines of Hydrogen and Deuterium. R. C. WILLIAMS AND R. C. GIBBS, *Cornell University.*—A further detailed study of the fine structure of the $H\alpha$- and $D\alpha$-lines has been made by using a discharge in hydrogen gas and in deuterium gas each of extremely high purity, the latter having been kindly furnished by Professor H. C. Urey. At least four photographs of the interference fringe pattern, obtained from the discharge in each of the gases at three substantially different pressures and at two different densities of the discharge current for each of these pressures, were made. While the measured peak to peak "doublet" interval, at least six values of which could be obtained from each plate, varied with the discharge conditions, remarkably uniform values for this interval were obtained from the plates taken under any given discharge condition. However, the diverse interval values obtained under different discharge conditions yielded practically the same interval between any two of the resolved components when suitable account was taken in each case of the shift in peak position due to overlapping components. The average interval between the two major components was found to be nearly the same for both hydrogen and deuterium but about 0.01 cm^{-1} less than that predicted by theory. In the case of deuterium the minor component nearest to the high frequency major component was clearly resolved from the latter. However, the interval between these components was found to be 0.134 cm^{-1} in contrast with that of 0.108 cm^{-1} obtained from theory. An equally large separation of these components was found to be consistent with the analysis of the intensity complex obtained for $H\alpha$. This large deviation from theory may possibly be due to a Stark effect produced by ionic electric fields in the discharge.

41. The e/m Ratio as Determined from the Interval Between Corresponding Components of $H\alpha$- and $D\alpha$-Lines. R. C. GIBBS AND R. C. WILLIAMS, *Cornell University.*—By using a mixture of hydrogen and deuterium such as to yield spectral lines of equal intensity from the two gases, and an interferometer spacing of such a size as to bring the interference fringes from one gas about half-way between those from the other gas and at the same time prevent overlapping of neighboring fringes, the ratio of e/m has been redetermined from intervals between corresponding components of the $H\alpha$- and $D\alpha$-lines. Several measurements of such intervals were obtained from each of five plates. After suitably correcting for shifts due to overlapping components and reducing the interval to vacuum conditions an average value of $\Delta\nu_{H-D} = 4.1470 \pm 0.0004$ cm^{-1} was obtained for the interval between the $2p\,^2P_{3/2} - 3d\,^2D_{5/2}$ components. Upon combining the above interval value with certain atomic data, in a manner heretofore reported, wherein the atomic weights of the proton and deuteron as recently determined by Bethe from disintegration data were used and the value of the Faraday was adjusted to conform with Aston's scale of atomic weights such that $O^{16} = 16$, the specific charge of the electron was determined as $e/m = 1.7577 \pm 0.0004 \times 10^7$ e.m.u./gram and its atomic weight as $5.4908 \pm 0.0005 \times 10^{-4}$.

42. The Paschen-Back Effect. III. $^2S^2P$ Multiplets in Strong Fields. J. B. GREEN AND R. A. LORING, *Ohio State University and the University of Louisville.*—The Paschen-Back effect of $^2S^2P$ multiplets has been discussed and the theory verified in detail. In particular, the $^2S^2P$ multiplet of Li, λ6708, has been resolved in reversal and shows the fine structure predicted but not heretofore observed.

43. The Paschen-Back Effect. IV. Mutual Spin-Orbit Interaction in Two-Electron Spectra. R. A. LORING AND J. B. GREEN, *University of Louisville and Ohio State University.*—The effect of a strong magnetic field on the Be triplet λλ3321, $^3P^3S$ has been studied. The experimental patterns have been compared with calculations which take account of the interaction between the spin of one electron and the orbit of the other. The experimental results are in excellent agreement with the theory, but in some disagreement with Back's work on this group of lines.

44. Forgotten Terms in the Isotope Effect in Molecular Spectra. J. H. VAN VLECK, *Harvard University.*—If molecular energy levels are represented by an empirical formula $W=W_0+h\omega(v+\frac{1}{2})+BJ(J+1)+\cdots$, the observed ratios $\rho_v=\omega_1/\omega_2$ and $\rho_r=B_1^{\frac{1}{2}}/B_2^{\frac{1}{2}}$ usually do not quite equal the square root of the ratio μ_2/μ_1 of the reduced masses for the two isotopes. Strict equality is characteristic only of the ideal rotator-vibrator of infinitesimal amplitude, and correction formulas due to various causes have been given by Dunham and Crawford, Kronig, and Mulliken. Even when their results are combined, we find that many correction terms of magnitude comparable with theirs have been omitted, some being of the order $B^2/h^2\omega^2$, others of the order $B/h\nu$ relative to unity, where ν is a typical electronic frequency. When all terms are included, there are so many constants that exact theoretical computation of ρ_v and ρ_r would be very difficult. ρ_v and ρ_r should not be exactly equal, and, at least for the ground state, should ordinarily both be slightly nearer unity than is the ideal value $(\mu_2/\mu_1)^{\frac{1}{2}}$. New terms are also found in the isotope shift in the constant term W_0.

45. Excitation of Sodium Hyperfine Structure in a Molecular Beam. BENJAMIN CARPENTER AND RUSSELL A. FISHER, *Northwestern University.*—A spectroscopic source suitable for hyperfine structure investigations has been constructed employing a molecular beam excited by high frequency oscillations in argon, the argon being at such a pressure that the beam is not destroyed by scattering. When sodium is excited in the apparatus the Doppler broadening is reduced such that the half-intensity breadths of the components of the D lines are less than 0.011 cm^{-1}. A consideration of the Doppler broadening in such an apparatus indicates that the half-intensity breadth to be expected if the exciting encounters are entirely with electrons is about half that observed, while if the encounters are with argon atoms or ions the broadening should be three times the observed value. Observations upon the hyperfine structure of the D lines by means of a Fabry-Perot interferometer with spacers of 48 mm and 110 mm yielded no structure in addition to that already observed by others. Our observed separation of the two components of D_1 is 0.062 cm^{-1} and of D_2 is 0.057 cm^{-1}. Accepting the value of $I=3/2$ for sodium and the theoretical ratio of 5 : 1 for the splitting factors of the states $3p\,^2P_{\frac{3}{2}}$ and $3p\,^2P_{1\frac{1}{2}}$ we obtain by graphical analysis that the splitting factor for the state $3s\,^2S$ is 0.030 cm^{-1} and for $3p\,^2P_{\frac{1}{2}}$ is 0.004 cm^{-1}.

46. Quenching and Depolarizing Collisions and Polarization of Resonance Radiation in a Magnetic Field. RAYMOND PETERSEN* AND A. ELLETT, *State University of Iowa.*—On assuming that excited atoms may leave the initial excited state (1) by radiation, (2) by a collision of the second kind, (3) by a depolarizing collision (i.e., a collision which merely destroys coherence), we may write for exciting light polarized along x, observation along z in a magnetic field parallel to z, in the absence of hyperfine structure,

$$\frac{I_x-I_y}{I_x+I_y}\equiv R=R_0\left\{[1+4(\omega\tau^*)^2]\left[1+\frac{(3-R_0)\alpha' p\tau}{3(1+\alpha p\tau)}\right]\right\}^{-1},$$

where α, α' are quenching and depolarizing efficiencies and $1/\tau^*=1/\tau+(\alpha+\alpha')p$. The extension to include hyperfine structure is obvious. A corresponding expression for the rotation of the plane of maximum intensity is also readily obtained. Observed and computed values of R for the mercury λ2537A line in the presence of hydrogen and for the angle of rotation of the plane of maximum intensity are in satisfactory agreement using $\alpha=1.39\times10^7$, $\alpha'=1.81\times10^7$ collisions per excited atom per sec. per mm Hg hydrogen pressure.

* Deceased July 25, 1935.

47. Design of an Ionization Gauge for Atomic Beam Measurements. R. D. HUNTOON AND A. ELLETT, *State University of Iowa.*—Use of two types of current measuring devices, galvanometer and vacuum tube amplifier, with an ionization gauge shows that the stable sensitivity,

$$\left(\frac{\text{positive ion current/mm gas pressure}}{\text{current fluctuation}}\right),$$

is greater for low electron emission densities thus favoring the use of the amplifier with its greater current sensitivity. Such factors as electrode size, relative potentials, electron emission, interelectrode leakage, type of inlet, gas adsorption, surface charges, temperature changes, B.K. oscillations, and variations of pumping speed which influence the design of a gauge are discussed and an arrangement to fulfill the necessary requirements is described. Performance tests show the gauge to be capable of measuring beam pressure changes at least as small as 3×10^{-11} mm of mercury or approximately 3×10^9 mercury atoms per square centimeter per second.

48. Intensity of Scattering of Electrons as a Function of Angle. H. J. YEARIAN AND J. D. HOWE, *Purdue University.*—Recent experiments on the scattering power (atom form factor) of Au and Ag for high velocity electrons[1] have shown that the scattering power deviates from that

given by the usual Born approximation when the electron energy is comparable with, or lower than the K excitation potential of the scattering atom. Since the diffraction from these cubic substances gave a small number of points on the scattering curves, the experiments have been continued using hexagonal Cd as a scatterer. The curves obtained from Cd (48) are similar to those from Ag (47) but the larger number of experimental points in the case of Cd show a greater and more complex deviation from the simple theory than do the experiments with Ag.

[1] H. J. Yearian and J. D. Howe, Phys. Rev. **48**, 381 (1935).

49. X-Ray Scattering in Molten Salts. I. K. LARK-HOROVITZ AND E. P. MILLER, *Purdue University.*—Diffraction patterns from molten salts have been obtained with monochromatic silver $K\alpha$ radiation. The liquid salt films of about 0.5 mm thickness are held in a hot platinum wire loop at a temperature close to the melting point. LiCl, LiBr, NaCl and KCl have been investigated so far: The diffraction patterns of LiCl, LiBr are sharper than the patterns usually observed in liquids. NaCl yields a diffuse diffraction pattern as contrasted with KCl, the pattern of which is much sharper. This can be understood by taking into account the influence of the different diameter and scattering power of the ions. The diffraction pattern of KCl has been analyzed under the assumption that the scattering power of K and Cl is approximately the same: *In the neighborhood of any scattering center there is a concentration of ions in a distance of about 3.3A and again at about 4.3A;* in the KCl crystal any atom has 6 equivalent neighbors in a distance of 3.14A and 12 equivalent neighbors in a distance of 4.44A.

50. Further Comparison by X-Ray Diffraction of Para-azoxyanisol in Liquid Crystalline and Liquid Phases. G. W. STEWART, *State University of Iowa.*—Additional experiments have emphasized the almost insuperable difficulties in securing a diffraction intensity distribution without introducing an error caused by convection. The conclusions are (a) that the structure of the liquid crystalline phase is the more orderly, (b) that the two structures are probably similar, differing also in stability, (c) that the liquid crystalline phase may be regarded as produced by aggregations of cybotactic liquid "groups" plus the above indicated changes, and (d) that a temperature gradient in the liquid crystal phase produces an effect equivalent to the preferential orientation of the swarms perpendicular to the direction of the heat flow.

51. Pseudo-Cubic Lattices and the Principle of " Variate Atom Equipoints." F. C. BLAKE, *Ohio State University.*—Pseudo-cubic lattices perhaps could be said to be of two sorts, those having angles slightly different from right angles and those having right angles in the tetragonal system but not completely equivalent to the cubic lattices. By an intensive study of both simple tetragonal and body-centered tetragonal lattices at the axial ratio $\sqrt{2}$ the parameter flexibility is greatly increased and it is in all probability possible to explain all of the intensity variations in the "spinels" without invoking the aid of the principle of "variate atom equipoints." An illustration is zinc stannate, kindly supplied by the staff of the Geophysical Laboratory at the Carnegie Institution. It can be definitely assigned to space group C_{4v}^{11}. This naturally raises the question for the need of this principle, at least in the "spinel" problem.

52. Theory of the Effect of Temperature on the Reflection of X-Rays by Crystals. I. Isotropic Crystals. G. E. M. JAUNCEY AND C. ZENER, *Washington University.*—The Debye-Waller temperature factor e^{-M} in $F=fe^{-M}$ is simply and briefly derived as follows: For a vibrating string the mean square displacement μ_r due to the rth vibrational mode of frequency ν_r is related to the energy W_r in this mode by $\mu_r=W_r/4\pi^2\nu_r^2m$, where m is the mass of the string. For a solid we have a similar formula but now μ_r is in any direction. In the z direction the relation for the mean square displacement is $\overline{z_r^2}=W_r/12\pi^2\nu_r^2m$, where m is the mass of the solid. In Debye's specific heat theory the thermal agitations are the result of adding many vibrational modes up to a limiting frequency ν_m. Since the phase relations between these modes are random the resultant $\overline{z^2}=\Sigma\overline{z_r^2}$. The number of modes in the range $d\nu$ is $dr=9n\nu_r^2d\nu/\nu_m^3$, where n is the number of atoms in the solid. Also in specific heat theory $W_r=h\nu_r/(e^{h\nu_r/kT}-1)+h\nu_r/2$. We now integrate and obtain $\overline{z^2}$. It is known that the Debye-Waller $M=8\pi^2\overline{z^2}(\sin^2\theta)/\lambda^2$. Putting in the value of $\overline{z^2}$ just found, we obtain Waller's formula for M.

53. Theory of the Effect of Temperature on the Reflection of X-Rays by Crystals. II. Anisotropic Crystals. C. ZENER, *Washington University.*—The method discussed in the previous paper is extended to include the general case of anisotropic solids. Since M is a quadratic function of the direction cosines of the normal to the reflection plane, M is completely determined by measurements from three mutually orthogonal reflection planes. For crystals with three-, four-, or sixfold axes of symmetry, M will be a function only of the angle Θ between the principal axis and the normal to the reflection plane. The function M has been determined for two metals with a sixfold axis of symmetry, Zn and Cd. The results are

$$M_{Zn}=1.1\times10^{-3}\{1.80\cos^2\Theta+\sin^2\Theta\}T\sin^2\theta/\lambda^2,$$
$$M_{Cd}=1.6\times10^{-3}\{1.73\cos^2\Theta+\sin^2\Theta\}T\sin^2\theta/\lambda^2.$$

The calculation is complicated by two factors. Firstly, for each direction of propagation there are three different wave velocities associated with a linearly polarized plane wave. Secondly, the vibration associated with each velocity is not either parallel or normal to the direction of propagation, corresponding to the longitudinal and transverse waves of isotropic solids, but forms an oblique angle with this direction.

54. Dependence of Diffuse Scattering of X-Rays from Quartz Upon the Angle Between the Crystal Axis and the Plane of Scattering. W. A. BRUCE AND G. E. M. JAUNCEY, *Washington University.*—According to Woo and Jauncey's theory the coherent part of the x-rays diffusely scattered from a crystal is proportional to $(1-e^{-2M})$, where M is the Debye-Waller temperature factor. For quartz, Young's modulus is 10.1 and 7.7×10^{11} dynes/cm^2 for directions

respectively parallel and perpendicular to the axis of the crystal. According to the previous paper by Zener this difference in the moduli should give different values of M for elastic vibrations parallel and perpendicular to the axis—in other words, different characteristic temperatures should be associated with the different directions. Rough calculations give 550 and 485°K, respectively. X-rays of average wave-length 0.5A were scattered from an X cut plate of quartz at 20° scattering angle for various settings of the axis relative to the plane of scattering. We assured ourselves of the absence of Laue spots by subjecting the crystal to piezoelectric oscillations which Jauncey and Deming have shown do not affect the diffuse scattering. Theory indicated a change of about 9 percent from axis perpendicular to axis parallel to the scattering plane. This order of change was found.

55. Properties of Prins' Formula for the Diffraction of X-Rays by a Perfect Crystal. ROY C. SPENCER, *University of Nebraska.*—Prins' formula for the intensity I may be reduced to the following forms. $I^{\frac{1}{2}}=r=|z-(z^2-1)^{\frac{1}{2}}|=a-(a^2-1)^{\frac{1}{2}}=(b^2+1)^{\frac{1}{2}}-b=a-b$ where z is the complex variable $(x-i\alpha)/(m+in)$, $m^2+n^2=1$, α and n depend on the absorption coefficients, and a and b are the semi-major and minor axes of the confocal ellipse which cuts the point x. (Its foci are at $x=\pm m$, $y=\alpha\pm n$.) *Graph.* Measure the average distance from the point x to the two foci. This is a. Substitute in $I=(a-(a^2-1)^{\frac{1}{2}})^2$ which is Darwin's formula for the case of no absorption. *Integration.* Change the variable from r to $b=(r^{-1}-r)/2$. Then

$$x=[-mn\alpha\pm b(b^2+1)^{\frac{1}{2}}(b^2+n^2-\alpha^2)^{\frac{1}{2}}]\div(b^2+n^2)$$

which enables the area, center of gravity and percent reflection to be obtained by elliptic integrals or approximated by simple expressions. *Effect on x-ray lines:* The effect of the crystal curve on the asymmetry of the x-ray line curve is discussed. Its effect in broadening the x-ray line curve was discussed by the author at the Minneapolis meeting.

56. Effect of Angle of Incidence Upon Relative Intensities of X-Ray Lines from Ruled Gratings. ELMER DERSHEM, *University of Chicago.*—Those who have worked with ruled gratings in the soft x-ray region know that the intensity of spectral lines varies with the glancing angle of incidence but the magnitude of the effects which may be caused by small changes of angle is perhaps not generally appreciated. For example using the inside order from a glass grating having 600 lines per mm the ratio of intensity of the $L\alpha_{1,2}$ to the L1 line of nickel changed from 3 : 1 at a glancing angle of 3° 0′ to a ratio of 1 : 3 at 3° 5′. The corresponding change in this ratio for the first outside order was about 50 percent. Spectrograms and photometer measures over the range of possible angles using the L spectra of iron and copper taken with three different gratings show similar results. In general the relative intensities of the longer wave-lengths are greater at the larger angles. These results show that the intensity of any particular line may be greatly enhanced by a proper choice of the angle of incidence thus permitting a better study of any property pertaining to that wave-length. Any measures of the relative intensities of lines from a ruled grating must, however, be interpreted with caution.

57. Relative Intensities of $K\alpha$ X-Ray Satellite Lines. LYMAN G. PARRATT, National Research Fellow, AND F. K. RICHTMYER, *Cornell University.*—With a two-crystal vacuum spectrometer the intensities of the $K\alpha$ satellite lines relative to the intensities of the $K\alpha_1$ diagram lines have been measured for elements S(16) to Ge(32). The satellite structure in the region of $K\alpha_{3,4}$ includes α', α_3, α_3', α_3'' (a new component) and α_4. For elements S(16) to Ti(22) an additional line is observed very close to $K\alpha_1$. The relative intensities of each of these satellites have also been measured. The ratios of the energy of the $K\alpha_{3,4}$ group (which does not include the satellite close to the α_1 line) to the energy of the $K\alpha_1$ line for the respective elements are (not corrected for the finite resolving power of the spectrometer)

Z	$(I_s/I\alpha_1)\times100$	Z	$(I_s/I\alpha_1)\times100$	Z	$(I_s/I\alpha_1)\times100$
16	6.90	23	1.75	27	0.73
19	3.71	24	1.34	28	0.61
20	3.20	25	1.08	29	0.53
21	2.65	26	0.89	30	0.41
22	2.10			32	0.28

The measurements are in qualitative agreement with the theoretical relative intensities as calculated (recent unpublished work of R. D. Richtmyer) on the assumption that the initial atomic state for satellite emission is one of KL ionization.

58. Variation of the Atomic Structure Factor of Potassium with Wave-Length in the Region of the Potassium K Absorption Limit. WILLIAM P. JESSE AND SAMUEL K. ALLISON, *University of Chicago.*—A vacuum ionization spectrometer has been constructed in which an externally controlled, motor driven slide brings either a briquet of powdered NaF or powdered KF over the axis of rotation and into the path of the x-ray beam. Comparisons of the diffracted intensities from NaF and KF have been made with an ionization chamber Pliotron circuit. A range of wave-lengths from 1.54A (Cu $K\alpha$) to 3.93A (Ag $L\beta_1$) has been used. In this range Sb $L\alpha_1$ (3.4318A) has been used as one of the wave-lengths. The wave-length of the potassium K absorption limit is given as 3.4277A. The potassium structure factors were computed, based on those of NaF, which were assumed invariant in this wave-length range. On the short wave-length side of the K limit, the expected decrease in the atom factor was observed, and the experiments show a remarkable agreement with Hönl's theory. The predicted invariance of the structure factor decrement with $(\sin\theta)/\lambda$ was experimentally confirmed. On the long wave-length side of the limit the structure factor rises with increasing wave-length but results higher than Hönl's theoretical values are always obtained. This agrees with results of Lameris and Prins on dispersion in nickel. A search for any systematic errors which may enter on the long wave-length side is being made.

59. Experiments on the Efficiencies of Production, and the Half-Lives, of Radio-Carbon and Radio-Nitrogen. SAMUEL K. ALLISON, *University of Chicago*, Fellow of the Guggenheim Foundation at Cambridge, England.—The experiments of Cockcroft, Gilbert, and Walton on artificial radioactivity produced by bombardment of boron and carbon with protons and deuterons have been continued. Targets of B_2O_3 which had been bombarded with deuterons at 520 kv were ignited in oxygen and the half-life of the resultant radio-carbon dioxide measured. This gave a reliable half-life of 21 ± 0.6 minutes, whereas previous measurements on the half-life of the solid target had given variable values from 18 to 25 minutes, due to various complicating factors. No evidence could be obtained for the production of radio-carbon from boron by 520 kv protons. Radio-nitrogen was prepared by bombardment of carbon by 520 kv protons and by 520 kv deuterons. Its period was found to be 10.3 ± 0.3 seconds. The efficiency of production of radio-nitrogen by protons of this energy was found to be 1 atom of radio-nitrogen for 1×10^{10} protons. The efficiency of production by deuterons of this same energy was one in 2.3×10^{8}. The bombarding beam had been magnetically analyzed, and the gas mixture used in the deuterium experiments was composed of deuterium (from 98 percent heavy water) and helium. The yields agree well with those given recently by Hafstad and Tuve at the same voltage.

60. Fluorescence of the Chlorophyll Series: Fluorescence and Photodecomposition of Solutions of Chlorophyll *a* under O_2, CO_2 and N_2. H. V. KNORR AND V. M. ALBERS, *Kettering Foundation, Antioch College.*—The fluorescence spectra of chlorophyll *a* in solution in anhydrous acetone, and benzene, under atmospheres of O_2, CO_2 and N_2, have been investigated by the method previously described.[1] The total radiation from Pyrex mercury arcs was used for excitation. In the acetone solutions, maxima on the densitometer curves were observed at 679, 647 mμ under O_2, 677, 646 mμ under CO_2, 679, 648 mμ under N_2. In benzene the corresponding maxima were located at 683, 651 mμ under O_2, 683, 650 mμ under CO_2, 679, 649 mμ under N_2. The appearance of the fluorescence spectra for the acetone solutions during the photodecomposition is quite different from that of the benzene solutions under the same atmospheres. Stable conditions are apparently established in the benzene solutions since the intensity of the fluorescence is quite strong after many hours of exposure to the radiation. The fluorescence in the acetone solutions under N_2 and CO_2 vanished after two hours exposure. The appearance of additional maxima, and variation of the relative intensities of the maxima, indicate that the solvent and atmosphere are some of the determining factors in the photodecomposition of chlorophyll *a*.

[1] H. V. Knorr and V. M. Albers, Phys. Rev. **43**, 379 (1933) (Cold Spring Harbor Symposia on Quantitative Biology, Vol. 3, 1935).

61. Extending the Range and Usefulness of the Zeleny Electroscope by Automatically and Mechanically Counting Rapid Oscillations. R. W. BOYDSTON, *Miami University.*—Several publications call attention to the usefulness of the Zeleny electroscope for demonstrations and other laboratory purposes. Some difficulties are inherent in the operation of this instrument. The leaf repeatedly sticks to the plate, and the current range is limited by the inability of the observer to accurately count rapid oscillations. The author's work shows how both of these drawbacks are overcome. The circuit used is both simple and positive in its action. Currents ranging from 10^{-12} to 10^{-8} ampere may be measured. The counting device is capable of recording leaf oscillations as high as 125 per second. This extends the range of the Zeleny to its maximum current measuring possibility and overlaps the range of an ordinary galvanometer. Data are given on applying this device to investigation of some electrical properties of paper. Attention is called to numerous other applications. The extensions discussed should make the Zeleny electroscope a useful and reliable research instrument. Demonstrations will accompany the paper.

62. A Copper Sulphide Photo-Cell.* JAMES J. BRADY AND W. F. SPRENGNETHER, JR., *Saint Louis University.*—A copper sulphide photovoltaic cell is described in which the amount of sulphur used to form the sulphide is controlled by means of a molecular beam. The sulphide is formed by depositing sulphur atoms on a copper plate heated by electronic bombardment in a high vacuum. A ground-glass joint permits the copper plate to be rotated through 90° in order that it may be brought in contact with a metallic grid through which the light passes to the sulphide surface. A tungsten filament lamp is used as a light source, and the photocurrent is measured with a galvanometer. With no light on the cell and while the plate is still warm, a current flows through the circuit but comes to zero after the plate cools. When the light falls on the surface, the current flows in the opposite direction. The magnitude of the photocurrent is found to be greatly dependent on the gas pressure within the cell. The sensitivity decreases by a factor of about 10 when the pressure is increased from 10^{-5} mm to atmospheric. The sensitivity is completely restored by pumping the cell down to a pressure of 10^{-5} mm.

* To be called for after paper No. 9.

63. Interference of Neutron Waves in Ortho- and Parahydrogen.* EDWARD TELLER, *George Washington University, Washington, D. C.*—The anomalously large cross section observed for the scattering of slow neutrons by protons can be explained according to Wigner by assuming a dependence of the scattering on the relative orientation of the proton and neutron spins. This hypothesis leads to an energy for the singlet state of the deuteron of about $\pm50{,}000$ volts. (The signs refer to a virtual or stable state respectively.) Direct evidence for the influence of the spin could be obtained from observations on the scattering of a homogeneous, monochromatic beam of neutrons in H_2. If no dependence on the spin exists, then one should expect that the scattering of neutrons by the two protons of H_2 should give rise to interference effects in both ortho- and parahydrogen. Assuming, however, that scattering takes place only when the neutron and proton spins have opposite orientations, interference effects would only exist in ortho-hydrogen. Actually the scattering for parallel spins should be small but not negligible. From the way in which

the phases of the neutron waves scattered by the two protons of para-H_2 are superimposed one can decide whether the singlet state of the deuteron is stable or virtual.

* To be called for after paper No. 20.

64. I. The Propagation of a Shock-Wave in Air. L. THOMPSON, *Naval Proving Grounds, Dahlgren, Va.*—From a consideration of conditions at the boundary at the instant of "explosion," and at great distances, a formula of the Riemann type has been derived for the velocity of propagation of the finite-condensation pulse, which fits the data obtained in the experiments of Part II throughout the field of observation. A corresponding formula for reduced times is given which represents in general the wave displacement (in half-diameters from the source), regardless of scale. Introducing the condition that the velocity at the surface of the explosive charge is V_d (the velocity of the detonating wave) the formula is $V=a[1+C(1/(\varphi+x))^2]^{\frac{1}{2}}$, of which C is a function of V_d, φ is a constant, and x is the distance of the source measured in units of "equivalent" diameter; the normal velocity of sound is a. The reduced times are defined by $\mathbf{K}a\delta t=[x^2+2\varphi x+(C+\varphi^2)]^{\frac{1}{2}}{}_{x=1}{}^{x_s}$, where $\mathbf{K}=x/s$, s being the distance. The formulas are applicable to sources other than detonating charges.

65. II. The Propagation of a Shock-Wave in Air. L. THOMPSON AND N. RIFFOLT, *Naval Proving Ground, Dahlgren, Va.*—Charges of granular T.N.T. were detonated, obtaining times of transit of the pulse with oscillograph elements connected at six points to piezoelectric screens, as well as zero time by rupture of a wire around the charge. With the expression for reduced times given in Part I, these observations determine the constant φ of the general formula for velocity.

66. An Anomalous Conductivity in Powdered Tellurium. C. HAWLEY CARTWRIGHT, *University of Michigan.*—It was found that tellurium powder under 1000 kg/cm² pressure has ten times greater specific electrical conductivity than a single crystal of tellurium. The influence of the electrodes, particle size, surface condition and the medium surrounding the particles were investigated. Momentarily passing an electric current through the powder under pressure caused its volume to diminish; but, also the electrical conductivity decreased to that of the massive metal. A hydrostatic pressure of 20,000 kg/cm² increases the electrical conductivity of massive tellurium about a hundred times and the rate of increase rises with pressure. However, the suggestion that local pressures exist that are greatly in excess of the average pressure does not account entirely for the observed magnitude of the anomalous conductivity. It seems necessary to assume (1) the conductivity of tellurium increases even much more for nonuniform pressures than for hydrostatic pressures or (2) very sharp points occur between particles which produce strong enough electric fields to liberate conduction electrons. This anomalous effect is very small in absolute magnitude and would be masked in conducting metals.

67. Quasi-Crystalline Structure of Water from Infrared Data. C. HAWLEY CARTWRIGHT, *University of Michigan.*—Considerable evidence of a quasi-crystalline structure in liquids is obtained by considering the specific heat, dielectric constant, x-ray spectra, Raman spectra and viscosity. The transmission and reflection measurements of liquid water in the infrared from 15μ to 150μ show characteristics which are unlike the vapor spectra of free rotation and can be interpreted as due to a hindered rotation and hindered translation of the molecules as a whole in a quasi-crystalline structure. From the characteristic reflection and absorption frequencies (which are naturally broad), the intermolecular binding energies of the water molecules are calculated.

68. A High Dispersion Linear Scale Mass Spectrograph with Velocity and Direction Focusing. KENNETH T. BAINBRIDGE AND EDWARD B. JORDAN, National Research Fellow, *Harvard University.*—The simultaneous fulfillment of the conditions for high resolving power, high sensitivity and high dispersion has been obtained in an instrument for the investigation of isotopes. An important feature of the design is the linearity of the mass scale over a broad region of the recording plate. The ions diverging from the second slit S_2 are deflected through $\pi/\sqrt{2}$ radians by using the radial field method of electrostatic focusing introduced by Hughes and Rojansky which produces an energy spectrum in front of the third slit S_3. Beams of ions of all m/e values comprising up to 3 percent of this energy spectrum, traversing S_3, are further deflected through a mean angle of $\pi/3$ radians by a magnetic field which focuses the ions and produces a mass spectrum on the recording plate. The mean dispersion is 5 mm for one percent mass difference, the mean radius is 25.4 cm, and a resolving power of 12,000 has been attained. Over 140 mm on the plate the maximum divergences from linearity are $\pm 1/7000$. Sample spectra will be shown of $O-CH_4$, NH_3-OH, $H_2{}^1-D^2$, and other doublets.

69. The Cooling of a Surface Due to Photoelectric Emission. HUGHES M. ZENOR, *Rice Institute, Housion, Texas.*—The energy loss due to photoelectric emission from a platinum surface activated with a thin layer of caesium has been measured. Two similar photoelectric cells were illuminated with the same source of light. Each cell contained a small platinum plate coated with caesium, the temperature of which was measured with a Fe–Ni thermocouple. The thermocouple junctions of the two cells were connected in series with a galvanometer in such a manner that the e.m.f.'s of the two cells opposed each other. In this way it was possible to determine with the galvanometer the change in temperature when the photoelectric current was allowed to flow or was stopped in one of the cells. The photoelectric current was controlled by the potential of the anode. The value found for the energy loss per electron is consistent with present photoelectric theories.

70. The Sign of the Magnetic Moment of the Proton. I. I. RABI, J. M. B. KELLOGG, J. R. ZACHARIAS, *Columbia University.*—Because of the large value found for the magnetic moment of the proton, theory has not sufficed to predict the sign. We have made this measurement by a method of nonadiabatic transitions. A beam of neutral hydrogen atoms is first deflected in a weak inhomogeneous

magnetic field and then in a strong inhomogeneous field arranged to deflect in the opposite direction. The whole arrangement forms a "magnetic moment spectrograph." In a magnetically shielded region between the two fields is placed a set of wires carrying current, which produce weak, rapidly varying magnetic fields to induce non-adiabatic transitions between the different magnetic levels and a slit to sort out the different levels. On examining the moments from the two $m=0$ levels it was found that the state which has the negative over-all moment made the transitions. The state with positive over-all moment did not. The state with positive over-all moment is therefore the $F=0$ state. The h.f.s. multiplet is normal. The proton moment is therefore positive, i.e., it has the spin direction.

71. The Scattering of Electrons after Ionizing Collisions in Helium. MAX GOODRICH, *University of Minnesota.* An electron scattering apparatus has been used to determine, in helium, the angular distribution [for 100-volt incident electrons] of electrons scattered with various energy losses equal to or greater than the ionization loss. The curves show that, in general, the greater the energy loss the more uniform is the distribution in angle of the scattered electrons. There is a pronounced preference for forward scattering when the energy loss over that required for ionization is small. Integration over the entire solid angle gives the probability for scattering with different energy losses. Curves so obtained for this probability as a function of energy loss are in qualitative agreement with Wetzel's theoretical calculations except for electrons which have lost nearly all their energy or just slightly more than the ionization energy.

72. A Continuously Sensitive Cloud Chamber. ALEXANDER LANGSDORF, JR., *Massachusetts Institute of Technology.*—This is a preliminary note on the development of a continuously sensitive cloud chamber designed to overcome certain difficulties inherent in the familiar Wilson expansion chamber. Initial tests made with the new device have utilized the diffusion of methyl alcohol vapor vertically downward through an atmosphere of carbon dioxide gas. The alcohol vapor at 75 degrees centigrade and at atmospheric pressure is supplied to the top of the chamber from a steam heated boiler and diffuses vertically downward from the top to the bottom of the chamber, where a temperature of -45 degrees centigrade is maintained by a refrigerated plate. Under these conditions there is an intermediate region sufficiently supersaturated to show characteristic tracks due to cosmic-ray primaries and secondaries, as well as those due to secondary electrons from gamma-radiation. No difficulties due to turbulence have been encountered, and various types of tracks ranging in length from a fraction of an inch to nearly two feet have been observed in profusion. The number of cosmic-ray tracks visible in the course of a few minutes is comparable to the number photographed in several thousand exposures with the expansion method. Satisfactory photographs of the tracks have thus far not been obtained because of a continuous rain of condensed droplets which interferes with photography, though it does not obscure visibility of the tracks to the eye. Work is now in progress having for its object the elimination of the rain and the obtaining of satisfactory photographs.

73. Formula for Asymmetrical X-Ray Lines. ROY C. SPENCER, *University of Nebraska.*—Asymmetrical x-ray lines appear to have the form of $x=\pm(1/y-1)^{\frac{1}{2}}+sy$. The first term is merely the equation of the witch $y=1/(1+x^2)$ introduced by Hoyt. The second is the equation of the median line and has the effect of a shear of magnitude s along the x axis. The solution for y is a series, $y=1/(1+x^2)+sx/(1+x^2)^3-s/(1+x^2)^4$. The tangents at the half-maximum points intersect at the peak as does also the median line. *Criteria of Asymmetry.* (1) The author first used the ratio of the tangents at the half-maximum points. This is $R_1=-(2+s)/(2-s)$. (2) Allison uses the ratio of the half-widths at half-maximum. This is $R_2=-(2+s)/(2-s)$. (3) The shift in the peak, or the reciprocal slope s of the median line may be substituted in $R_3=-(2+s)/(2-s)$. Theoretically $R_1=R_2=R_3$, and all three criteria agree. *Application.* The equation is applied to an x-ray line ($s=0.2$) and to an absorption line in light ($s=0.8$) with good fit except at the extremities of the curve.

74. The Observation of Negative Hydrogen Ions. PAUL F. DARBY AND WILLARD H. BENNETT, *Ohio State University.*—Negative ions with mass approximately the same as that of the hydrogen atoms were drawn from a low voltage arc in water vapor. The ions passed through a hole in the anode of the discharge and were focused by a system of cylindrical electrodes on a willemite screen. The electrons were deflected out of the beam by a transverse magnetic field leaving the beam of negative ions but slightly displaced. A Faraday cage measured the current in the focused ion spot to be 1×10^{-8} ampere. Constricting the anode area, and using an oxide-coated filament as a cathode, was effective in raising the current to 8×10^{-8} ampere. The electron lens of cylindrical electrodes brings ions having all values of e/m to a focus at the same point. These beams will be used in a single section tube for nuclear disintegration work.

75. Debye-Waller Temperature Factor for Anisotropic Crystals. E. O. WOLLAN, *Washington University.*—In another paper to be presented at this meeting, C. Zener has extended to the case of anisotropic crystals the Debye-Waller theory for the effect of temperature on x-ray reflection. This extension predicts that the intensity of reflection will be a function of the angle which the reflecting plane makes with the principal axis. Recent measurements[1] of the structure factors for metallic zinc make it possible to compare the theory with experiment. The measured structure factors for two angles of reflection are considerably displaced from a smooth curve. However, when the anisotropic character of the zinc crystal is considered on the basis of the extended theory, it is found that the apparently anomalous reflecting power is in accord with the predictions of the theory.

[1] G. W. Brindley and F. W. Spiers, Phil. Mag. **20**, 865 (1935).