Proceedings of the American Physical Society

Minutes of the Chicago, Illinois, Meeting, December 1–2, 1939

THE 230th regular meeting of the American Physical Society was held at Chicago, Illinois, on Friday and Saturday, December 1 and 2, 1939, at the University of Chicago. The presiding officers were Professors Arthur H. Compton, Carl H. Eckart, W. D. Harkins and Ralph A. Sawyer. The attendance at the meeting was about three hundred.

On Friday evening the Society held a joint dinner with the Chicago Physics Club at the Windermere Hotel. Dean George B. Pegram presided at the dinner. After the dinner a demonstration lecture was given in the Lecture Room of the Museum of Science and Industry by Dr. Frederick S. Goucher of the Bell Telephone Laboratories on "Microphonic Action and Contact Phenomena."

Meeting of the Council. At the meeting of the Council held on Friday, December 1, 1939 the deaths of four fellows (Arthur E. Kennelly, Charles F. Lorenz, J. B. Nathanson and F. K. Richtmyer) and of six members (Arthur F. Dittmer, A. A. Dixon, Hampton D. Ewing, E. E. Free, Samuel V. Hoffman and Harold Mestre) were reported. Two candidates were transferred from membership to fellowship and one hundred and one candidates were elected to membership. *Transferred from membership to fellowship:* Stanley N. Van Voorhis and Viktor F. Weisskopf. *Elected to membership:* Ernest J. Abbott, Royal P. Allaire, Charles L. Andrews, Robert M. Ashby, James F. Bacon, George J. Baldwin, William Band, A. E. Benfield, Edward P. Bentley, Phillip R. Beutel, Herman R. Branson, Charles J. Burton, D. M. Chapin, Frances L. Christison, George C. Claridge, Robert K. Clark, Eric T. Clarke, Francis L. Code, Kenneth S. Cook, Herbert C. Corben, Gilbert H. Curl, Louis J. Cutrona, Max Dresden, Beulah P. Field, A. Theodore Finkelstein, Verne Frese, Max Garbuny, Eugene Gardner, Paul F. Gast, Sanford C. Gladden, Harold C. Glahe, Moses A. Greenfield, Richard O. Grisdale, Bruce L. Hicks, Mary W. Hodge, J. Vance Holdam, Haig Iskenderian, Donald H. Jacobs, James A. Jacobs, George Jaffé, George A. Jarvis, Robert C. Jones, J. A. Jukes, Brother Gabriel Kane, G. A. Kelsall, Arthur E. Kenney, Harold J. Kersten, George S. Klaiber, Alexander Kolin, Masao Kotani, Gustav Kuerti, James A. LeConte, Jr., Sidney Lees, Franklin A. Long, A. C. B. Lovell, Johann F. Ludloff, Malcolm R. MacPhail, Henry P. Manning, Jr., F. Albert Matsen, H. N. Maxwell, Nicholas Metropolis, Max Morand, Edward B. Nelson, Itaru Nonaka, Kiichiro Ochiai, Russell D. O'Neal, Floyd W. Parker, S. L. Parsons, William T. Payne, Alexander A. Petrauskas, Robert D. Rawcliffe, Nelson F. Riordan, Bruno Rossi, W. Rowles, Sister M. Roswitha Schauls, William T. Scott, William C. Sears, Frederick G. P. Seidl, Thomas M. Shaw, Hsi-yin Sheng, John N. Shive, G. J. Sizoo, Harold L. Stout, Eiiti Takeda, Mitsuo Taketani, Hidehiko Tamaki, Hubert M. Thaxton, George J. Thiessen, E. Ward Tillotson, Fred M. Uber, M. P. Vore, Eric A. Walker, Paul Weisz, H. L. Welsh, Robert W. Woods, John E. White, Wilfred C. White, J. O. Wilhelm, Evan J. Williams, John D. Williams, and Garnet A. Woonton.

The regular scientific program of the Society consisted of thirty-eight contributed papers of which one, number 7, was read by title. The abstracts of these papers are given in the following pages. An *Author Index* will be found at the end.

HAROLD W. WEBB
Acting Secretary

Abstracts of Contributed Papers

1. A New General Effect in the Diffraction of X-Rays by Crystals. W. H. Zachariasen, *University of Chicago.*—The writer has made a simplified derivation of the intensity expression for the coherent scattering of x-rays by a small crystal. The usual intensity formula for the "diffuse" scattering is to be replaced by a more complicated expression which predicts diffraction maxima in the directions u given by: $(1+\tau_0)u=u_0+\lambda B_H$, where u_0 is the direction of the incident beam and B_H a vector of the reciprocal lattice. The intensity for a direction near such a maximum is:

$$I_{(\epsilon)}=Sf^2e^{-2M}4\sin^2\theta\frac{kT}{Vmc^2}\frac{2\pi L^2}{\lambda^2+2\pi L^2(\tau_0^2+\epsilon^2)}\delta V.$$

S is the Thomson scattering for a single electron, fe^{-M} is the atomic scattering power, k the Boltzmann constant, T the temperature, V the volume of the unit cell, m the atomic mass, $\overline{c^2}$ the average square of the elastic wave velocities, L and δV the average linear dimension and the volume of the crystal. The half-width of the diffraction maximum is in radians $(\lambda^2+2\pi L^2\tau_0^2)^{\frac{1}{2}}/(2\pi)^{\frac{1}{2}}L$, thus giving very sharp peaks when τ_0 is small. The average value of the intensity over a large solid angle leads to the Debye expression for the "diffuse" scattering. Earlier work by Faxén[1] and by Waller[2] will be discussed, and it will be shown that the theory explains quantitatively some puzzling observations including the radial streaks of Laue photographs.

[1] Faxén, Zeits. f. Physik **17**, 266 (1923).
[2] Waller, Dissertation, Uppsala (1925).

2. Preliminary Experimental Studies of the New Diffraction Maxima in X-Ray Photographs. S. S. Siegel and W. H. Zachariasen, *University of Chicago.*—An x-ray beam from a copper target tube falls on the cleavage face of a stationary crystal of rocksalt or calcite under a glancing angle of incidence $\theta_B+\Delta$, where θ_B is the Bragg angle for Cu $K\alpha$. Δ is varied by steps of a few minutes of arc over a range of several degrees. Some wave-lengths of the continuous spectrum produce an ordinary Bragg reflection with a scattering angle of $2(\theta_B+\Delta)$. In addition we find a diffraction line with a scattering angle slightly different from $2\theta_B$. This is a diffraction maximum due to Cu $K\alpha$ predicted by the theory presented in the preceding abstract. The position, the peak intensity, the integrated intensity and the width of this spurious line have been studied as functions of Δ. The results agree with the theory.

3. Relations Between Elastic Properties of Solids. H. Ludloff, *Cornell University. (Introduced by H. A. Bethe.)*—From the quantum theory of solids one can derive for $T\lesssim\theta$ the approximate equation of state:

$$p\sim f_1(v)+f_2(T). \tag{1}$$

f_1 corresponds to the lattice forces and f_2 to the radiation pressure of thermal waves. From (1) we obtain the compressibility:

$$\kappa=-\frac{1}{v}\left(\frac{\partial v}{\partial p}\right)_T\sim\kappa(v),\quad\text{so that}\quad\left(\frac{\partial\kappa}{\partial T}\right)_v=0. \tag{2}$$

For a solid whose isotropic contraction ϵ may be produced by either isothermal compression (hydrostatic pressure) or isobaric cooling, we have the relation:

$$\left(\frac{\partial\kappa}{\partial\epsilon}\right)_p=\left\{\left(\frac{\partial\kappa}{\partial\epsilon}\right)_T+\left(\frac{\partial\kappa}{\partial T}\right)_\epsilon\Big/\left(\frac{\partial\epsilon}{\partial T}\right)_p\right\}, \tag{3}$$

which by the introduction of (1) yields:

$$(\partial\kappa/\partial\epsilon)_p\sim(\partial\kappa/\partial\epsilon)_T. \tag{4}$$

Therefore we can put:

$$(\partial\kappa/\partial T)_p\sim(\partial\kappa/\partial\epsilon)_T\cdot(\partial\epsilon/\partial T)_p. \tag{5}$$

Few examples are known, in which all 3 functions have been measured; the best example, Na, shows deviations less than $\frac{1}{3}$ percent between 80°K and 250°K. If $(\partial\kappa/\partial\epsilon)_T$ has not been measured, it can be replaced by a theoretical expression. One can recognize that $(\partial\kappa/\partial\epsilon)_T$ can be derived exclusively from elastic considerations. The theory of finite strain yields:

$$(\partial\kappa/\partial\epsilon)_T=5\kappa+27(l+m+n), \tag{6}$$

l, m, n being the elastic constants of the 3 order. If $\partial\kappa/\partial T$ and $\partial\epsilon/\partial T$ are measured, relation (5) determines the 3rd-order constants, whose magnitude is i.g. more than 10 percent of that of the normal constants of 2nd order.

4. The Initial Stage of Plastic Deformation in Lead. W. James Lyons, *Loyola University of the South.*—Long-time tensile and compressive tests on metals indicate that in the steady-creep stage, the hyperbolic sine function relates the velocity of deformation to the stress. In the case of lead and tin at constant temperature it has been shown that this law reduces to a simple exponential relation. These laws, however, fail completely to describe the initial stage of plastic deformation in lead. The present series of tests is an investigation of this initial stage in compression. An optical lever system and high speed kymograph are employed. On the photographic time records obtained, the resolution is 0.0042 sec./cm, while the magnification of the deformation is about 56. Tests under pressures of 121 and 142 kg/cm² indicate that the initial stage lasts about 0.09 sec. The deformation *vs.* time relation is essentially linear.

5. Transformations of Radiation-Material Gas Mixtures. R. M. Whitmer, *Purdue University.*—Emden, in his *Gaskugeln*,[1] has found that for a perfect material gas the transformations along the isochor, adiabat, isotherm and isobar are particular forms of the general polytropic transformation $dQ/dT=$const. An alternative expression for a polytrope is $pv^\Gamma=$const., or in differential form $\Gamma=-(dp/p)/(dv/v)$, where Γ is also a constant. In the present investigation it has been found that when radiation energy and pressure are considered, Γ is not a constant for any of

the above-mentioned transformations, and dQ/dT is constant only for the adiabat. The relation of these results to the polytropes discussed by Eddington[2] and Milne[3] are indicated.

[1] Emden, *Gaskugeln* (Leipzig, 1907).
[2] Eddington, *The Internal Constitution of the Stars* (Cambridge, 1926).
[3] Milne, *Handbuch der Astrophysik*, III/1, p. 215.

6. The Phenomenological Theory of Superconductors. EMORY COOK, *University of Chicago. (Introduced by Carl Eckart.)*—The usual derivation of the London equations for a superconducting medium starts from the Maxwell field equations and the idea that the conduction electrons are free classical particles under the influence solely of the electrostatic field. The additional assumption must then be made that an arbitrary function of integration vanishes identically. When the same ideas are put into a variation principle, the need for this assumption disappears. The nonpenetrating fields demanded by experiment are obtained directly. In the very precise linear approximation, the Eulerian equations are equivalent to the London system. Uniqueness theorems developed show that the persistent currents of the London theory do not partake of the rotation of the medium. The second-order terms seem much too small to cause this effect. The second-order terms, however, may possibly effect a coupling between the various characteristic solutions of the linear system, amounting to a small resistance.

7. Derivation of Boltzmann's Law by Means of Bohr's Frequency Condition. ARTHUR E. HAAS, *University of Notre Dame.*—Boltzmann's law according to which (1) $P_1/P_2=e^{-E_1/kT}/e^{-E_2/kT}$ (where two atomic states are considered with the energy values E_1 and E_2 and P_1 and P_2 are the probabilities of these states) may be derived from Bohr's frequency condition by using Wien's displacement law and the postulate of equilibrium between spontaneous and induced transitions in the radiation field. If we put the number of atoms in a state of energy E equal to $p\phi(E)$, where p is the *a priori* probability, the calculation leads to the functional equation (2) $[p_1\phi(E_1)/p_2\phi(E_2)][B_{12}/B_{21}]=f[(E_2-E_1)/T]$ where B_{12} and B_{21} are the coefficients of positive and negative absorption of radiation. The solution is found to be (3) $p\phi(E)=(n_0/E)e^{-\gamma E/T}$ where n_0 is the number of atoms in the state of zero energy with an *a priori* probability one. By applying this result to the distribution of the kinetic energy in a monatomic gas, γ is finally found to be equal to $1/k$ so that Eq. (1) results.

8. On the Mechanics of Protoplasmic Streaming. GALE YOUNG, *University of Chicago. (Introduced by N. Rashevsky.)*—Living cells frequently show a steady circulation or streaming of their protoplasm. The motion is slow, being of the order of twenty centimeters per hour. The energy equation for the steady motion of a viscous compressible fluid within a fixed boundary under the action of an applied force field shows that a *necessary* condition for the existence of such streaming is that either (1) the applied forces do not have a potential per unit mass of fluid, or (2) the density of the fluid is not determined solely by its pressure. A dissolved substance affects the mechanics of the solvent in two ways: (a) it exerts drag forces on the latter whenever there is relative motion between them (diffusion), and (b) it introduces another argument into the equation of state of the solvent, since the solvent density is, in general, affected by that of the solute. The diffusion drag (*a*) may produce nonpotential forces on the solvent as in (1), while the expansion effect (*b*) gives rise to condition (2). There is thus the possibility of streaming being caused by the diffusion of a dissolved substance, and several cases have been worked out actually to exhibit such motion.

9. Circuit for Anticoincidences with G-M Counters. G. HERZOG, *University of Chicago.*—Anticoincidences can be used to suppress the recording of the discharges in a coincidence circuit when one additional G-M counter is fired simultaneously. This is achieved by taking off an impulse from the anticounter which is opposite in sign to the usual impulses. With vapor-filled counters the sign can be changed by shifting the quenching resistance together with the coupling capacity from one side of the h.v. supply to the other. When using the Neher-Harper circuit for quenching, a reversed pulse is achieved by coupling to the grid of the first tube instead of to the anode. The coincidence pulses are mixed with the anticounter pulse in a Rossi circuit, where the tube amplifying the antipulses has a negative bias. Simultaneous discharges in all counters thus give only small pulses on the mixing resistance, whereas coincidence pulses which are not accompanied by an antipulse are not reduced in size. Both kinds can be separated by adjustment of the grid bias on the output-Thyratron. A set for threefold coincidences balanced by one anticoincidence stage was tested and showed an efficiency of 98.6 percent. The 1.4 percent of anticoincidences which are missing can easily be explained by disturbing effects.

10. The Variation of the Hard Component of Cosmic Rays with Height and the Disintegration of Mesotrons. BRUNO ROSSI, *University of Chicago*, H. VAN NORMAN HILBERRY, *New York University*, AND J. BARTON HOAG, *University of Chicago.*—The vertical intensity of the hard component of cosmic rays was measured at different altitudes with a threefold coincidence counter tube arrangement. Measurements were taken with and without a graphite layer above the counters in order to compare the absorption of the hard component in air and carbon. The counting rate observed under a given mass of air-plus-carbon was found to be considerably larger than the rate observed under the same mass of air alone. We interpret the difference as due to the spontaneous decay of the mesotrons which form the hard component of cosmic rays. Three independent values of the average range before decay (L) can be deduced from our measurements. They are listed below, together with the atmospheric depths between which they were measured.

Depth intervals in g/cm^2	616–700	700–787	856–943
L in 10^5 cm	9 ± 0.5	10 ± 1.0	9 ± 1.3

A lifetime of the order of 2×10^{-6} second follows from the above values of L.

11. East-West Asymmetry of Cosmic Rays at 40° N Latitude. P. S. GILL, *University of Chicago.*—A study of the east-west asymmetry in cosmic radiation using two triple coincidence counter sets (A and B) was made in Beverly Hills, California, geomagnetic latitude 40° N. In the counter set A, 12 cm of lead was placed between the tubes, while no lead was used in set B. The east-west difference in the countrate in percent at three different zenith angles has the following values, given with probable errors:

ZENITH ANGLE	15°	30°	45°
A	5.4±2.0	3.7±1.2	2.4±1.2
B	0.0±1.6	1.6±1.0	0.9±1.0

At the knee of the ionization-latitude curve the average of these data thus shows a west-east difference of about 2.2 percent. Comparison of data A and B strongly suggests that this difference is greater for the penetrating than for the nonpenetrating component.

12. Fine Structure in the Zenith Angle Distribution of Cosmic-Ray Intensity. DENSIL M. COOPER, *University of Missouri. (Introduced by N. S. Gingrich.)*—Studies of "fine structure" in the directional intensity of cosmic rays have been made with a triple coincidence circuit of Geiger counters. Three counters, each of diameter 8.8 cm, active length 36 cm, and with a separation of 50 cm between adjacent counters, were used in a modified circuit of the Neher-Harper type. Readings were taken in a cyclic fashion to minimize errors due to possible instrumental sensitivity drifts, changes in barometric pressure, and changes in the magnetic field of the earth. Five-degree intervals were investigated in the range from 0° to 45°, inclusive, in the directions studied. The survey of intensities in the east, west, north, south, south-east, and south-west directions exhibits intensity patterns with small oscillations. The prominences measured in terms of the largest positive deviations from the $\cos^2$ curve are of the order of two or three percent of the intensity, and they occur at approximately 7°, 20°, and 37°. These "fine structure" prominences are roughly the same for all the above directions; that is, these patterns show symmetry about the zenith. These results tend to confirm the predictions of Schremp[1] relative to the possible existence of this "fine structure" due to a line or banded nature of the energy spectrum for cosmic rays at infinity.

[1] E. J. Schremp, Rev. Mod. Phys. July & Oct. (1939).

13. Mesotron Intensity and Rate of Production in the Stratosphere. MARCEL SCHEIN, W. P. JESSE AND E. O. WOLLAN, *University of Chicago.*—Two high altitude flights have been made with a coincidence counter arrangement which records the vertical intensity of mesotrons and also the number of mesotrons which are produced in a 2-cm lead block.[1] At a pressure of 8 cm the mesotron intensity was 11 times as great as at sea level. This is about 12 percent of the total intensity of the cosmic rays at this altitude. From the second flight, which reached a barometric pressure of 3.6 cm, it was determined that the mesotron intensity attains a maximum at a pressure of about 6.6 cm Hg and then falls off rapidly reaching, at a pressure of 3.6 cm Hg, a value which is approximately half that at the maximum. The production of mesotrons in the 2-cm lead block sets in noticeably at about 35 cm pressure and increases with altitude at about the same rate as the soft component. From our measurements we obtain a value for the resulting cross section for the creation process equal to 1.7×10^{-27} cm² per proton of lead which agrees with that calculated by Nordheim.

[1] Cf. Phys. Rev. **56**, 613 (1939) for counter arrangement.

14. The Effect of the Slowing Down in the Source on the High Energy Portions of Beta-Spectra. EMIL J. KONOPINSKI, *Indiana University.*—Because forward scattering predominates for high energy electrons and back scattering cannot occur without large fractional energy losses, it is to be expected that the backing used for beta-ray sources should contribute very little to the distortion of the high energy portion of beta-spectra. If such distortion occurs it must be due to losses incurred during passage out of the source. This effect can be calculated if use is made of the linearity of the range-energy relation for electrons of more than 200 kv. It was done for the Fermi distribution and more completely for the simplified distribution $\sim E(E_0-E)$. Essential to the results is the value given to the maximum angle of emission accepted by the detecting device. If the usual values of the angle subtended by spectrograph slits are taken, it is found that a significant alteration of the spectrum shape (sufficient to distort a Fermi distribution into an apparent K-U type) takes place only for source thicknesses corresponding to an energy loss comparable with the mean spectrum energy. It can be argued, however, that due to the large angle straggling of even high energy betas, a much larger "effective" angle should be taken. This results in an effective thickening of the source so that a significant distortion of the spectrum may occur for even some of the thinnest sources which have been used.

15. The Scattering of Fast Electrons by Thin Foils of Metal. JASON L. SAUNDERSON* AND O. S. DUFFENDACK, *University of Michigan.*—Beta-rays from radium E of energy between 0.2 and 1.1 Mev were scattered by thin foils of Al, Cu, Ag, and Au under conditions which made possible a comparison with the single scattering theory of Mott. The scattered electrons were observed at various angles of scattering between 0° and 45° by means of a Geiger-Müller counter placed inside the evacuated scattering chamber. Metal foils of equal scattering power, Z^2nt constant, were made by the evaporation of the metals from a tungsten filament on to an organic film. A beta-ray spectrograph was used to determine the energy spectrum of the radium E source, using the same counter as was used in the scattering experiments, and an integration over this energy spectrum was carried out in order to compare the experimental results with the theory. Near the Wentzel angle the number of scattered electrons is greater than the number predicted by the theory for the elements of small atomic number, indicating that the Wentzel criterion for single scattering is too lenient for the lighter elements. The Wentzel criterion improves with increasing Z.

* Now with Dow Chemical Company.

16. Electrical Fields Produced in Interstellar Space by Cosmic Rays. FOSTER EVANS, *University of Chicago.* (*Introduced by Carl Eckart.*)—Swann[1] has shown that if cosmic rays passed through empty space as charged particles predominantly of one sign, the resultant space charge would produce enormous potential differences between points not very widely separated. Further, that a star emitting such cosmic rays would acquire a very large potential in a short time. Later, Alfvèn[2] showed that space charge might be neutralized by displacement of interstellar ions, but that large magnetic fields would be produced by the cosmic-ray current. In the present work it is shown that if interstellar ions neutralize the space charge, they will also neutralize the current flow, and, therefore, the magnetic field. For a single star the electric field E is given by $A=r^2kE$, where k is the conductivity of interstellar space at a distance r from the center of the star, and $4\pi A$ is the quantity of charge emitted, or intercepted, by the star per second. Ohm's law enters into the derivation of this equation; the justification for its application to interstellar space is discussed. For a star that only intercepts cosmic rays, the resulting potential turns out to be exceedingly small—approximately 10^{-13} volt—and the average potential produced on the galaxy is even smaller. For the case of emission, an upper limit for the potential is of the order of 1000 volts.

[1] W. F. G. Swann, Phys. Rev. **44**, 124 (1933).
[2] A. Alfvèn, Phys. Rev. **55**, 425 (1939).

17. Interpretation of the Proton-Proton Range. R. D. PRESENT, *Purdue University.*—The "charge independent" formulations[1] of the vector meson theory give a second-order proton-proton ^1S potential with the simple spatial dependence $e^{-\kappa r}/r$ where $\kappa=\mu c/\hbar$ and μ is the meson mass. Analysis of the proton-proton scattering data in terms of this potential[2] leads to a range $1/\kappa=0.42e^2/mc^2$ within an accuracy of 5 percent and the corresponding value of μ is 326 ± 16 m. Since recent[3] measurements of meson tracks give $\mu\sim170\pm20$ m, the range is about half the predicted value. A general argument shows that the $2n$th-order interaction of meson perturbation theory has a leading term of range $\sim\hbar/n\mu c$. The observed proton-proton range corresponds to a force that either (1) enters in fourth order or (2) enters in second order but is large in fourth and higher orders, this conclusion being independent of the exact form of the fourth-order potential (which unfortunately does not converge). Alternative (1) avoids introducing the unobserved[4] neutral meson but implies that the neutron-proton force has a larger range than the proton-proton force. Alternative (2) implies that the lowest order of perturbation theory does not give even approximately correct results. A third possibility is that the cosmic and nuclear mesons are not identical particles.

[1] Kemmer, Proc. Camb. Phil. Soc. **34**, 354 (1938); Bethe, Phys. Rev. **55**, 1261 (1939).
[2] Breit, Hoisington, Share and Thaxton, Phys. Rev. **55**, 1103 (1939); Share, Hoisington and Breit, Phys. Rev. **55**, 1130 (1939).
[3] Nishina, Takeuchi and Ichimiya, Phys. Rev. **55**, 585 (1939); J. G. Wilson, Proc. Roy. Soc. **172**, 517 (1939).
[4] A. C. B. Lovell, Proc. Roy. Soc. **172**, 568 (1939).

18. The Theory of β-Decay and the Radius Discrepancy for Sirius B. R. E. MARSHAK, *University of Rochester,* AND H. A. BETHE, *Cornell University.*—Recently several papers have appeared[1,2] which lend theoretical support to the Gamow-Teller selection rules for the β-decay of light nuclei. We wish to call attention to the astrophysical implication of these selection rules which has emerged from our investigations into the energy sources of the white dwarf stars. Using accurate expressions for the radiative and conductive opacities and the free electron density, the extension of the nondegenerate envelope and the internal temperature have been calculated for Sirius B. This calculation has been performed under several widely different assumptions regarding the chemical composition of the star as well as possible errors in the observed luminosity and radius. Even under the most extreme assumptions (pure helium star, etc.) the envelope constitutes only a very small fraction (about one percent) of the radius of the star and the central temperature must be at least five million degrees. At this temperature and at the high densities (up to 3.10^7 g/cm^3) which prevail in the degenerate core, the proton-proton reaction (on the Gamow-Teller theory) sets an upper bound to the hydrogen content of 10^{-3}. The theoretical value of the radius of Sirius B is then only $5.7\cdot10^8$ cm as compared with an observed radius of $13.6\cdot10^8$ cm. This large discrepancy is quite serious since the observational value seems good (in view of the agreement obtained between two distinct methods of measurement); a possible though extremely improbable solution is to return to the original Fermi version of the β-decay.

[1] B. O. Grönblom, Phys. Rev. **56**, 508 (1939).
[2] E. P. Wigner, Phys. Rev. **56**, 519 (1939).

19. Automatic Barometer Pressure Compensator for a Large Grating Spectrograph. H. BEUTLER AND MARK FRED, *University of Chicago.*—Since the refractive index of air is 1.0003, a change in barometric pressure Δp of one inch produces a wave-length shift of one part in 10^5. In the case of the laboratory's 30-foot, 150,000-line grating, having a resolving power of over 300,000, this effect shifts the maximum of a diffraction pattern to the next minimum for $\Delta p=0.3$ inch. Therefore good definition demands a smaller variation in pressure, which condition is seldom fulfilled for long exposure times (10 hr.). A compensator has been constructed for the spectrograph which has the effect of moving the position of the slit by an amount proportional to the pressure change, for variations of more than one inch. Behind the fixed slit is mounted a quartz plate (1 mm thick) which can be rotated about its vertical axis, thereby producing a lateral shift of the virtual position of the slit. This rotation is accomplished by the motion of a sealed metallic bellows acting on a lever arm fastened to the axis. Provision is made for adjusting the length of the lever arm according to the wave-length and order being studied. Ball bearings reduce the friction to a negligible amount. Details and data on the behavior will be presented.

20. Circular Dichroism in Crystalline Nickel Sulphate. L. R. INGERSOLL AND PHILIP RUDNICK, *University of Wisconsin and Vanderbilt University.*—Circular dichroism in crystalline α-$NiSO_4 \cdot 6H_2O$ has been measured for wave-lengths from 0.6μ to 2.2μ, using previously described apparatus[1] and a method of measurement which distinguishes elliptic polarization introduced by dichroism (in incident plane-polarized light) from ellipticity caused in any way by double refraction. Maximum ellipticities of 1.45° and 11.5° per mm thickness were found at respective wave-lengths 0.69μ and 1.155μ, where maxima of total absorption also occur. The dissymmetry factor,[2] $|(\mu_l - \mu_r)|/\mu$, is 0.03 at 0.69μ and 0.23 at 1.155μ. No measurable dichroism appears beyond 1.7μ. The anomalous rotatory dispersion[3] around 1.155μ is the only prominent instance of its kind reported for the infra-red region, as far as we know. The quantitative relation between circular dichroism and rotatory power can be studied in unusual detail here because the rotatory power curve is almost "purely anomalous," its maxima having about ten times the magnitude of the "normal" rotation in the region. The theoretical expectations[4] are well fulfilled. In particular, the wave-length, height, and half-width of the dichroism peak are correlated with the corresponding features of the rotatory power curve within the small experimental uncertainties.

[1] L. R. Ingersoll, J. Opt. Soc. Am. **27**, 411 (1937).
[2] T. M. Lowry, *Optical Rotatory Power*, p. 394.
[3] L. R. Ingersoll, P. Rudnick and F. G. Slack, Phys. Rev. **55**, 672 (1939).
[4] T. M. Lowry, *Optical Rotatory Power*, Chapter XXXIV.

21. Depolarization Factors of the Raman Lines of Some Derivatives of Phenylacetylene. FORREST F. CLEVELAND AND M. J. MURRAY, *Armour Institute of Technology.*—Using a method previously described,[1] depolarization factors have been measured for the main lines of twelve acetylenic compounds of the type $C_6H_5C{\equiv}CR$, where R is H, Cl, CH_3, C_2H_5, CH_2OH, CH_2Cl, CH_2Br, CH_2CH_2OH, CH_2CH_2Cl, $CHOHCH_3$, $CH_2C_6H_5$, and $CH_2CH_2CH_2Cl$. The two strong lines near 2230 cm^{-1}, when resolved, were found to have the same depolarization factors, thus indicating that they do not correspond to a symmetrical and an asymmetrical vibration, respectively, as has been suggested for dimethylacetylene. No previous data on the depolarization factors of these compounds have been reported and the Raman frequencies of $C_6H_5C{\equiv}CCH_2C_6H_5$ are listed for the first time. The single strong line at 2113 cm^{-1} in $C_6H_5C{\equiv}CH$ has the same depolarization factor as the two strong lines in the disubstituted compounds. Within experimental error, the value of this factor for the strong lines in the 2200 cm^{-1} region is 0.6 for all the compounds. The possibility that the two lines in this region may, as suggested by Badger, be due to a Fermi resonance interaction with the second overtone of a fundamental frequency near 750 cm^{-1} is discussed.

[1] F. F. Cleveland and M. J. Murray, J. Chem. Phys. **7**, 396 (1939).

22. A $^1\Sigma \rightarrow {}^1\Sigma$ Transition of the C_2 Molecule. O. G. LANDSVERK, *University of Chicago.* (*Introduced by H. Beutler.*)—The λ2300 band of the carbon arc, previously noticed by Bloomenthal and other investigators and measured by Hori, who attributed it to a C_3 molecule, has been accurately measured and analyzed, using photographs taken on the 30-foot, 30,000-line grating spectrograph. The structure consists of superposed (0,0), (1,1), (2,2), and (3,3) headless bands of a $\Sigma \rightarrow \Sigma$ transition of C_2 (or possibly C_2^+), in agreement with the earlier diagnosis of Mulliken and Dieke. Alternate lines are missing in each series, as expected for the zero spin of the carbon nucleus. Most probably the transition is $^1\Sigma_u^+ \rightarrow {}^1\Sigma_g^+$ of C_2. The molecular constants are very nearly equal for the upper and lower electronic states. They correspond rather closely to the average values of the same constants for other known states of C_2. The following values were obtained: $B_e' = 1.8334$ cm^{-1}, $B_e'' = 1.8223$ cm^{-1}, $\alpha' = 0.0204$, $\alpha'' = 0.0195$, $r_e' = 1.2382$A, $r_e'' = 1.2419$A, $\omega_e' = 1748$ cm^{-1}, $\omega_e'' = 1774$ cm^{-1}, $\nu_0^{0,0} = 43{,}227$ cm^{-1}. The ω_e values were obtained indirectly from the B and D values, since only one sequence of bands could be analyzed.

23. Hindered Rotation in Methyl Alcohol. J. S. KOEHLER AND D. M. DENNISON, *University of Michigan.*—Hindered rotation in methyl alcohol is dealt with by assuming a rigid molecule; only internal rotation and rotation of the entire molecule are considered. The entire molecule is taken to be a symmetrical top, an assumption which introduces errors of about 2 percent in the J spacing. Using as a hindering potential, $V = A \cos 3x$, the wave equation is separated into a Mathieu-like equation governing the internal motion and a symmetrical top equation describing the rotation of the entire molecule. The Mathieu-like functions, because of invariance condition, obey quasi-periodic boundary conditions. The internal energy levels, wave functions, and transition probabilities are calculated using an exact method involving continued fractions; the dependence of certain of the energy levels upon barrier height is given. The calculations predict a series of overlapping perpendicular bands each containing irregularly spaced zero branches. The extent of absorption, the irregular spacings, and the intensity distribution all agree qualitatively with the findings of Borden[1] and Lawson.[2] It is shown that hindered rotation will affect the zero branch spacings in all perpendicular bands of methyl alcohol. The barrier height in methyl alcohol is found to be 470 ± 30 cm^{-1}.

[1] Borden, J. Chem. Phys. **6**, 553 (1938).
[2] Lawson, thesis.

24. Band Spectra and Sensitized Fluorescence of Mercury-Indium Mixture. J. G. WINANS, FRANCIS J. DAVIS AND VICTOR A. LEITZKE, *University of Wisconsin.*—The sensitized fluorescence of indium in mercury vapor was excited by λ2536 light with apparatus like that previously used for tin.[1] All indium lines observed by Donat[2] and additional lines at 2860, 2775, and 2465A were obtained. A Tesla discharge through the mercury-indium mixture showed seven band systems, two resolved into bands with heads on the long wave-length side, and five either continuous or unresolved. Preliminary measurements of the wave-lengths at the intensity maxima and their estimated intensities are 4132 (3), 4449 (1), 4470 (3), 4539 (10),

4574 (2), 5227 (10), and about 5800 (3). The 5800 system extends from 6390 to 5400 with minima of intensity at 5726, 5672, 5639, and 5600. The 5227 system contained bands spaced 11–15A apart and it extended from 5270 to 4880 with a second maximum of intensity at 4998A. All of these band systems were obtained only with a relatively high concentration of both mercury and indium. A change in conditions of pressure and temperature changes the intensity of 5227 relative to 4539. The variations indicate as the emitting molecules, HgIn for 5227 and 5800, and In_2 for the remainder. Each of the band systems observed in the mercury-indium mixture corresponds to a band system previously observed in a mercury-thallium mixture.[3]

[1] J. G. Winans and R. M. Williams, Phys. Rev. **52**, 930 (1937).
[2] K. Donat, Zeits. f. Physik **29**, 345 (1924).
[3] J. G. Winans and Francis J. Davis, Phys. Rev. **53**, 930 (1938).

25. Magnetic Susceptibilities in Weak Fields. W. W. MEEKS AND N. C. JAMISON, *Northwestern University.*—Hector and Peck[1] have reported weak field measurements of the susceptibilities of benzene, carbon tetrachloride and toluene relative to water. Their measurements indicated that water was approximately 6 percent more diamagnetic in weak fields than in the intense fields usually employed. In the present investigation the relative susceptibilities of very pure samples of these same three liquids have been measured in weak fields (~50 gauss) using the modified form of Rankine balance suggested by G. Temple.[2] Six independent determinations on each of the three liquids gave for the susceptibilities of benzene, carbon tetrachloride and toluene the respective mean values (assuming 0.7200×10^{-6} for water) of 0.7036, 0.4376, 0.7172, all multiplied by 10^{-6}, with the greatest probable error, 0.0012×10^{-6}. The excellent agreement of these values with those reported by other investigators using strong fields indicates that there exists no discrepancy of the order of 6 percent between the susceptibility of water in high fields and in low fields. This work also indicates that the modified form of balance may yield absolute values of magnetic susceptibility as suggested by Temple.[2]

[1] L. G. Hector and M. F. Peck, Phys. Rev. **55**, 672 (1939).
[2] G. Temple, Proc. Phys. Soc. **48**, 39 (1936).

26. Effect of a Current Through an Iron Bar on Residual Magnetism. H. A. PERKINS AND H. D. DOOLITTLE, *Trinity College.*—A bar of Norway iron is surrounded by a solenoid composed of two windings. One of these is used to magnetize the bar; the other is connected to a galvanometer. Very small sudden changes in the flux through the iron are indicated by the throw of the galvanometer coil. A third circuit sends a current lengthwise through the bar. If the bar has been magnetized by a current whose circuit is then opened, a certain amount of residual magnetism remains. Then the galvanometer circuit is closed and the longitudinal current turned on. The galvanometer deflects in a sense which indicates a decrease of magnetism for a small residual flux, but an increase with larger values. This phenomenon has been studied with bars of various lengths and diameters and with various kinds of iron. The effect of a current flowing in a wire through the bored out axis of a bar was also examined, and finally a study was made of the effect of a succession of equal mechanical blows on the iron, in which varying amounts of residual flux had been set up.

27. The Ferromagnetic Relaxation Constant. J. BARTON HOAG, *University of Chicago.*—The domains of a ferromagnetic substance are able to adapt themselves to an external alternating field, by virtue of their restoring and damping forces, giving a comparatively high and nearly constant susceptibility χ_0 until the frequency of the alternations reaches the ultra-high radiofrequency range. Here the domains gradually fail to keep up with the applied field and the susceptibility slowly drops to the paramagnetic value. Data on the inner, initial permeability or susceptibility (χ) of iron in the high radiofrequency range have been accumulating for a number of years, to the point where a rough comparison with theory is now possible. A graph will be shown of the data in comparison with a typical dispersion equation of the form $\chi = \chi_0/(1+\omega^2/\omega_1^2)$. When the angular frequency ω is made equal to the constant ω_1, the value of χ will be just one-half of the "low frequency" value χ_0. From the data, I find $\omega_1 = 3.0 \times 10^9$ radians per second. Hence, the relaxation constant $\sigma = 1/\omega_1 = 3.3 \times 10^{-10}$ second, for iron.

28. An Ion Source of the Low Voltage Capillary Arc Type. SAMUEL K. ALLISON, *University of Chicago.*—The present status of ion source development in connection with our nuclear disintegration program will be described. The improvements introduced over a period of two years have increased the ion beam currents by a factor of 20. The present arc is made from a small rectangular copper block which can be thrust into the acceleration tube and placed some 5 cm from the first 100,000-volt focusing gap. The arc runs through a short constriction 9.5 mm long and 4.7 mm in diameter, at a current of 0.5 to 1.0 ampere. The probe is placed close to the constricted portion of the arc and consists of a solid tungsten button, 6 mm in diameter and 3 mm thick, with a probe hole 0.034 cm in diameter through it. An ingenious method of grinding this hole through the tungsten has been devised for us by Mr. F. B. Pearson. The assembly will emit 800–1000 microamperes of positive ions from the probe hole with 2000–3000 volts on the probe. Such a current is more than can be handled with the present low capacities in our Cockroft-Walton circuit, but with 250 microamperes a focal spot of magnetically analyzed protons, 6 mm in diameter and of 10 microamperes intensity, is attained.

29. Radioactive Indium Isotopes Produced by Alpha-Particles on Silver. L. D. P. KING AND W. J. HENDERSON, *Purdue University.*—The production of artificial radioactivity when silver is bombarded by 16-Mev alpha-particles has been reported previously.[1] Further work has shown that four periods are present, 20 min., 65 min., 9.4 hr., and 2–3 days. The first two periods have been chemically identified as indium. The 20-min. indium period was first reported by Lawson and Cork[2] using deuterons on cadmium and was assigned to In^{111}. Barnes[3] checked

this period using protons on cadmium. The additional information obtained by using alpha-particles assigns this period definitely to In^{112} instead of In^{111}. The 65-min. period assigned tentatively to In^{110} by Barnes[3] is checked by our results. The presence of a slight copper impurity in the silver is apparently responsible for the 9–10-hr. period. The 2–3-day period is very weak and may also be due to an impurity, or possibly be the same as the 2.7-day indium activity reported by Cork,[4] and independently by Barnes.[3] No indications of the 72-sec. period previously assigned to In^{112} was found, indicating a further revision in the indium isotope assignments.

[1] King, Henderson and Risser, Phys. Rev. **55**, 1118 (1939).
[2] J. L. Lawson and J. M. Cork, Phys. Rev. **52**, 531 (1937).
[3] S. W. Barnes, Phys. Rev. **56**, 414 (1939).
[4] J. M. Cork and J. L. Lawson, Phys. Rev. **56**, 291 (1939).

30. Excitation of the 450-Kev Level of Li^7 by Proton Bombardment. COLIN M. HUDSON, R. G. HERB AND G. J. PLAIN, *University of Wisconsin.*—The yield of gamma-rays from a thin film of lithium bombarded by protons has been investigated up to 2.08 Mev by recording both single and coincidence counts in G-M tubes. Above the 0.440-Mev resonance the gamma-ray yield of single counts is very low up to 0.850 Mev, and rises from there to a broad maximum at 1.050 Mev. From 1.150 Mev to 1.300 Mev the yield is about 0.8 as great as at 1.050 Mev. Above 1.300 Mev the yield again rises and the excitation curve up to 2.080 Mev shows a series of steps possibly indicating resonance excitation. The radiation above 0.850 Mev was predominantly soft, since very few coincidence counts were obtained at any point in the region. Lead absorption measurements of the soft lithium radiation and of annihilation radiation of positrons from N^{13} showed that the lithium radiation is softer than the positron annihilation radiation. The measurements indicate that the soft radiation is due to excitation of the 450-kev energy level of Li^7.

31. The Specific Charge of the Positron. A. H. SPEES AND C. T. ZAHN, *University of Michigan.*—The work on the specific charge of beta-rays[1] has been continued in order to include data on positive beta-rays. These were obtained from the radioactive isotope Cu^{64}, which emits both positrons and electrons with a half-life period of 12.8 hours. This branch feature made possible a good determination of the specific charge of the positron relative to that of the electron. For, in order to change from an electron to a positron source, it was unnecessary to disturb the geometry of the apparatus; only the electric and magnetic fields had to be reversed. In each case the procedure consisted of keeping the magnetic field constant and measuring the number of particles transmitted by the apparatus for various settings of the electric field. For a certain value of the electric field, corresponding to a compensated velocity, a maximum transmission occurred; i.e., a plot of the number of particles transmitted, against the values of the electric field, yielded a peak at the value for compensation. The positron peak was found to have the same position as the electron peak, indicating that the ratio e/m for positrons is the same as for electrons within an error of less than one percent.

[1] C. T. Zahn and A. H. Spees, Phys. Rev. **53**, 365 (1938).

32. Analysis of a Class C Radiofrequency Power Amplifier. S. L. SIMON, P. R. BELL, R. J. MOON AND L. SLOTIN, *The University of Chicago.*—The performance of triodes in class C operation can be calculated if characteristic data are known for many values of the space current between cut-off and saturation. This calculation is especially important for large power triodes such as are used in a cyclotron. A method has been developed for measuring complete triode characteristics which uses equipment found in most laboratories and which eliminates the difficulties in previous methods. Several sets of operating conditions have been determined from characteristic data. Application of the results gave an improvement in cyclotron performance.

33. Anode Effect as a Function of Temperature. PAUL L. COPELAND, *Armour Institute of Technology.*—Work on the anode effect previously reported[1] has been extended and refined by the use of triodes in which the surface potential of a nickel grid as a function of the electron current collected by it was investigated. The temperature of the grid was controlled and measured by the passage of a current through it. The results indicate: (1) that, with the grid at or near room temperature, its surface charge may be high enough to shift its effective contact potential by as much as two or three volts, and (2) that the magnitude of the surface charging decreases rapidly with temperature, being limited to about a tenth of a volt at 600°K, and not being detected at all above 675°K. Time studies for the drift of contact potential, like those reported by Nottingham,[2] were made. It was found that if the contact potential shift was plotted against the logarithm of the time, the resulting graphs were nearly linear. This fact suggests that the drifts involve groups of electrons with different binding forces; so that the effective time constant of the discharge of the surface varies continuously during the history of the drift.

[1] P. L. Copeland, Phys. Rev. **55**, 1145 (1939).
[2] W. B. Nottingham, Phys. Rev. **39**, 183 (1932).

34. Ionization by Positive Ions in Atmospheric Sparks. ROBERT N. VARNEY, *Washington University.*—Three problems arise in calculating the chance of ionization by positive ions in spark breakdown: First, what energy do positive ions really need to ionize by collision? Second, what chance does an ion have of gaining this energy? Third, what method of calculation is to be applied in determining this chance? In answer to these questions the following evidence is offered: (1) Recent results show that an ion must have at least three times as much energy as an electron to ionize by collision in the most favorable case. (2) Further results indicate that the mean free path of an ion of 20 electron volts energy is not very different from that of a molecule, a figure which is necessary to answer question 2.

(3) Application of these results by any reasonable method shows that the chance of ionization by positive ions is extremely small. The Townsend theory of spark breakdown based on ionization by positive ions thus becomes invalid, for that theory requires more than 10^{10} times as many ionizing collisions as can be accounted for under the most favorable circumstances.

35. Multiple Scattering of Electrons. S. GOUDSMIT AND J. L. SAUNDERSON, *University of Michigan.*—The theoretical treatment of the problem of multiple Rutherford scattering announced previously[1] has been worked out in more detail. The final scattering distribution is expressed as a series in Legendre polynomials which can be evaluated numerically. It can be shown that the results are very sensitive to deviations from the Rutherford formula caused by the screening effect of the electrons. This may probably explain the discrepancies between the experimental data and preliminary theoretical calculations. It is also shown that Williams' theory contains approximations which are not always permissible.

[1] S. Goudsmit and J. L. Saunderson, Phys. Rev. **56**, 122 (1939).

36. Time-Lag Analysis of the Townsend Discharge in Argon with Activated Caesium Electrodes. R. W. ENGSTROM,* *Northwestern University.*—The Townsend discharge was studied in the range of argon pressures 0.1 to 0.8 mm of Hg, parallel plate separations from 2 to 16 mm and gas amplification current ratios from 2 to 20. Analysis of equilibrium currents yielded ionization coefficients over the extended range from 40 to 2000 volts per cm per mm of Hg. Measurement of the instantaneous current as a function of the time after the beginning or cessation of cathode illumination was accomplished by a technique previously developed.[1] For the above range of variables, the exponential constant of the time-lag current amounts to from 0.1 to 7 milliseconds. Analysis of these data showed the source of the lag to be diffusion of metastable argon atoms and the release of about 0.4 secondary electron *per metastable atom* reaching the cathode. The coefficient of diffusion of metastable atoms in argon was determined and shown to be that expected for a metastable atom having a diameter effectively 1.74 that of the normal atom. In addition to those secondary electrons resulting from metastable atoms were those caused by impact of positive ions. The number of secondary electrons *per positive ion* varied from 0.04 to 0.41.

* Now at State Teachers College, St. Cloud, Minnesota.
[1] W. S. Huxford and R. W. Engstrom, Rev. Sci. Inst. **8**, 385 (1937).

37. Volume Rectifying Action in Cu_2O Crystals. JOSEPH M. LAMBERT, *Toledo, Ohio.*—Experiments have been made to find how far a rectifying action is connected with the crystal photoelectric effect in cuprite crystals (Dember effect). It was found that natural Cu_2O crystals, which show the Dember effect, exhibit rectifying properties when illuminated. As is proved experimentally, this new effect does not occur at the electrodes, but, like the Dember effect, is caused by action in the body of the crystal (bulk rectification). The resulting rectification in relation to the alternating voltage and illumination applied to the crystal will be shown graphically. If the spectral composition of the light is altered so as to reverse the sign of the Dember effect, the direction of the rectifying action also alters. In artificial Cu_2O crystals, which do not show the Dember effect, the rectifying effect is also absent. Some theoretical implications will be discussed.

38. Streaming of the Solvent in a Diffusion Field. GALE YOUNG, *University of Chicago.* (*Introduced by N. Rashevsky.*)—A vertical loop of solution becomes mechanically unstable and goes into circulation under the action of a dissolved substance diffusing downward when the concentration gradient of the latter exceeds a critical value. This is an instance of solvent streaming due to diffusion drag forces. If the dependence of solvent density upon solute concentration is taken into account a similar situation is realized, except that now the streaming energy originates from the solvent elements running through a cycle of expansion and contraction as they move. The situation is entirely analogous to instability of a fluid heated from below. If the small but finite viscosity of the solute is taken into account there arise streamings in the solvent quite independently of any external forces such as gravity. If a dissolved substance is diffusing along the axis of a cylinder in which the solvent is confined, it is found that the solvent circulates forward with the dissolved substance in the central part of the cylinder and returns in the opposite direction in the outer part of the cylinder. A similar result obtains for the flow between parallel flat plates.