Proceedings of the American Physical Society

MINUTES OF THE WASHINGTON, D. C. MEETING, DECEMBER 27–29, 1938

THE 40th Annual Meeting (the 225th regular meeting) of the American Physical Society was held at Washington, D. C., on Tuesday, Wednesday and Thursday, December 27, 28 and 29, 1938. All sessions of the meeting were held at the National Bureau of Standards. The presiding officers were Dr. Lyman J. Briggs, President of the Society, Dean John T. Tate, Vice President, Dr. H. L. Curtis, Dr. Karl K. Darrow, Dr. W. E. Forsythe, Professor Dayton C. Miller, Dr. F. L. Mohler and Professor G. W. Stewart. There were four hundred and fifteen registrations at the meeting.

On Wednesday afternoon, December 28, at two-thirty o'clock Dr. Lyman J. Briggs of the National Bureau of Standards, President of the American Physical Society delivered an address "The National Standard of Measurements" which was followed by an inspection of the standards in the laboratories.

Dr. Briggs presided at the speakers' table on the evening of December 28 at the joint dinner with the American Association of Physics Teachers held at the Wardman Park Hotel. He called upon the newly elected President of the Physical Society, Dean John T. Tate, to speak. There was also present at the speakers' table Professor C. Drummond Ellis of the University of London who spoke briefly. The other speakers were Dr. Harvey Fletcher and Dean F. K. Richtmyer. There were two hundred and eighty-six members and their guests at the dinner.

Annual Business Meeting. The regular annual Business Meeting of the American Physical Society was held on Wednesday afternoon, December 28, 1938 at two o'clock, President Briggs presiding. The President had appointed Messrs. William H. Crew and Karl K. Darrow to canvass the ballots for the officers of the Society. They reported the following elections:

President, John T. Tate; *Vice President*, John Zeleny; *Secretary*, W. L. Severinghaus; *Treasurer*, George B. Pegram; *Members of the Council*, four year term, E. U. Condon and A. J. Dempster; *Members of the Board of Editors*, three year term, Walker Bleakney, Gregory Breit and D. M. Dennison.

The Secretary reported that during the year there had been 202 who accepted election to membership. The deaths of fifteen members were reported, thirty-nine members resigned and five were dropped. The membership as of December 24, 1938 was as follows: Honorary Members, 5; Fellows, 754; Members, 2497; total membership, 3256.

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 Meeting because the fiscal year ends on December 31st. The Treasurer's financial report will be audited, printed and distributed to the members.

The Managing Editor made a brief report on the general status of the publications of the Society and stated that a detailed and audited financial report for 1938 would be printed and distributed.

The Annual Business Meeting adjourned at two-twenty P.M.

Meeting of the Council. At the meeting of the Council held on Monday afternoon, December 26, 1938 two candidates were elected to fellowship, thirty-one candidates were transferred from membership to fellowship and sixty-three candidates were elected to membership. *Elected to fellowship:* D. D. Montgomery and Arnold Nordsieck. *Transferred from membership to fellowship:* W. E. Albertson, J. G. Albright, Alexander Allen, Luis Alvarez, John Bardeen, E. L. Bowles, William F. Brown, Jr., R. C. Colwell, Albert S. Coolidge, Palmer H. Craig, Maurice Ewing, W. A. Fowler, G. G. Harvey, Leland J. Haworth, Joseph E. Henderson, J. Barton Hoag, Willis E. Lamb, Jr., John J. Livingood, A. H. Nielsen, A. O. C. Nier, Melba Phillips, J. R. Richardson, Robert Serber, Robert S. Shankland, William Shockley, William R. Smythe, A. F. C. Stevenson, R. L. Thornton, J. G. Trump, L. C. Van Atta and Karl S. Van Dyke. *Elected to membership:* Fadel G. Antippa, William J. Archibald,

Otto J. Baltzer, Mary Banning, Sidney Borowitz, Alexander V. Bushkovitch, Arnold F. Clark, William A. Cole, Gyfford D. Collins, George C. Comstock, A. M. Crooker, Ulrich Dehlinger, Alexis A. B. Dember, Jacobus S. de Wet, William G. Driscoll, A. G. F. Duncan, Clarence A. DuPont, Raymond Ellickson, Bruce Eytinge, Enrico Fermi, Charles B. Green, Carl M. Herget, George C. Higgins, Paul Huber, Richard F. Humphreys, H. Inuzuka, Warren C. Jones, A. Kastler, Nikolai Kemmer, Akio Kobayasi, John D. Kraus, G. J. Kynch, Ernest W. Landen, Eugene Lankford, Jr., S. T. Ma, George E. MacWood, John Marshall, Jr., A. Victor Masket, Robert J. Maurer, Ralph L. McCreary, Henry C. Meadow, Karl W. Meissner, Burton J. Moyer, Maurice E. Nahmias, Kenneth A. Norton, Joseph T. O'Callahan, Herbert M. Parker, Peter Preiswerk, Arnold Raines, Hans H. Renner, Robert G. Sachs, Guenter Schwartz, W. Wallace Sellers, Jr., Erle I. Shobert, II, G. M. Shrum, Charles F. Squire, Joseph B. Stucky, Jr., James K. Thornton, Louis Slotin, Thomas N. White, Jr., Charles M. Wilson, Robert G. Wilson and Syozi Yasimoto.

The regular scientific program of the Society consisted of seventy-nine contributed papers of which one, number 55, was read by title. The abstracts of the contributed papers are given in the following pages. An Author Index will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. The Far Infra-Red Pure Rotation Spectrum and the Molecular Structure of Heavy Water Vapor. N. FUSON,* H. M. RANDALL, AND D. M. DENNISON, *University of Michigan.*—An investigation has been made of the spectrum of heavy water vapor (D_2O) in the region from 23mu to 135mu. The instrument used was a recording spectrograph of large aperture.[1] The gratings were of the echelette type, higher order spectral impurity being removed by a combination of filters, *restrahlen* plates, and shutters. Absorption maxima could be located with an accuracy of about 0.05 cm^{-1} over most of the range. Lines 0.5 cm^{-1} apart could be partially resolved, higher resolution and dispersion being unproductive since the true width of the absorption lines is large. A feature of the spectrograph was that a completely evacuated radiation path could be obtained, thus eliminating the intense absorptions of the atmospheric water vapor which overlie this entire region. From this research over 200 pure rotation frequencies have been obtained together with rough intensity estimates. Using an analysis similar to that already used for ordinary water vapor,[2] the rotational energy levels for the ground state of D_2O have been evaluated through quantum number $j=8$. Corrections have been made for centrifugal stretching of the molecule. Cross-identification of the calculated transitions with the observed rotational transition frequencies has been made with some degree of success.

* Now at Rutgers University.
[1] H. M. Randall, Rev. Mod. Phys. **10**, 72 (1938).
[2] H. M. Randall, D. M. Dennison, N. Ginsberg, L. R. Weber, Phys. Rev. **52**, 160 (1937).

2. A Thermal-Gravitational Method for the Separation of Gases and Isotopes. A. KEITH BREWER AND ARTHUR BRAMLEY, *Bureau of Chemistry and Soils, Washington, D. C.*—Methods for separating gases by thermal diffusion[1] have been improved by making the process accumulative. Clusius and Dickel[2] accomplished this by using a long vertical tube with a hot wire down the center. A thermal-syphoning action carries the light gas to the top of the tube and the heavy to the bottom. The writers have modified this procedure by using two large concentric cylindrical members, one being heated and the other cooled. In a glass apparatus consisting of a heated inner and a cooled outer tube, one and two cm in diameter, respectively, and one meter in length, a 350° temperature difference separated He and Br so that no Br could be detected at the top of the tube after 15 minutes. Under similar conditions a 50–50 CH_4-NH_3 mixture underwent a 25 percent enrichment in NH_3 at the bottom of the tube. If l denotes the cylinder length, r the radius of the outer tube, and the d the difference in radii, then to a first approximation, the rate of separation varies as rd and the purity of l/d.

[1] Chapman and Dootson, Phil. Mag. **33**, 248 (1917).
[2] Clusius and Dickel, Naturwiss. **33**, 546 (1938).

3. The Distribution of Ozone in the Stratosphere. W. W. COBLENTZ AND R. STAIR, *National Bureau of Standards.*—Measurements of the spectral quality of ultraviolet solar radiation, with a photoelectric cell and filter radiometer, made in September and early October, 1938, at Flagstaff, Arizona (elevation 7300 ft.), showed that during a well-defined cyclonic disturbance the barometric "low" preceded, by five to six hours, the well-known attendant increase in concentration of ozone, indicating a possible method of studying air circulation in the stratosphere. A decrease of 0.2 in. (five mm) in barometric pressure produced an increase of perhaps eight to ten percent in the amount of atmospheric ozone. In four balloon ascensions, made in Washington, D. C., in June, 1938, the photoelectric cell and filter radiometeorograph attained heights ranging from 83,000 to 88,000 ft. (25 to 27 km), penetrating about 60 to 70 percent of the atmospheric ozone, which became perceptible at a height of about 12 km (as observed in 1937)

and was fairly uniformly distributed through a height of 18 to 27 km, with a wide maximum between 20 and 27 km. At the highest elevations the ultraviolet intensity was about five times the value observed at sea level.

4. Energy Transformations in Novae. ROSS GUNN, *Naval Research Laboratory, Washington, D. C.*—Common novae, at maximum, radiate 10×10^{37} ergs/sec. or about 25,000 times more than the sun, whereas so-called "super" novae radiate about 2×10^{41} ergs/sec. The original stars of both types exhibit no unusual characteristics. Nova Pictoris (1925.39) is a common nova which has been observed to develop from a single dwarf F5 type of star into three components of estimated mass A–$0.86\odot$; B–$0.34\odot$; C–$0.30\odot$. Components B and C are now observed to be receding from A with a velocity of 540 km/sec. and are several parsecs from it. The energy necessary to separate the components and provide the present observed velocity is 4×10^{48} ergs. Moreover this energy was provided in a time less than 3.7 years. The average rate of energy conversion, therefore, exceeds 3.3×10^{40} ergs/sec. and this approximates the luminosity of "super" novae. Consequently the rates of energy conversion in common and "super" novae are of the same order of magnitude. This suggests that the observed differences arise from the different distribution of the transformed energy rather than from a cataclysm of a different order. The difference in the gravitational potential energy of the original and final configurations fails to account for any part of the present observed kinetic energy. Therefore, one concludes that unconsidered sources of energy are immediately available in a star and that a massive body may be ejected from it. These processes have an important bearing on the author's interpretation of the origin of the solar system.

5. Radioactive Content of the Atmosphere as Affected by the Presence of Condensation Nuclei. G. R. WAIT, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The rate of ion-production inside a closed chamber with extremely thin walls, installed in a closed room, is found to diminish when large quantities of condensation nuclei are introduced into the air. It was at first assumed that this diminution was due to some of the nuclei falling to the floor, carrying radioactive matter collected by them out of range of the instrument. This assumption was, however, not supported by results from simultaneous measurements of the concentrations of small and large ions. According to theory, the product of the two ion-concentrations is proportional to the rate of the production of small ions (when the small ions are not numerous). This product, when a large quantity of condensation nuclei was introduced into the air, decreased in the same proportion as the ionization inside the thin-walled chamber, thus establishing the authenticity of the ionization measurements. These results imply that the radioactive matter in the atmosphere is either diminished in amount or that it becomes less effective in the production of small ions, when condensation nuclei are present in the air.

6. Concentration of the Chlorine Isotopes by Centrifuging.* C. SKARSTROM, H. E. CARR, AND J. W. BEAMS, *University of Virginia.*—The evaporative centrifuging method of Mulliken has been used to concentrate the isotopes of Cl in carbon tetrachloride. The centrifuge used consisted of a 20-lb. chrome molybdenum steel tube 12″ long, 4″ outside diameter by $\frac{1}{2}$″ wall thickness, capped at both ends. The rotor was hung in a vacuum chamber by a small hollow shaft (hypodermic needle tubing gauge 14) which passed through oil-sealed vacuum glands, and to which was attached an air-supported air turbine located above the vacuum chamber. In operation the rotor was initially charged with 105 cc of CCl_4 and accelerated to 1000 r.p.s. The spinning tube was then evacuated through the hollow shaft. The CCl_4 evaporated at the periphery and was collected at the rate of $\frac{1}{2}$ cc of liquid per min. in separate fractions in dry ice traps in series with the pump. Repetition of this process has reduced 3150 cc of liquid to a set of fractions of various isotopic compositions, the heaviest of which (16 cc of liquid) has a density 0.1 percent above that of ordinary CCl_4. Analysis of this fraction in a mass spectrometer shows the ratio of Cl_{35} : Cl_{37} has been decreased five percent below that in ordinary CCl_4.

* Supported by a grant from the Research Corporation.

7. Impulse Breakdown in Long Discharge Tubes. J. R. DIETRICH* AND L. B. SNODDY, *University of Virginia.*—A study of the progressive breakdown in a discharge tube (14.2 cm diameter, 1200 cm long) produced by a positive potential impulse applied between an electrode in one end of the tube and a grounded concentric shield (two meters diameter) has been continued.[1,2] The output end of the tube is insulated. Maximum current and average speed of potential propagation at constant pressure (0.145 mm dry air) increase from 5.0 amp. and 13.6×10^8 cm/sec. at 19.4 kv to 134 amp. and 41×10^8 cm/sec. at 125 kv. The total charge from current-time oscillograms is constant to within 20 percent at 125 kv (pressures 0.06 to 0.3 mm) and varies linearly with applied potential at constant pressure (0.145 mm). The ratio of the charge entering the tube during the progress of the wave from input to output end to the total charge decreases with increasing pressure. If the progressive breakdown traverses only part of the tube (very short applied impulses), the previously described[2] contracted luminous column is observed to have a diffuse head about two meters long (0.044 mm pressure).

* Coffin Fellow.

[1] L. B. Snoddy, J. R. Dietrich and J. W. Beams, Phys. Rev. **52**, 739 (1937).
[2] J. R. Dietrich, L. B. Snoddy and J. W. Beams, Phys. Rev. **53**, 923 (1938).

8. The Separation of Gases by Centrifuging.* J. W. BEAMS, *University of Virginia.*—The air-driven vacuum-type tubular centrifuge was used to test the theoretical equation of Lindemann and Aston for the separation of gases at equilibrium in a centrifugal field. A mixture of CO_2 and N_2 at slightly above atmospheric pressure entered the spinning tube at the top and was collected at the bottom in two equal fractions by volume, one taken from

the axis, the other from the periphery of the tube. The chrome-molybdenum steel tube was 14″ in length, 4″ in external diameter, ½″ in wall thickness and capped at both ends. It spun in a vacuum at room temperature. The rotational speed was constant to at least 0.2 percent during an experiment. At speeds of 1000 r.p.s. with steady rates of flow up to 500 cm³/min., the observed separation agreed with the equilibrium theory, within a few percent. At rates of flow of 1000 and 2000 cm³/min. the observed separations were 85 and 68 percent of the theoretical equilibrium values, respectively. It is believed that a part of this reduction, at least, is due to stirring at the exits of the tube. At a series of rotational speeds from 500 r.p.s. to almost 1100 r.p.s., with steady rates of flow of about 100 cm³/min., the theory was verified within the limits of experimental error (three percent).

* Supported by a grant from the Research Corporation.

9. A Possible Cause of the Glow to Arc Transition. F. A. MAXFIELD, H. R. HEGBAR, AND J. R. EATON, *University of Wisconsin.*—Further experimental studies with an unstable glow discharge in mercury vapor lend support to the theory proposed by Maxfield and Fredendall[1] that the causes initiating glow to arc transitions are probably bursts of gas non-uniformly emitted from small patches on the electrode surface. Tests showed that transition probability continually decreased when the electrode was kept hot and bombarded with positive ions over a period of several days. Two quite different curves of transition probability as a function of vapor pressure were obtained. With moderate values of glow current the probability of a transition increases with pressure but with very low values of glow current the probability of a transition decreases with an increase of pressure. These effects, as well as many other well-known glow or arc discharge phenomena, can be explained by the gas burst theory. Calculations have been made which show that even if less than 10^{10} atoms of gas are emitted in a burst a sufficient amount will have been emitted to initiate the glow to arc transition. This is a much smaller amount of gas than can be detected by ordinary means.

[1] Maxfield and Fredendall, J. App. Phys. **9**, 600 (1938).

10. Absorption and Reradiation by Resonators. C. R. FOUNTAIN AND E. G. PIGG, *George Peabody College for Teachers.*—Tuned resonators absorb and reradiate radio wave energy. The equation for the current induced in such a resonator was checked experimentally for 3.9 meter waves. The induced current varies inversely with the distance and the energy varies inversely with the square of the distance as expected. Another tuned resonator, placed anywhere in the field, also absorbs and reradiates according to these laws. The additional current induced in the first receiver by radiation from the second resonator can also be represented by an equation and checked by experiment. However, there is a change in phase of half a wave-length when the energy is reradiated. Maximum effects are found when the sum of the distances from transmitter to resonator and from resonator to receiver are an odd number of half-wave-lengths greater than the direct distance from transmitter to receiver. Under these conditions the total energy induced in the receiver seems to be far greater than expected from the inverse square law. Such resonators seem to absorb all the energy within a wave-length on either side of them. Two such resonators, each four λ from the transmitter and $\frac{3}{2}\lambda$ from the receiver, more than doubled the normal energy at the receiver.

11. Decay of Phosphorescence After Electron Bombardment. R. B. NELSON* AND R. P. JOHNSON, *General Electric Co.*—An apparatus has been constructed for measuring the luminous output of phosphors under electron bombardment as a function of time, during a cycle in which the exciting beam is turned on and off for any desired intervals. The phosphorescence of green willemite decays approximately exponentially with time, the decay rate being independent of current density, voltage, and duration of the exciting beam. The time constant of the decay varies from seven milliseconds, just after excitation, to 14 milliseconds in the later stages. A simple picture of the luminescence process in willemite is proposed which is consistent with the exponential decay and the observed saturation of steady light output with increasing current density. A sample of pure $CaWO_4$ shows no detectable phosphorescence lasting 10^{-4} seconds, the resolving time of the apparatus. For two samples of ZnS activated with Ag the first part of the decay follows the law $L=A/(t+b)$, where L is the light output, t is the time, A and b are constants. Later, the luminescence falls faster than this. For a ZnS : CdS activated with Ag $L=A/(t+b)^2$. The shapes of the decay curves for sulphides are independent of voltage, but dependent on current density.

* Now at Massachusetts Institute of Technology.

12. On the Mechanism of Air-Blast Atomization (Air-Injection; Ante-Chamber Methods). R. A. CASTLEMAN, JR., *Falls Church, Virginia.*—It is well known that Diesel was side-tracked from his original partial success with a coal-dust internal-combustion engine by discovering that liquid fuel could be efficiently atomized directly into the cylinder by applying behind it a pressure considerably in excess of the momentary cylinder pressure. For years this has remained the favorite method of injection and atomization of liquid fuel in great stationary Diesels, but, since a two or three stage air compressor must be carried along, solid injection has largely displaced this in the vehicle Diesel. It was early observed that this method, when, as is customary, some thirty atmospheres *net* injection pressure was used, gave a spray of uniform fineness comparable to that yielded by air-stream atomization (successfully used for years in carburetors). As the N.A.C.A. has shown, this is quite insufficient to give uniform fineness in solid injection, so that the fuel is not atomized by being pushed ahead of the compressed air. However, the air is blown in at a velocity, relative to the liquid, which is quite sufficient for air-stream atomization. The uniform fineness of the spray formed in air injection is thus explained. This explanation also applies to ante-chamber methods, where the blasting

pressure is furnished by a preliminary partial explosion in a small ante-chamber in the cylinder head.

13. On the Statistical Theory of Rubber Elasticity and Related Experiments. EUGENE GUTH, *University of Notre Dame.*—The high reversible elasticity and the thermoelastic behavior of rubber can be explained in terms of the molecular structure of rubber. Rubber consists of large chain molecules which can exhibit two kinds of Brownian motion: 1. An intramolecular one due to the possibility of free rotations around single C−C bonds and giving rise to a more or less kinked form of the chain molecule; 2. An intramolecular one due to the possibility of a motion of the chain as a whole. Reversible rubber elasticity results if the intermolecular motions are not hindered above a certain degree, and if, at the same time, the translatory intermolecular Brownian motion is completely hindered. The kinked form due to the intramolecular Brownian motion is the most probable one according to the statistical interpretation of the second law of thermodynamics. If a stress is applied, these curved molecules will be straightened, thus giving a transition to a less probable state. When the stress is released the thermal agitation causes a retraction. A predominance of this statistical mechanism gives rise to the anomalous thermoelastic behavior (e.g., stress a constant length rises with increasing temperature) of certain rubber samples. A simple theoretical equation of states holding for this case will be presented.

$$z=a(L)+b(L)T; \quad b(L)=P^{\frac{2}{3}}\frac{2}{nl_\alpha}k\left(L-\frac{3}{2L}\right).$$

L, relative length; P, number of chains per cc; n, number of C−C bonds per chain; $l_\alpha=l\cot^2\alpha/2$; l, C−C distance; α, valence angle (approx. 109 deg.). For such a "quasi-ideal" rubber, the specific heat at constant length depends only upon the temperature and not upon the elongation. Generally, the thermal and the caloric equations of state together completely determine the thermodynamics of stretched rubber.

The normal thermoelastic behavior of certain other rubber samples can, on the other hand, be caused by the predominance of the inter- and intramolecular forces. Generally, both the statistical and the force mechanisms can be present. A dynamometer giving directly the stress of a stretched rubber sample in dependency upon the temperature, i.e., the thermal equation of state, will be described and the results obtained by another automatic stress-strain apparatus will be discussed.

14. Effect of Gas Pressure on the Point-to-Plane Discharge in Several Gases. H. C. POLLOCK AND F. S. COOPER, *General Electric Company.*—A maximum in the breakdown voltage *vs.* pressure curve with point-to-plane electrodes, reported in N_2 by Goldman and Wul,[1] has been observed also in O_2, CO_2, SO_2, SF_6, and CCl_2F_2. No effect was observed in A or He up to 300 lb./sq. in. pressure, although with the three-mm gap used, maxima occurred below 120 lb./sq. in. for the other gases. With a fixed voltage between electrodes, corona currents decrease as gas pressure increases until a critical pressure is reached. Above this pressure, no corona is observed preceding spark discharge. An oscillograph indicates a change in the type of positive corona in some gases, at a voltage slightly above that at which corona starts. As Kip[2] found, a very steep rise in current occurs when corona starts from a positive point. These effects have not been observed with negative corona.

[1] Goldman and Wul, Tech. Phys. U. S. S. R. **1**, 497 (1936).
[2] Kip, Phys. Rev. **54**, 139 (1938).

15. Effect of Hydrostatic Pressure on the Resistance of Single Crystals of Selenium. R. M. HOLMES AND H. W. ALLEN, *University of Vermont.*—Single crystals of the hexagonal type about 1 cm long and 0.5 mm in diameter were grown in a partial vacuum by condensation from the vapor phase. Resistances between points a few mm apart were measured using potential leads to a vacuum tube circuit. The crystals were in an insulating oil under pressures up to 700 kg/cm². The resistances decrease with increasing pressures but there is a marked hysteresis effect, the resistances at decreasing pressures falling below the corresponding values at increasing pressures. If the crystals are kept at each pressure for about 30 minutes then values of resistances at both increasing and decreasing pressures fall on a straight line within this pressure range. The value of $\Delta R/R_0\Delta p$ is -3.1×10^{-4}. This is believed to be the largest resistance pressure coefficient so far reported. If the pressure on a Se crystal is quickly increased from atmospheric to 700 kg/cm² the resistance decreases rapidly at first, then at a lower rate and finally attains a constant value after about 30 minutes. When pressure is reduced the increase in resistance is similar in behavior. Oil temperatures were read. The resistance temperature coefficient for Se crystals was found to be 2.4×10^{-2} at 21.5°C. Illumination decreases the resistance pressure coefficient.

16. The Ultrasonic Method for the Determination of Elastic Properties of Solids. H. LUDLOFF, *Cornell University. (Introduced by H. A. Bethe.)*—A method of investigating elastic properties of solids has been devised. The method involves the piezoelectric excitation of spatial ultrasonic wave gratings and the irradiation of the solid with visible light. Interference patterns obtained in this way uniquely determine the elasticity and symmetry behavior of the solid. If the solid is transparent, the action on the light is that of a *spatial* grating. If the solid is opaque, the interference pattern appears in reflected light, the diffraction taking place on the oscillating surface. The interference patterns can be understood and derived quantitatively by integration of the wave equations of the system; it must be taken into account that a *great number* of spatial gratings are excited for each frequency, and that all these gratings will influence the interference pattern. In this respect, the situation is quite different from that encountered in the diagrams in the x-ray range. From our interference pictures one can determine simultaneously all the elastic constants with an accuracy hitherto unattained. From the intensity distribution in the interference pattern, one can draw conclusions concerning the energy distri-

bution of ultrasonic waves of a given frequency; there exists a certain analogy with the equipartition theorem for thermal waves.

17. An X-Ray Investigation of Crystallinity in Rubber. S. D. GEHMAN AND J. E. FIELD, *The Goodyear Tire and Rubber Company, Akron, Ohio.*—X-ray diffraction evidence has shown that a crystalline structure can be produced in rubber by stretching or by freezing. In the former case, a fiber diagram is generally secured, in the latter, Debye-Scherrer rings. When raw rubber was stretched to moderate elongations and frozen, an intense fiber diagram was found, showing that the crystallization proceeded from the nuclei set up by the stretching. A series of diffraction patterns illustrating the effect are reproduced. The geometrical conditions of stretching under which "higher orientation" occurs in stretched rubber were studied by photometric measurements of the relative densities of the first two equatorial spots. Graphs are included demonstrating the effect of variations in gauge, width, length and elongation of the specimens. The different physical structures of vulcanized pure gum stocks became apparent in the "higher orientation" characteristics, although the same diffraction pattern was secured. A correlation of the results with current views on the micellar or secondary structure of rubber and the crystallization of super-cooled liquids is attempted.

18. Negative Power Factors in Air Capacitors. ALLEN V. ASTIN, *National Bureau of Standards.*—Using a method* which permits absolute evaluation of power factors as small as 0.5×10^{-6}, it has been found that certain guard ring capacitors when in an atmosphere of high humidity will occasionally show definite negative power factors. The observed negative values are a maximum at about 80 percent relative humidity and the largest negative value recorded is 70×10^{-6} at 60 cycles. The values are stable provided the capacitor is not disturbed and a constant humidity is maintained, but cleaning and reassembling the electrodes may cause the negative values to disappear.

The capacitors were well shielded so that there was no possibility of capacitative coupling to some other source. The values were independent of the voltage across the capacitor and of the wave form of the voltage. The negative value for two capacitors in parallel, each of which had a negative power factor, agreed with the value computed from the individual values. The negative values decreased as the frequency of the applied voltage is increased. No d.c. effects were observed with capacitors which showed a negative power factor.

* This method is described in detail in the Nat. Bur. Standards J. Research **21**, 425 (1938).

19. An Explanation of the Negative Power Factors in Air Capacitors. HARVEY L. CURTIS AND ALLEN V. ASTIN, *National Bureau of Standards.*—In order to explain the negative power factor of an air capacitor it is necessary to assume some source of energy in the capacitor itself or in an electric circuit connected with the capacitor. A source of energy in the capacitor itself is the latent heat of the water vapor, since negative power factors are only observed when there is moisture in the capacitor. An explanation of negative power factors can be based on the assumption that the latent heat of water vapor is converted directly into electrical energy. The second possible source of energy is in the guard circuit of the capacitor since all capacitors in which negative power factors have been observed have been shielded capacitors. By assuming certain conditions in connection with the shield it is possible to explain negative power factors by this method. Neither of the proposed explanations has received a definite experimental proof.

20. The Thermal Distribution and Temperature Gradient in the Arc Welding of Cylindrical Tubing. W. A. BRUCE, *The Carter Oil Company, Tulsa, Oklahoma.*—The assumption is made that the n welders move their electrodes at a constant speed on a circle of a right cylindrical shell, and with a uniform separation w cm between welders. The method of stationary sources, as developed by Kelvin and described by Rayleigh,[1] is used. By integration of the effect of the stationary sources, the general effect of a moving welder is obtained. Similarly, the effect of the n welders is obtained. Demonstration of the validity of this summation is given. Proof is given that an infinite plate with an infinite number of sources w cm apart along a line in the plate is equivalent to a thin right cylinder with n sources separated w cm on a circle of the cylinder. The solution is in the form of a sum of definite integrals. It is shown that under certain conditions these definite integrals may become Bessel functions of the second kind. The temperature gradient and rate of cooling at any point may be obtained by partial differentiation under the definite integral. Experimental results which verify the equation are shown.

[1] Rayleigh, Phil. Mag. **22**, 381 (1911).

21. Quiet Boiling. N. ERNEST DORSEY, *National Bureau of Standards.*—The use of more or less rounded points for reducing the severity of such bumping as occurs when air-free water is boiled in clean glass vessels is common practice, but the results so obtained are seldom satisfactory. It seems not to have been recognized that if the material of which the points are made is such that it is perfectly wetted by the liquid at the temperature considered, then the point cannot be efficacious, as it will have no effect whatever upon the form or size of the incipient bubble of vapor. On the other hand, the presence in the liquid of a substance that is completely unwetted by the liquid at the temperature concerned will be efficacious, whatever its shape. Since in this case the contact angle is 180°, the curvature of the incipient bubble at its very beginning will be slight and will at first increase as the volume increases; the first facilitates the formation of the initial bubble, the second stabilizes the initial stages of its growth. Among such substances for water are the stearates of zinc and of aluminum. Each of these is very effective. A simple mechanical device for the prevention of bumping will be described.

22. Reducing the Reflection from Glass by Evaporated Films. C. HAWLEY CARTWRIGHT AND A. FRANCIS TURNER, *Massachusetts Institute of Technology.*—The conditions were investigated for reducing the reflection from optical surfaces by the deposition of evaporated films of LiF, MgF_2, CaF_2, NaF and chiolite. Films of these materials with an optical thickness of 1200A when evaporated under suitable conditions reduced the reflection of visible light from two glass surfaces to about 0.4 percent and resulted in a transmission of about 99.6 percent, as recorded by the Hardy color analyzer. The optical thickness, the geometrical thickness, and the index of refraction of an evaporated film were determined by interference methods and the absolute reflecting power.

23. The Chladni Patterns on Circular Plates. R. C. COLWELL, J. K. STEWART AND A. W. FRIEND, *West Virginia University.*—The solution for the nodal lines on a circular plate appears in the form

$$W=AJ_n(kr)\cos n(\theta-\alpha_n)\pm BJ_m(k'r)\cos m(\theta-\alpha_m)=0.$$

The first term of this equation has heretofore been given as the complete solution of a vibrating plate. In reality however it represents only circles and radii corresponding to the straight lines on a square plate. If another vibration, which may arise in many ways, is represented by the second term of the equation above, the two terms may be added together with different values of A and B to give the complicated figures which actually appear on circular plates. It is better to add the terms by a graphical method. The mathematical figures will be compared with those obtained experimentally on vibrating plates. The same method may also be applied to circular membranes.

24. Magnetic Moments of the Proton and the Deuteron. J. M. B. KELLOGG, I. I. RABI, N. F. RAMSEY, JR., AND J. R. ZACHARIAS, *Columbia University and Hunter College.*—The molecular beam magnetic resonance method for measuring nuclear magnetic moments has been applied to the proton and deuteron. In this method the nuclear moment is obtained by measuring the frequency of the Larmor precession ($\nu=\mu H/hi$) in a uniform magnetic field. For this purpose HD molecules at liquid nitrogen temperatures are most suitable because they are largely in the ground state of zero rotational moment. This circumstance eliminates disturbing effects which are described in the following paper. The details of the apparatus and method will be described. Very sharp resonance minima were observed which made it possible to show precisely that the observed values of ν/H are independent of H. Observations were also made on a resonance of the CCl_2F_2 molecules in order to connect our results with the measurements made on Li^7, Li^6, and F^{19}. The results obtained for the various moments are

$$_1H^1 \quad 2.780\pm0.02$$
$$_1D^2 \quad 0.853\pm0.007$$
$$_9F^{19} \quad 2.616\pm0.02.$$

The values are in excellent agreement with those obtained by the atomic beam method of Kellogg, Rabi, and Zacharias,[1] which is entirely different in principle, but lie outside of the limit of error of the latest measurement of the proton moment of Estermann, Simpson, and Stern.[2] It is noteworthy that our value of the fluorine moment from CCl_2F_2 agrees with that previously obtained from LiF in a different apparatus.[3]

[1] Kellogg, Rabi, and Zacharias, Phys. Rev. **50**, 472 (1936).
[2] Estermann, Simpson, and Stern, Phys. Rev. **52**, 535 (1937).
[3] Rabi, Millman, Kusch, and Zacharias, Phys. Rev. **53**, 495 (1938).

25. Magnetic Resonance Experiments on H_2 and D_2 Molecules. I. I. RABI, J. R. ZACHARIAS, N. F. RAMSEY, JR., AND J. M. B. KELLOGG, *Columbia University and Hunter College.*—The molecular beam magnetic resonance method applied to H_2 at the temperature of liquid nitrogen reveals a close group of sharp resonance minima. The ratio ν/H for the center of this group is independent of H and thus affords a determination of the proton moment. This value agrees with that obtained using HD molecules. The resonance minima agree in number and in spacing with reasonable predictions based on the assumptions of spin-spin magnetic interaction of the two protons and interaction of the proton moments with the molecular rotation. It will be shown that these experiments yield information with regard to the finer details of molecular dynamics, such as the field produced by the molecular rotation at the positions of the nuclei. In the case of D_2 the resonance minima are not yet completely resolved. The total spread of the group is too great to be accounted for by the theory used successfully for H_2. The center of the group yields a value of ν/H independent of H. The deuteron moment so evaluated agrees with the one obtained with HD.

26. Rotational Magnetic Moment Measurements on H_2 and D_2. N. F. RAMSEY, JR., *Columbia University.*—The molecular beam resonance method for measuring nuclear magnetic moments has been applied to the measurement of the rotational magnetic moments of H_2 and D_2 at liquid nitrogen temperatures. A group of resonance minima has been obtained corresponding to reorientations of the molecular rotational moment rather than of the nuclei within the molecule as in previous experiments. The rotational moment can be evaluated from that member of the group for which ν/H is independent of H. The rotational g and hence the rotational moment of the first rotational state is found to be 0.887 ± 0.018 nuclear magnetons for H_2. This is within the limits set experimentally by Estermann and Stern[1] and theoretically by Wick.[2] A rotational g of 0.445 ± 0.009 nuclear magnetons is found for D_2. This is just half that of H_2 as expected theoretically.[2] At the temperatures used, practically all the H_2 and most of the D_2 is in the zero or one rotational state. The positions and shapes of the different H_2 rotational minima have been studied. The total spread of the rotational group of minima is found to be that predicted by the theory of the nuclear resonance group discussed in the preceding paper.

[1] Estermann and Stern, Zeits. f. Physik **85**, 17 (1933).
[2] Wick, Zeits. f. Physik **85**, 25 (1933).

27. Determination of the Nuclear Magnetic Moment of Caesium by the Molecular Beam Magnetic Resonance Method. P. KUSCH AND S. MILLMAN, *Columbia University.* —An apparatus for the application of the molecular beam magnetic resonance method to the determination of magnetic moments of nuclei in molecules that can be detected by the method of surface ionization has been built. The essential features of the apparatus and the procedure used in obtaining the resonance minima from which magnetic moments are determined will be discussed. A specific application to the case of the nuclear moment of Cs^{133} will be made. A ν/H resonance minimum common to CsCl and CsF and constant, within experimental error, over wide ranges of magnetic field was attributed to the magnetic moment of the Cs^{133} nucleus. The magnetic moments of Li^6, Li^7 and F^{19}, previously determined on another apparatus utilizing the same method, have been redetermined and the values are in agreement with those published.[1] Referred to the published value of the nuclear moment of Li^7, the magnetic moment of Cs^{133} is 2.556 in units of nuclear magnetons.

[1] Rabi, Millman, Kusch and Zacharias, Phys. Rev. **53**, 495 (1938).

28. The Nuclear Magnetic Moments of Na^{23} and K^{39}. S. MILLMAN AND P. KUSCH, *Columbia University.*—The apparatus described in the previous paper has been used to determine the magnetic moments of the Na^{23} and K^{39} nuclei. The molecules used for observing resonance minima for Na were NaF, NaCN and Na_2, and for K were KCN and K_2. From the observed resonance minima the moments of Na^{23} and K^{39} were found to be 2.224 and 0.391 nuclear magneton, respectively, referred to the published value of the nuclear moment of Li^7. Fine structure observed in the resonance minima of Na^{23} and K^{39}, when these resonance minima were observed with homonuclear molecules, will be discussed. It will be shown that the asymmetrical structure sometimes observed in the resonance minima is due to end effects in the wires which produce the radiofrequency oscillating field. Advantage may be taken of this asymmetry to determine the signs of nuclear magnetic moments.

29. The Collimation of Fast Neutrons. PAUL C. AEBERSOLD,* *University of California.* (*To be read by Luis Alvarez.*) —A well-defined, intense beam of fast neutrons has been achieved by using a collimation arrangement in conjunction with a cyclotron. Essentially the collimation is affected by a channel through a tank of water, 55 cm thick, placed in front of the source, a beryllium target bombarded by 8 Mev deuterons. However, this tank becomes a source of gamma-rays by neutron absorption and by scattering from the source. These gamma-rays are greatly reduced by lining the channel with a lead cone having walls 3 cm thick and by putting a 5 cm thick layer of lead on the outside of the tank. Also the radiation coming down the channel is filtered through 3 cm of Pb to suppress the gamma-rays from the source. This arrangement localizes the effect of the fast neutrons to a sharply defined region, and it is particularly well suited for biological and clinical applications. The ionization due to fast neutrons is over a hundred times greater in the beam than outside of it. The ionization produced outside is mainly due to gamma-rays and is only about 5 percent of the total ionization within the beam. As measured in a Bakelite walled thimble chamber the biological effect is smaller per unit of ionization due to the background gamma-rays so that localized biological effects produced by fast neutrons can be observed without significant effects on surrounding regions. Absorption of the beam in various materials corresponds to that given by Dunning for fast neutrons, while the ionization observed in various gases agrees with expectations. The intensity at the end of the cone, 70 cm from the source, using 60 microamperes deuteron current, is 3 e.s.u. per cc of air per min. in a small Bakelite chamber but only 0.6 e.s.u. per cc per min. in a carbon chamber. With such an intensity the epilation of a rabbit requires only a 2-hour exposure.

* Finney-Howell Research Foundation Fellow.

30. The Scattering of Ultra-Slow Neutrons in Ortho- and Parahydrogen. LUIS W. ALVAREZ AND KENNETH S. PITZER, *University of California.*—The three measurements so far reported on the ratio of the scattering cross sections of slow neutrons in ortho- and parahydrogen are not self consistent, due to the "high energy tail" of the cadmium filterable neutrons employed, and also to the difficulties of cooling neutrons. It seemed worth while to repeat this experiment with a source of monochromatic neutrons of low energy, in order to eliminate these two difficulties. In addition, Schwinger and Teller have shown that a measurement of the parahydrogen scattering cross section for neutrons of this type will give a very accurate value for the range of the neutron-proton force. A scattering chamber has been constructed which allows *o*- and *p*-hydrogen to be investigated in the gaseous phase (eliminating any effects due to liquid forces), at the boiling point of hydrogen, to avoid Doppler broadening. Preliminary experiments with gaseous *o*- and *p*-hydrogen cooled to liquid-air temperatures show that the *ortho* cross section is more than five times that of *para* for 30° neutrons. Alterations being made in the cryogenic laboratory have interrupted the work, but results on the scattering of 10°K neutrons in 20°K hydrogen should be available for presentation at the meeting.

31. The Transmission of Medium Fast Neutrons. R. B. ROBERTS* AND P. WANG, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The transmission of the neutrons from carbon bombarded by deuterons has been observed in various elements. Any neutron energy from 275 to 550 kv could be obtained by varying the deuteron energy. It was found possible to restrict the energy spread of the neutron beam to 30 kv by using suitably thin targets and small angles. The transmission of carbon and that of paraffin decreased in a regular way with the energy of the neutrons. The transmission of oxygen also showed a variation with the neutron energy.

* Carnegie Institution Fellow.

32. The Scattering of Neutrons by Protons. V. W. COHEN AND H. H. GOLDSMITH, *Columbia University.*—In order to obtain the free proton-neutron cross section from an experiment in which neutrons are scattered by paraffin it is necessary that the energy of the neutrons be greater than the energy of the lowest vibrational level of the paraffin molecule ($\sim\frac{1}{4}$ volt). This condition is satisfied by resonance neutrons for which the energies are of the order of a few volts. We have performed an experiment in which the transmission of a paraffin sheet for a beam of Rh resonance neutrons was measured. The source of neutrons was 600−300 mC Rn-Be. The detector was a Rh film 45 cm² in area. The beam length was 30 cm with the scatterer placed midway between source and detector. Cd shielding was used to eliminate the effect of thermal neutrons. An Rh filter placed between source and scatterer served to select neutrons of the resonance energy. From the observed transmissions we find the mean free path of these neutrons in paraffin to be 0.56 cm corresponding to a neutron-proton cross section of $20\pm2\times10^{-24}$ cm². This result, though in distinct disagreement with the value of 11×10^{-24} cm² obtained by Amaldi and Fermi, is in accord with recent experiments on the scattering of thermal neutrons by paraffin and by ortho- and parahydrogen.

33. Ultraviolet Microscopy as a Means of Determining Chemical Structure in the Cell. PETER A. COLE, *Washington Biophysical Institute, Washington, D. C.*—The Köhler ultraviolet microscope has been adapted to new radiation sources. Optical problems in connection with its use will be discussed. The relation of microscopic photographs obtained with monochromatic radiation to the major absorption bands of the essential compounds of the cell will be demonstrated. Details of chromosome structure obtained in cooperation with Dr. C. W. Metz, Department of Embryology, the Carnegie Institution of Washington, will be shown in monochromatic ultraviolet microscopic photographs.

34. Absorption and Fluorescence Spectra in Relation to the Photolethal Action of Methylcholanthrene on Yeast. ALEXANDER HOLLAENDER AND PETER A. COLE, *Washington Biophysical Institute and Division of Industrial Hygiene, National Institute of Health.*—The absorption spectrum of methylcholanthrene shows two series of bands in the ultraviolet (2100A to 4000A). The fluorescence spectrum as excited by these bands shows a series of maxima in the short visible region (3950A to 4700A). The use of the fluorescence in detection of small concentrations of methylcholanthrene down to one in 10^7 will be demonstrated. Lethal action by methylcholanthrene (dissolved in physiological salt solution) on a typical microorganism (yeast) is found in the presence of ultraviolet radiation between wave-lengths 3450 and 4500A, whereas, on the contrary, in the dark a stimulative action resulting in the breaking of the early resting phase is produced. It has been possible to detect methylcholanthrene through its toxic action in the presence of near ultraviolet radiation down to one to 10^8 to one to 10^9 parts. Possible photodynamic function of methylcholanthrene will be discussed.

35. A Spherical Coil for a Mass Spectrometer. JOHN A. HIPPLE, JR.,* *Westinghouse Research Laboratories.*—In order to construct a mass spectrometer of high intensity together with considerable resolving power, it was desired to have a rather strong field of great uniformity extending throughout a large volume. It is possible to satisfy these conditions with a large economy in power and copper by employing a spherical coil, in which the current density varies as the sine of the angle θ with respect to the axis of the coil. The variation with respect to r is immaterial. Theoretically, the field of such a coil is uniform throughout the volume. A coil employing these principles has been constructed. Preliminary measurements have shown that the field is uniform to at least 0.3 percent throughout the volume. The coil was constructed by winding $\frac{1}{4}''$ square copper tubing to a depth of 5″ upon a spherical brass casting of 20″ outside diameter. The tubing was wound in conical sections having two layers to each section and maple wedges were placed between the sections. The wedges were varied in size from one section to the next to provide for the variation in current density demanded by the theory. The sphere splits into halves at the equatorial plane, and there are openings 5″ in diameter at both ends —the absence of turns in this region having slight effect, since sin θ is small in this region. With water circulating through the tubing, it is quite easy to obtain a field of 2500 gauss.

* Westinghouse Research Fellow.

36. Infra-Red Absorption Bands of Some Perturbed Hydroxyl Groups. JOSEPH W. ELLIS, *University of California at Los Angeles.*—The valence band near 1.5μ and the valence-deformation band near 2μ are compared for water in a nonpolar solvent, liquid water, water molecules bound to a protein (gelatin), an alcohol in liquid and nonpolar solution states, crystalline sucrose and cellulose (ramie fibers). The structures of these bands are used to interpret the magnitudes and the types of perturbations to which the OH groups which produce them are subjected. Thus, for example, cellulose has only perturbed OH groups; sucrose has unperturbed and two types of perturbed groups; the bands produced by water bound to gelatin are sharpened on both sides, thus showing that the vapor-like molecules and the very highly perturbed molecules found in liquid water are not present there. An unperturbed state means that no forces greater than van der Waals and Lorentz-Lorenz forces occur, whereas a perturbed state means that relatively large forces enter, usually referred to as arising from hydrogen bonds, but probably really electrostatic in nature.

37. Plasma Oscillations and Scattering in Low Pressure Discharges. HARRISON J. MERRILL AND HAROLD W. WEBB, *Columbia University.*—The velocity distribution of the electrons emitted from the hot cathode in a low pressure (2 to 7 microns) discharge in mercury vapor was studied with a movable probe. The paths of these primary electrons lay within a truncated cone of mean diameter 10 mm and length 16 mm, with the anode and cathode as bases.

With small currents the scattering of these electrons could be followed in detail and was found to occur principally in several distinct approximately plane regions a few tenths of a millimeter thick. Oscillations in the plasma were studied with a crystal detector and a Lecher wire system in the probe-cathode circuit. Corresponding to each of the regions of scattering there were found distinct regions where periodic oscillations existed, the distance between them being approximately that covered by the primary electrons in one half-cycle. The frequencies (about 10^9) agreed well with those given by the formulae of Tonks and Langmuir,[1] and the results agree with their conclusion that the plasma oscillations cause the scattering. The results show further that the oscillations are due to the passage of the fast electrons through the plasma.

[1] Tonks and Langmuir, Phys. Rev. **33**, 195 (1929).

38. Excitation of the New Nitrogen Line. JOSEPH KAPLAN, *University of California, Los Angeles.*—Since the discovery last spring in high pressure nitrogen afterglows of a new line at 3466.3A agreeing with Bowen's predicted value of 3466.4A for the $^2P-{}^4S$ transition in atomic nitrogen, further studies of this line have been made. The most interesting observation is the remarkably high relative intensity of the line in weak afterglows produced by very weak discharges in nitrogen at about 30 mm, in a tube in which the part showing the glow has a volume of about 100 cc. This is entirely like the excitation of the green auroral line when small amounts of O_2 are added to nitrogen and the afterglow associated with a very weak discharge is observed.[1] The large relative intensity of the new line and the Vegard-Kaplan bands in more intense afterglows in the small tube is also of considerable interest since one would expect radiations from metastable levels to grow weaker as the tube size is diminished. This probably indicates the importance of surfaces for the production of metastable particles. The large relative intensity of the 3466 line points to the high-pressure afterglow as an important source of atomic nitrogen.

[1] Pub. Astronom. Soc. Pac. **47**, 257 (1935).

39. A Self-Consistent Field for Doubly Ionized Chromium. ROBERT L. MOONEY, *Georgetown University.*—A self-consistent field based on Hartree's equations has been calculated for Cr III in the configuration $(3p)^6\,(3d)^4$. The calculations were started by estimating an initial field by a method of graphical interpolation between the results already calculated for other ions. All of the differential equations involved in the computations were integrated numerically with the aid of a calculating machine. Three approximations in the cases of the $(1s)^2$, $(2s)^2$ and $(2p)^6$ groups, and seven approximations for the $(3s)^2$, $(3p)^6$ and $(3d)^4$ groups were made towards self-consistency. Tabulations of the $Z_{n,l}$'s in the last approximations show a divergence from self-consistency of not more than ± 0.004. The normalized wave functions for the individual electrons and the total radial electronic charge density distribution have been plotted as functions of the radius—a spherically symmetrical distribution has been assumed throughout. The results are principally significant in that the self-consistent field for Cr III offers a convenient starting point for calculations of self-consistent fields for singly ionized and for neutral chromium. The tendency toward "over-stability" (in the sense described by Hartree) is strongly marked in the $(3d)^4$ sub-group. Empirical rules are determined for the best method of overcoming the difficulties of the phenomenon of "over-stability."

40. Quantities of Charge Transfers in Lightning Discharges. E. J. WORKMAN AND R. E. HOLZER, *University of New Mexico.*—Five synchronized recording-generating voltmeters developed for indicating electric field intensity under storm conditions (see paper 78) were located at the boundary of a nearly circular area of 25 square miles at Albuquerque. The surface densities of the image charge were obtained from the measured surface field intensities and changes in the contour pattern of the image charge were used to calculate the quantity of charge in observed flashes. More than a thousand discharges of various kinds show on the records of all instruments for the several storms studied. From two to three hundred discharges were observed (visually) as to type and position and may be identified on the records. Seventeen of these discharges were photographed on the high speed lightning camera. Eight simple cloud to ground discharges of one storm have been analyzed and show gross transfers of 26, 54, 50, 37, 100, 30, 33, 29, and 200 coulombs from heights of approximately 1.5 miles. The application of this method to the study of charge development, charge distribution, potential differences, and space charge effects is discussed.

41. Compressibility of Lithium. CONYERS HERRING,* *Massachusetts Institute of Technology.*—Recent calculations of the energy of metallic lithium, made by Bardeen[1] using the method of Wigner and Seitz,[2] yield values for the compressibility which are roughly 15 percent larger than the values observed by Bridgman[3] over a range of pressures. For sodium however the agreement was very good. The most likely source of the discrepancy for lithium seemed to be the failure of the assumption that the energy of an electron with wave vector $\mathbf{k}$ is exactly proportional to k^2. In an attempt to better this assumption, the energies of three excited electronic states have been calculated for a number of values of the lattice constant. To calculate these energies a perturbation method is used starting from free electron wave functions of appropriate symmetry; the convergence is found to be rapid. The correction to be applied to Bardeen's values for the total energy of the electrons can be estimated by interpolation.

* National Research Fellow.
[1] Bardeen, J. Chem. Phys. **6**, 367 (1938).
[2] Wigner and Seitz, Phys. Rev. **43**, 804 (1933); **46**, 509 (1934); Seitz, Phys. Rev. **47**, 400 (1935); Wigner, Phys. Rev. **46**, 1002 (1934).
[3] Proc. Am. Acad. **72**, 207 (1938).

42. The Angular Distribution of the α-Particles from B+H^1. R. O. HAXBY[1] AND J. S. ALLEN, *University of Minnesota.*—Measurements have been made of the angular distribution of the α-particles arising from the reactions:

$$_1H^1 + {}_5B^{11} \rightarrow {}_4Be^8 + {}_2He^4 \qquad (1)$$

$$_1H^1 + {}_5B^{11} \rightarrow 3\,{}_2He^4. \qquad (2)$$

These reactions have been studied by Neuert,[2] who found the angular distribution of α-particles from (1) at 200 kv proton energy could be represented approximately by $1+\cos^2\theta$. Those from (2) were found to have a similar distribution for the longest range particles, gradually changing to a uniform distribution for α-particles of less than about 2.4-cm range. At 190 kv proton energy, we found a distribution from reaction (1) which could be represented by $1+0.7\cos^2\theta$. Measurement of the α-particles from (2) within about 1 cm from the end of range gave a similar distribution. Measurements taken at 143 kv, however, gave a uniform distribution for the particles from (2). It was found that the distribution of these α-particles between 143 and 190 kv could be represented by $1+A\cos^2\theta$, where A, as a function of voltage for a thick boron target, showed a similar variation to the efficiency curve of reaction (1).

[1] At present a Westinghouse Research Fellow, Westinghouse Research Laboratories, East Pittsburgh, Pa.
[2] Neuert, Physik. Zeits. **38**, 618 (1937).

43. A Precise Measurement of the Mass Difference $_4Be^9-{}_4Be^8$; the Stability of $_4Be^8$. SAMUEL K. ALLISON, ELIZABETH R. GRAVES, L. S. SKAGGS, AND NICHOLAS M. SMITH, JR., *University of Chicago.*—In a previous communication[1] we described an electrostatic analyzer for the energies of short range disintegration particles and reported the energy Q_4 of $_4Be^9(p,\alpha)_3Li^6$ to be 2.152 ± 0.04 Mev. In an extension of these experiments we have now found Q_3 of the concomitant reaction $_4Be^9(p,d)_4Be^8$ to be 0.557 ± 0.006 Mev. This latter value establishes the mass difference $_4Be^9-{}_4Be^8$ as 1.00720 ± 0.00007, and the binding energy of the odd neutron in $_4Be^9$ as 1.651 Mev, which should be the threshold for the photodisintegration of $_4Be^9$. With these precise values, it is now possible to express the masses of $_4Be^9$, $_4Be^8$, $_3Li^6$ *entirely* in terms of $_1H^1$, $_1H^2$, $_2He^4$ and the energies of nuclear reactions which have been measured with high precision. Using Bethe's values for the hydrogen isotopes, Bainbridge's helium[2] as 4.00386, and Q_1 of $_4Be^9(d,\alpha)_3Li^7$ as 6.95 Mev,[3] Q_2 of $_3Li^7(p,\alpha)_2He^4$ as 17.13 Mev,[4] we obtain:

$$
\begin{aligned}
{}_4Be^8 &= Q_1+Q_2-Q_3 \;+3\,{}_2He^4-2\,{}_1H^2 = \;\; 8.00739\\
{}_4Be^9 &= Q_1+Q_2-{}_1H^2+3\,{}_2He^4-\;{}_1H^1 = \;\; 9.01459\\
{}_3Li^6 &= Q_1+Q_2-Q_4 \;+2\,{}_2He^4-\;{}_1H^2 = \;\; 6.01655\\
{}_4Be^8-2\,{}_2He^4 &= Q_1+Q_2-Q_3 \;+\;{}_2He^4-2\,{}_1H^2 = -0.00033.
\end{aligned}
$$

Accepting the author's estimate of their error in Q_1 as 0.04 Mev, the largest error in the above relations arises from the mass of helium and is 0.06 Mev. Thus $_4Be^8$ is stable with respect to two alpha-particles by 0.31 ± 0.06 Mev.

[1] Phys. Rev. **54**, 171 (1938).
[2] Phys. Rev. **53**, 922 (1938).
[3] Williams, Haxby and Shepherd, Phys. Rev. **52**, 1031 (1937).
[4] Oliphant, Kempton and Rutherford, Proc. Roy. Soc. **149**, 406 (1935), corrected by Bethe and Livingston.

44. Interactions of Heavy Electrons. J. FRANKLIN CARLSON, *Purdue University.*—The Coulomb scattering in nuclear fields, the collisions with free electrons and with bound electrons, have been studied theoretically for "heavy electrons," "dynatons" or "barytrons," which may be described by a vector wave equation. This vector wave equation, first suggested by Proca,[1] has been developed subsequently from the standpoint of the quantum theory of wave fields as a field theory which among other things gives forces of an exchange nature between nuclear particles.[2] The electromagnetic interactions of these particles will be discussed here. There are peculiarities in the Coulomb scattering by nuclei of these particles, which are intimately connected with their polarization. The points of agreement and difference between the Coulomb scattering by nuclei and the collisions with ordinary electrons of "heavy electrons" describable by a vector wave equation and with those described by a scalar wave equation will be discussed.

[1] Proca, J. de phys. **7**, 347 (1936).
[2] Bhabha, Proc. Roy. Soc. **166** (1938). Nature (1938).
[3] Kemmer, Proc. Roy. Soc. **166**, 127 (1938); Fröhlich, Heitler and Kemmer, Proc. Roy. Soc. **166**, 154 (1938).

45. Design and Construction Features of the Westinghouse Electrostatic Generator. W. H. WELLS, *Westinghouse Research Laboratories.*—The belt type electrostatic generator designed and constructed at the Westinghouse Research Laboratories during the past two years will be described. A fifteen-foot diameter, high voltage terminal is supported inside the spherical thirty-foot diameter dome of a "pear" shaped pressure vessel by a porcelain-steel tower of a new simplified design. The pressure vessel is forty-seven feet in length, is designed for a working pressure of 120 lb./in.^{2} and has been tested at 160 lb./in.^{2}. Two eighteen inch belts give 500 microamperes at atmospheric pressure and after complete installation of the corona rings, seven and one-half foot sparkover occurs from the electrode to the pressure vessel wall. The accelerating tube has been assembled and evacuated under unusual mechanical conditions and preliminary test data will be given.

46. Incoming Cosmic-Ray Energies as Function of Latitude More Accurately Determined. R. A. MILLIKAN AND H. V. NEHER, *California Institute of Technology.*—Ten new flights up to pressure of ten millimeters mercury lead to following tentative conclusions: (1) cosmic-ray electrons enter the atmosphere down to energies of two billion electronvolts but no lower; (2) fluctuations at Bismark amounting to four percent divergence from mean value are greater than observational uncertainties; (3) the energies of the incoming electrons are again found confined to a sharply limited band with a pronounced maximum at about six million electronvolts; and (4) the results at Bismark agree closely with those found by Carmichael and Dymond near the north magnetic pole.

47. An Automatic Apparatus for Recording the History of Shower Phenomena Primarily in Relation to Showers Produced by Penetrating Cosmic Rays. W. F. G. SWANN AND W. E. RAMSEY, *Bartol Research Foundation of the Franklin Institute.*—The apparatus comprises ten trays, each containing eighteen Geiger counters. The trays are

arranged in a vertical column of total length 150 cm, each tray having an area of 400 square cm. A slab of lead 10 cm thick placed between the upper trays limits the phenomena produced below to phenomena of penetrating rays. Each of the remaining trays has a slab of lead 1 cm thick placed above it. Each of the 180 counters is connected to an electroscope provided with a mirror which reflects a spot upon a photographic plate. The electroscopes are only allowed to operate when a ray passes through the whole system; and in that case the record of every counter discharge is automatically imprinted upon the photographic plate and the history of all that has happened in the event is obtained.

48. Cosmic-Ray Measurements in the Stratosphere by Geiger-Müller Counters in an Integrating Circuit. L. F. CURTISS, A. V. ASTIN, L. L. STOCKMANN AND B. W. BROWN, *National Bureau of Standards.*—Earlier measurements by the authors[1] with small Geiger-Müller counters, directly keyed to a radio transmitter and carried aloft by free balloons, have revealed the desirability of observations less affected by statistical errors. These errors were necessary with the previous equipment because of the low maximum counting rate of the radio recording system on the ground. The large numbers of counts required to smooth out the random fluctuations can be obtained conveniently by using a fast counting circuit, such as that of Neher and Harper, and feeding its output to some type of integrating circuit which keys the radio transmitter once for a definite number of pulses. This has been done by a modification of the method reported by Johnson.[2] Approximately 20 successful flights were made from the National Bureau of Standards at Washington during the summer. These observations yield relatively smooth curves of cosmic-ray intensity *versus* pressure. The decrease in intensity beyond the maximum was not found to be as great as the single counter measurements seemed to indicate. By repeated observations with the identical balloon equipment some evidence has been obtained of variations in the shape of the intensity curve at different times.

[1] Phys. Rev. **53**, 23 (1938).
[2] Phys. Rev. **53**, 914 (1938).

49. Absence of Solar Component of Cosmic Radiation at High Elevations. S. A. KORFF AND T. H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—Measurements of the total intensity of the penetrating radiation at high elevations have been carried out by the radio-balloon method, with single Geiger counters. The counters were of large area, and operated at a high counting rate in the upper atmosphere, the pulses being scaled 50 : 1 before transmission. The counting rates of the instruments used on the several flights were calibrated with a standard radium source. Flights have been made both during the day and the night. No significant difference between daytime and nighttime intensities was found, greater than the experimental uncertainty, amounting to five percent of the total intensity, up to elevations of 24 km (19 mm Hg). Flights three months apart show good agreement. The observations indicate the absence of any solar component in the penetrating radiation at 24 km, of more than five percent of the total intensity at that level. One daytime flight was caused to level off at 20 km, and remained at that level for about seven hours. During this time a prominent solar flare took place. No increase in counting rate as great as two percent was observed. It is concluded that the radiation from a solar flare is not sufficiently penetrating to enable it to reach a depth of 0.5 m water equivalent in the atmosphere.

50. Difference in the Absorption of Cosmic Rays in Air and Water and the Mean Life of the Barytron. T. H. JOHNSON AND M. A. POMERANTZ, *The Bartol Research Foundation of the Franklin Institute and the University of Pennsylvania.*—The intensity j_1 of the hard component of the cosmic radiation after passage through the atmosphere and an additional 8.9 meters of water contained in a large cylindrical tower has been compared with the intensity j_2 of the same radiation after passing along an inclined path at 58° from the zenith through an equal mass of air. A quadruple coincidence train of aperture less than that of the tower was mounted in a room beneath and counting rates were recorded alternately in the two positions. Lead plates of total thicknesses 17 cm and 38 cm, respectively, were interposed between the counters in two independent experiments. The ratio of counting rates in the two positions had the values $j_2/j_1=0.60\pm0.02$ with 17 cm lead; and 0.68 ± 0.02 with 38 cm lead. The lower intensities from the air path agree with Ehmert's experiments and may be interpreted as suggested by Heisenberg and Euler by the higher probability of spontaneous disintegration of the barytrons during the longer time required for traversal of the inclined path. The values of j_2/j_1 which we have measured give the mean life of a barytron at rest between 2 and 4×10^{-6} sec. depending upon our choice of rest mass, energy distribution and rate of loss of energy in air, water and lead.

51. Band Spectra in Nitrogen at Atmospheric Pressure. A Source of Band Spectra Excitation. OLIVER R. WULF AND EUGENE H. MELVIN, *Bureau of Chemistry and Soils, Washington, D. C.*—An apparatus, essentially an ozonizer, consisting of a condenser, a portion of the dielectric of which is a gas, has been used as a source of band spectra excitation. In such a source the temperature of the gas remains practically that of the walls. Nitrogen bands $A\rightarrow X$ have been photographed in emission at atmospheric pressure under resolution sufficient to permit measurement of part of their rotational structure. In this source the first positive group is considerably weaker relative to the second positive group than in an ordinary glow discharge. The rather striking difference between this type of source and a high voltage low current arc at atmospheric pressure is illustrated by some band spectra in oxygen containing a small amount of nitrogen.

52. Raman Spectra of Phenyl-1-Propyne-1 and Chloro-2-Phenyl-1-Acetylene. FORREST F. CLEVELAND AND M. J. MURRAY, *Lynchburg College.*—Previous work[1] on the Raman

spectra of derivatives of phenylacetylene has been extended to include (I) $C_6H_5C\equiv CCl$ and (II) $C_6H_5C\equiv CCH_3$. Interest has been focused primarily upon the lines in the neighborhood of 2220 cm^{-1} and the technique of diaphragming the camera lens to improve the definition and thus to detect possible splitting of lines in this region has been continued. Two lines have been observed in this region for I, 2203(2) and 2222(10), and four lines for II, 2210(8), 2230(4), 2246(10), and 2262(6). A total of 22 frequencies were observed for I. Fourteen of these agree with the results of Bourguel and Daure.[2] Additional frequencies, 334(3), 654(1), 754(2), 1208(1), 1224(2), 2203(2), 2977($\frac{1}{2}$), and 3079(2), have been observed in the present work, while the frequency 766, listed by Bourguel and Daure, has not been observed. A total of 36 frequencies have been observed for II. Sixteen of these agree with frequencies obtained by Bourguel and Daure[2, 3] and also by Gredy.[4] Seven agree with values listed by Bourguel and Daure, but not found by Gredy. Three frequencies, 1443, 1493, and 2253, listed as single by Bourguel and Daure and by Gredy, appear as doublets in the present work. Seven frequencies, 953(1), 1053($\frac{1}{2}$), 1245(1), 1286(2), 2231(4), 3111(1), and 3143(1), were not observed by the above workers. Frequencies 2974 and 3017, listed by Gredy, were not found by Bourguel and Daure or in the present work. It is a pleasure to acknowledge grants in aid of this research by Sigma Xi, the Virginia Academy of Science, and the American Association for the Advancement of Science.

[1] Phys. Rev. **53**, 330, 931 (1938); J. Am. Chem. Soc. **60**, 2664 (1938).
[2] M. Bourguel and P. Daure, Bull. Soc. Chim. **47**, 1349 (1930).
[3] M. Bourguel, Comptes rendus **195**, 311 (1932).
[4] Blanche Gredy, Thèses, Paris, 1935; Comptes rendus **196**, 1119 (1933).

53. Van der Waals Forces in the Boron Molecule. JULIAN K. KNIPP, *Purdue University*.—A very important class of molecules arises from atoms not having spherical symmetry. An example is the boron molecule which dissociates into two boron atoms in normal P states. The interaction energy of these molecules depends on the relative orientation of the atomic angular momenta and at large interatomic distances is due to the quadrupole-quadrupole term in the molecular Hamiltonian. At smaller distances the van der Waals forces become important. The quadrupole-quadrupole energy is a first-order effect with an inverse fifth dependence on the interatomic distance and the van der Waals energy is a second-order effect coming from the dipole-dipole term in the Hamiltonian and having an inverse sixth power dependence. These effects are treated simultaneously. Potential energy curves are followed from large separation distances to distances where exchange and other effects become important. The constants which enter are estimated with the aid of the Hartree-Fock atomic model.

54. On Depolarization of Neutrons Passing Through Ferromagnetic Media. O. HALPERN AND TH. HOLSTEIN, *New York University*.—A beam of neutrons which is partially polarized undergoes depolarization when passing through a nonsaturated ferromagnetic medium. This is because of the existence of randomly oriented domains of spontaneous magnetization in the material. These haphazardly directed magnetic fields lead to a "Brownian movement" of the spin axis of the neutrons. The treatment is straightforward in the case that the period of the Larmor precession is large compared to the time spent in one domain of magnetization. If this condition is not satisfied, more complicated phenomena obtain. Under simple conditions the original polarization decreases as $e^{-(\omega^2\delta d)/3v^2}$ (ω=Larmor frequency, v=neutron velocity, δ=thickness of domain, d=total thickness traversed). Observations in this field could lead to a new estimate of the size of these "Barkhausen domains" and to information about the amount of spontaneous magnetization. The phenomena are also of interest in connection with observations on the polarization of neutrons transmitted through, or scattered by a ferromagnet.

55. Depolarization Effects in the Double Scattering of Electrons. M. E. ROSE AND H. A. BETHE, *Cornell University*.—In an attempt to explain the discrepancy between Mott's theory[1] and Dymond's experiments[2] on the polarization of electrons, we have investigated theoretically the depolarizing effect of (1) multiple elastic scattering, (2) inelastic scattering with spin change, (3) exchange scattering with spin change. Multiple scattering is no doubt present with the 2.5×10^{-5} cm Au foils used by Dymond, but the depolarizing effect caused by such scattering is negligible. For a screened Coulomb field the depolarization is of order one percent whereas 90–100 percent is needed to reconcile theory and experiment. The depolarization arising from inelastic scattering, in which the incident electron changes spin direction, and from exchange scattering, in which the exchanged electrons have opposite spin directions, is much smaller than the depolarization caused by multiple scattering. This is largely because of the fact that for the inelastic scattering, the scattering angles and energy losses are small; and for the exchange scattering only the valence electron of Au can participate in the exchange process.

[1] N. F. Mott, Proc. Roy. Soc. **135**, 429 (1932).
[2] E. G. Dymond, Proc. Roy. Soc. **145**, 657 (1934).

56. Retarded Interaction Between Electrons. IRVING S. LOWEN, *New York University*.—The expression for the retarded interaction between two electrons, first given by Breit,[1] can be obtained without the use of the perturbation theory in the following fashion. If in the Hamiltonian for the interaction of matter with the radiation field, from which the longitudinal waves have been eliminated, the term quadratic in the transverse field amplitudes be combined with the term giving the interaction with matter, which is linear in the field amplitudes, by completing the square, one has left over a term in which the field amplitudes do not appear and which is just the expression for the retarded interaction between two electrons given by Breit. The new field Hamiltonian can then be transformed back into its original form by a contact transformation.

[1] Phys. Rev. **39**, 616 (1932).

57. Catalytic Activity and Crystal Orientation of Metal Films. OTTO BEECK, A. WHEELER AND A. E. SMITH, *Shell Development Company*.—Metal films of high and reproduc-

ible catalytic activity were prepared by condensation of their vapors on glass in an atmosphere of an inert gas (N_2, A, etc.) at low pressures and room temperature. Nickel films thus prepared in 1 mm Hg of N_2 or A were shown by electron diffraction (see also following abstract) to be completely oriented with their (110) plane parallel to the backing, the two remaining axes showing random distribution. Iron films were oriented with their (111) plane parallel to the backing. Unoriented nickel films of 5.5 times lower activity were obtained by condensation of nickel vapor in high vacuum, the films showing a slight orientation when more than 10,000 atoms thick. The high vacuum films possess four times the electrical conductivity of the films condensed in gas and one-half of their surface as found by adsorption measurements of H_2 at room temperature and of CO at liquid-air temperature. For both film types catalytic activity, surface area and conductivity increase with film thickness, the last two being linear functions of the thickness. This shows that the interior of the film is accessible through pores. After elimination of the surface factor the oriented gas-condensed films have still more than two and one-half times the catalytic activity of the unoriented high vacuum films. The larger distances between the nickel atoms in the (110) plane are probably the seat of this greatly enhanced catalytic activity. The investigation was extended to Fe, Pd and Pt with essentially similar results.

58. Preparation and Structure of Oriented Metal Films. A. E. SMITH AND OTTO BEECK, *Shell Development Company, Emeryville, California.*—Although the tendency for metal films prepared by condensation to take preferred orientation has long been observed, conditions during deposition that produce this effect are not well understood. The observation that metal films of high catalytic activity prepared by condensation on glass at room temperature in an inert gas (N_2, A, etc.) of low pressure also exhibit a high degree of orientation (see also preceding abstract) has helped considerably to clarify this problem. The degree of orientation induced by the presence of an inert gas during condensation increases with the pressure from high vacuum to 1–2 mm Hg. Film thickness has an important influence on the degree of orientation. On glass surfaces which are well baked out nickel films 3000 atoms thick are completely oriented when deposited in 1 mm Hg of N_2 or A, whereas films of the same thickness deposited in high vacuum are unoriented, though they show a slight orientation with increasing thickness. The influence of air, oxygen, and water vapor on the formation of oriented films will be discussed. Besides nickel, various other metals—iron, cobalt, palladium, platinum, and also copper and gold—have been investigated. It is of special interest that iron (cubic body centered) orients with the (111) plane parallel to the backing whereas Ni (cubic face centered) exhibits the (110) plane. A possible mechanism for the orientation has been deduced from these results.

59. Double β-Disintegration and the Theory of the Neutrino. W. H. FURRY, *Harvard University.*—There are two possible general theories of β-disintegration. If the neutrino obeys the same sort of Dirac theory as the electron, one may suppose that the emission of a neutrino accompanies that of a positron, and an antineutrino must accompany the emission of an electron. In Majorana's modification of the Dirac theory there are no antineutrinos, and the emission of either an electron or a positron has associated with it the emission of a neutrino. Both pictures give the same results for ordinary β-disintegration. In the case of double β-disintegration, however, there is a marked difference. On the original Dirac theory the emission of two electrons (or positrons) must be accompanied by that of two antineutrinos (neutrinos), and, for $\Delta M \sim 0.002$ mass unit, the lifetime is of the general order of magnitude 10^{24} years. On the Majorana theory the disintegration can take place without any neutrino emission, and the lifetime, for $\Delta M \sim 0.002$ mass unit, is something like 10^{16} years (Fermi Ansatz) or 10^{9} years (K-U Ansatz). More accurate investigation of the masses and stabilities of isobars may accordingly make possible a decision between the two theories.

60. Thermal Equilibrium and Microscopic Entropy. EDWIN C. KEMBLE, *Harvard University.*—Exceptions to the second law of thermodynamics due to fluctuation phenomena can be eliminated by two modifications of procedure. The first is to replace assertions regarding individual systems in thermodynamics by corresponding statements regarding Gibbsian assemblies of identical independent systems similarly prepared. The second is to discard the common definition of thermodynamic equilibrium as the ultimate state approached by any system isolated for a long period of time. We redefine thermodynamic equilibrium as follows. Let each member of an assembly of systems A be placed in thermal contact with a corresponding member of an assembly of constant temperature baths of very large heat capacity, the combined system being isolated. The baths must have a common initial temperature T as measured by a thermometer. The ultimate state of the assembly of systems A is then called a state of thermodynamic equilibrium at temperature T. The redefinition of thermodynamic equilibrium obviates difficulties encountered by von Neumann in connection with his "microscopic" definition of entropy in quantum statistical mechanics. The state of thermodynamic equilibrium becomes identical with the canonical assembly of Gibbs and with the state of maximum microscopic entropy S_m for the appropriate energy. A redefinition of the reversible path gives

$$dS_m = (dQ/T)_{\text{rev}}.$$

61. On the Derivation of Nuclear Forces from Field Theories. EUGENE FEENBERG, *Washington Square College, New York University.*—The Hamiltonian for a system consisting of a Yukawa field and heavy particles (neutrons, protons) contains (a) a field Hamiltonian which is quadratic in the field amplitudes, (b) a coupling term linear in the field amplitudes, (c) the Hamiltonian operators of free heavy particles. Nuclear forces may be computed by a perturbation method[1] or by applying a canonical trans-

formation[2] to the Hamiltonian of the total system. The two methods do not yield the same forces in all cases, but do agree when the heavy particles are constrained to move in a prescribed manner (in this case, Part (c) of the Hamiltonian is omitted, which amounts to neglecting the reaction of the field on the heavy particles when they absorb or emit quanta of the field). Parts (a) and (b) can be combined into one term by completing the square and subtracting a function which is identical with the nuclear potential given by the second order perturbation calculation when recoil effects are neglected. A canonical transformation then reduces the Hamiltonian to the form (a) plus a sum of interaction potentials between pairs of particles. If Part (c) is included in the Hamiltonian a modified form of this procedure yields forces which agree, where comparison is possible, with the approximately relativistic forces computed by Breit.[3]

[1] N. Kemmer, Proc. Roy. Soc. **166**, 127 (1938).
[2] E. C. G. Stueckelberg, Comptes rendus **207**, 387 (1938).
[3] G. Breit, Phys. Rev. **51**, 248 (1937).

62. Nuclear Reactions Produced by 6.5 Mev Protons. L. A. DuBridge, *The University of Rochester.*—A survey of the radioactivities induced by 6.5 Mev protons in all the readily available elements of the periodic table has been partially completed by the members of the Rochester group. Definite activities are observed in elements as heavy as $_{76}$Os and there is some evidence for a reaction in $_{90}$Th. Most of the elements above $_{52}$Te, however, show no activity. Where identification is possible the reactions are found to be of the $p-n$ type in nearly all cases. An interesting reaction of the (p,p) type leading to a radioactive excited state of In^{115} has been found by Barnes.[1] Over 30 $(p-n)$ reactions leading to radioactive isotopes already produced by other methods and 20 leading to new isotopes have been found and will be summarized. The thick target yields have been determined in many cases and are found to decrease regularly with increasing atomic number. The actual values range from 500 radioactive atoms per 10^6 protons for $Li^7(p-n)Be^7$ down to 0.1 per 10^6 for $W(p-n)$Re.

[1] Chicago Meeting abstracts, 1938.

63. Proton-Proton Scattering. N. P. Heydenburg, L. R. Hafstad and M. A. Tuve, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—During the past year we have made a new series of observations on the scattering of protons by protons in the range 700 kv to 900 kv, using the linear amplifier for detection. A completely new scattering apparatus was used, the voltmeter was recalibrated, and the scattering from gold was used as a current-integrator. The calibration was reduced to absolute values by observing the scattering of protons by spectroscopically pure argon. Although completely independent, the results are in agreement with our observations of two years ago. The Mott-ratios differ at most by five percent from our earlier values, which were subject to fluctuating errors arising from the current measurements.

64. The Kinetic Energy of the Electrons in the Wigner-Seitz Theory. R. Landshoff, *University of Minnesota.*—The total energy of a system as calculated from approximate wave functions is a much better approximation to the actual energy than either the kinetic or the potential energy is to its actual values. The comparison of the theoretical and experimental values of the kinetic energy is thus a better criterion for the degree of approximation attained by a given wave function than the comparison of the values of the total energy. Bridgeman and Slater have pointed out the value of the virial theorem for the calculation of the kinetic energy. The application of this theorem on solids under stress leads to the expression

$$T=-E-(X_x+Y_y+Z_z)V$$

for the kinetic energy. The electronic constitution of metals in the theory of Wigner and Seitz will be discussed from this aspect. It is necessary to modify the theory slightly. As long as only the calculation of the total energy was desired, it was sufficient to express the interaction of the electrons in the atom by means of a simple potential function. The calculation of the kinetic energy requires a more thorough consideration of the electronic interaction. The change does not affect the basic idea of the Wigner-Seitz scheme.

65. The Scattering of Protons by Protons. R. G. Herb, D. W. Kerst, D. B. Parkinson and G. J. Plain, *University of Wisconsin.*—The cross section for scattering of protons by protons has been measured for angles from 15° to 45° at voltages of 860, 1200, 1390, 1830, 2105, and 2392 kv. The general design of the scattering chamber follows that used by Tuve, Heydenburg, and Hafstad.[1] However, modifications were made in many details and a different system is used for measurement of incident proton current. The proton beam after traversing the scattering chamber passes through an aluminum foil into an evacuated region and enters a collector cup. Observed scattering cross sections at 15° are close to Mott values for all voltages. Ratios of observed cross section to Mott cross section rise with increasing angle and with increasing voltage. At 45° the ratio rises from 3.90 at 860 kv to 42.9 at 2392 kv. At 1830 kv measurements were made at scattering angles up to 60° and the scattering cross section showed the theoretically expected asymmetry ($\cos\theta$) about 45°. Precautions were taken to avoid systematic errors due to factors such as generator voltage, measurement of incident proton current, and the counting of scattered protons. As an additional check on the proton-proton measurements the scattering from krypton and argon was investigated for voltages between 850 kv and 2440 kv.

[1] M. A. Tuve, N. P. Heydenburg, and L. R. Hafstad, Phys. Rev. **50**, 806 (1936).

66. Interpretation of Experiments on Proton-Proton Scattering. G. Breit, H. M. Thaxton and L. Eisenbud,* *University of Wisconsin.*—The data of Herb *et al.* give no evidence for the presence of p or d wave anomalies in agreement with theory. The phase shift $|K_1|$ is probably

less than 1° at 2400 kev while a repulsion $38e^{-16r^2}$ n.u. gives $K_1=-0.4°$. The values of the phase shift K_0 are fitted nicely using a constant potential -11.3 Mev superposed on the Coulombian repulsion through a distance e^2/mc^2. This potential is 0.3 Mev shallower than the corresponding $^1S_{\pi\nu}$ value needed for the value 16.5×10^{-24} cm² of the free slow neutron-proton scattering cross section. The data determine the effective range of the $\pi-\pi$ potential with an apparent accuracy of 5 percent. Preliminary probable values are: 0.97 e^2/mc^2 for constant potential; $\alpha=21.(6)$, $A=51.(4)$ for $Ae^{-\alpha r^2}$. Experiment disagrees with $\alpha=16$. For $\alpha=20$: $A_{\pi\pi}=47.4$, $A_{\pi\nu}=48.3$. An error of 1 percent in scattering gives 0.2 percent error in $A_{\pi\pi}$. This range agrees with that suggested by Rarita and Present who used the binding energy of H^3 and, according to them, is in contradiction with He^4. Unpublished results of Tuve *et al.* are taken account of above. Possible velocity dependence: $\delta\alpha=2$ corresponds roughly to $\delta A=0.7$ percent per 2400 kev.

* Now at Princeton University.

67. Proton Induced Activity of Manganese. ARTHUR HEMMENDINGER, *University of Oklahoma.**—The reaction $Cr^{52}(p,n)Mn^{52}$ at 6.6-Mev proton energy produces isomers with periods of 21.3 min. and 7.4 (±1.0) days. These are positron emitters with maximum positron energy of 2.2 Mev (21 min.) and 0.77 Mev (7 days). There is gamma-radiation of energy 1.2 Mev (21 min.) and 1.0 Mev (7 days). By a comparison of the ionization due to the annihilation radiation and that due to the 1.2-Mev radiation (the two are separated by absorption measurements) it can be shown that the 21-min. isomer emits 2 gamma-quanta per positron, and this is just what one would expect as a consequence of the high threshold (6.4-Mev proton energy) for the formation of the 21-min. isomer. The gamma-radiation from the 7-day isomer is 10 times as intense as that from the 21 min. In addition to positron emission followed by the radiation of one gamma-quantum, there must be the alternative mode of disintegration by K-electron capture, leaving the nucleus in the 1 Mev excited state.

* A report on work done at the University of Rochester during the summer of 1938.

68. The Iteration Method. GABRIEL HORVAY, *Columbia University.*—The averages of the powers of H, $\langle H^k\rangle=\int\Psi_0{}^*H^k\Psi_0 d\tau$, in terms of the approximate wave function Ψ_0, yield valuable information about the eigenvalue problem, $H\varphi=E\varphi$. For example, the variational principle applied to the wave function $\Psi=\Sigma_0{}^n\lambda_k\Psi_k$ ($\Psi_k=H^k\Psi_0$) leads to the secular equation of $(n-1)$th order, $|E\langle H^{i+j}\rangle-\langle H^{i+j+1}\rangle|=0$. The lowest root of this equation is an upper bound for the lowest eigenvalue, E_0, of H. If Ψ_0 is a very close approximation to the ground state eigenfunction, then the $\langle H^k\rangle$'s also furnish interesting lower bounds for E_0.[1] Another method of approach is the following. The knowledge of the averages for $k=0, 1, \cdots, n$ permits the determination of the polynomials in η, $K(k,\eta)=\Sigma_0{}^\infty\epsilon_i{}^2(E_i-\eta)^k$ ($k=0, 1, \cdots, n$), where the E_i are the eigenvalues of H and ϵ_i the Fourier coefficients of Ψ_0 with respect to the true eigenfunctions of H. For values of the parameter $\eta>E_0$, there is a marked difference in behavior of K for k odd and k even. For $\eta<E_0$ these differences disappear. Thus a study of the tentative curves $K(k)$ which can be drawn for various η permits an estimate of E_0. This method, when applied to the oxygen problem in Wigner's first approximation, seems to indicate that a binding energy slightly greater than that of four α-particles is not an unreasonable estimate.

[1] Results of Weinstein and MacDonald, discussed in Pauling and Wilson, *Introduction to Quantum Mechanics*, Chapter VII. Further discussion will appear in a forthcoming issue of the *Physical Review*.

69. Complex Roots of Fifteenth-Degree Polynomials. S. LEROY BROWN, *University of Texas.*—A mechanical synthesizer[1] with thirty harmonic elements (fifteen sine and fifteen cosine components) is converted into a multi-harmonograph by communicating the sum of the sine-component motions to vertical motion of a tracing point while the sum of the cosine components produces backward and forward motion of the drawing board in a horizontal direction. Each term a_nz^n of the polynomial may be expanded by DeMoivre's theorem into $a_nr^n(\cos n\theta+i\sin n\theta)$ where r is a modulus of z (complex). When the coefficients a_n are real, set the n harmonic components (sine and cosine) of the machine to the respective amplitudes of a_nr^n and the trace obtained will show all values of $-a_0$ (real, imaginary, and complex) for which $r(\cos\theta+i\sin\theta)$ is a root of the polynomial. The modulus r may be so chosen that the trace goes through a particular $-a_0$ and, thereby, a root (or roots) of a particular polynomial is determined (root of modulus r and angle θ, angle being determined by angle of the fundamental on machine as the trace goes through the position $-a_0$). Since there are fifteen multiple harmonic components in the machine, the complex roots of a 15th-degree polynomial may be determined; and, for lower degree polynomials, only the lower harmonic components of the machine are needed. If the coefficients a_n of the polynomial are complex, as well as the roots, the procedure is similar to the one outlined above except that the so-called sine and cosine components of the machine must each be set to an amplitude (magnitude of a_nr^n) and to an angle (angle of a_n).

[1] "A Mechanical Synthesizer-Analyzer," Phys. Rev. **53**, 333 (1938).

70. Soft X-Ray Emission Spectra of Valence Electrons. H. W. B. SKINNER, *University of Bristol,* AND H. M. O'BRYAN, *Georgetown University.*—Emission spectra of simple solid compounds in the region between 18A and 300A indicate that the widths of the energy bands of their valence electrons vary from about 0.5 electron volt for halides to over 30 ev for certain oxides. These soft x-ray spectra show greater detail of the structure and nature of the valence electron states than can be obtained from either optical absorption or ordinary x-ray emission. With sufficient care both contamination and decomposition within the x-ray tube can be avoided for many compounds and spectra obtained which are free from impurity and metallic lines. The halide ions in the very polar alkali halide crystals show, in addition to the structure expected from atomic states, shorter wave-length structure some-

what similar to x-ray satellites. The widths of the halide bands are much less than predicted by theory. Spectra emitted by transitions of the valence electrons into the K shells of both the positive and the negative ions of BeO and B_2O_3 have been observed. There is no close correspondence in the widths and structure of these positive and negative ion spectra of any compound so far studied. This indicates that the distribution and character of the energy states of valence electrons must be quite different in the vicinity of the positive ions from that near the negative ions.

71. Excitation Potential of $L\alpha$ Satellites. R. E. SHRADER AND F. K. RICHTMYER, *Cornell University.*—Coster and Kronig[1] have suggested that the doubly-ionized state required for the production of x-ray satellites can result from an Auger transition. Their theory assumes that the $L\alpha$ satellites arise from the atomic transition, $L_{III}M_{IV,\,V} \rightarrow M_{IV,\,V}M_{IV,\,V}$, and that the initial state is obtained as a result of the Auger transition, $L_I \rightarrow L_{III}M_{IV,\,V}+\epsilon$, where ϵ represents the kinetic energy of the ejected $M_{IV,\,V}$ electron. This assumption seems to be confirmed by recent measurements of the intensity (relative to the $L\alpha_1$ line) of the $L\alpha$ satellites of Au(79) as a function of tube voltage. Using a well-filtered voltage supply, the authors have found that at low voltages the satellite intensity decreased with decreasing tube voltage and are not observed for voltages below the excitation potential of the gold L_I state.

[1] D. Coster and R. deL. Kronig, Physica **2**, 13 (1935).

72. Arrangement of Atoms and Molecules in Extremely Thin Films. L. H. GERMER, *Bell Telephone Laboratories, Inc.*—Films of various inorganic substances, produced by vaporization in high vacuum upon organic supporting foils, have been investigated by electron diffraction by the transmission method. Varying amounts of material have been vaporized from V-shaped tungsten ribbons upon foils supported across narrow slits.[1] Mean thickness of each of these films has been calculated from the total amount of vaporized material, distance of the film from the tungsten ribbon, and calibration of the apparatus based upon weighing the material making up a known area of film. Many substances have been studied, from gold (atomic number 79) to beryllium (atomic number 4). For the heavier materials, at least down to copper (atomic number 29), interpretable diffraction patterns can be obtained from films which contain only enough material to form a single layer of atoms or molecules. *In all cases true three dimensional crystals are formed.* In films of caesium iodide, which forms unusually large crystals, the mean linear dimension of a crystal is about 100A in a film having an average thickness of only 1.8A. In films of appreciable thickness ionic compounds form, in general, larger crystals than metals.

[1] See Fig. 4, Proc. Nat. Acad. **23**, 390 (1937).

73. Measurement of the Self-Diffusion of Copper. J. STEIGMAN, *Columbia University*, W. SHOCKLEY AND F. C. NIX, *Bell Telephone Laboratories.*—The high speed rotating cathode technique of electroplating has been applied to the separation from the parent zinc of radioactive copper, transmuted from zinc by neutron bombardment. The radioactive copper, together with a trace of ordinary copper, used as a carrier, is plated upon a copper disk, forming a very thin layer.[1] Spectrochemical tests fail to show the presence of zinc in most instances and in those cases where traces of zinc were found, its presence did not appear to influence the results. Quadrants cut from the disk are clamped face to face between two copper blocks and heated in an evacuated quartz tube, thus permitting the radioactive copper to diffuse into the bulk copper. Measurements of the initial and final activities observed from the surface of the disk supplemented by the known values for the half-life of radioactive copper and the absorption coefficient for the copper radiation in copper yield values for the diffusion constant. The results indicate that the rate of self diffusion of copper is considerably smaller than the value predicted by Rhines and Mehl[2] from an extrapolation to pure copper of the rates of diffusion of small percentages of Si, Al, Zn, Sn and Be in copper.

[1] J. Steigman, Phys. Rev. **53**, 771 (1938).
[2] F. N. Rhines and R. F. Mehl, Am. Inst. Min. and Met. Eng., Technical Pub. No. 883, Class E, Inst. of Metals Div., No. 250. Published in Metals Technology, Vol. 5, No. 1, Jan. 1938.

74. A Dilatometric Study of the Order-Disorder Process in Single Crystals of Copper-Gold Alloys. FOSTER C. NIX AND D. MACNAIR, *Bell Telephone Laboratories.*—Dilatometric studies were made on single crystals of copper-gold alloys, made in a vacuum furnace, containing 22, 28 and 30 atomic percent gold. For temperatures below about 250°C, the temperature where disordering sets in on heating of ordered alloys, the instantaneous or true temperature coefficient of expansion of previously well-ordered alloys is constant. This "disordering" temperature is only slightly dependent on composition for alloys in the composition range from 22 to 30 atomic percent Au. For higher temperatures, the temperature coefficient of expansion increases very rapidly with increasing temperature, passes through a maximum, and then declines until a constant value is again reached. The latter value remains constant up to the highest temperatures studied, which in some cases reached 600°C. The decline to that value above the maximum covers a temperature range varying from 8 to 15°C depending on the composition. Plots of temperature coefficient of expansion-*versus*-temperature for disordered alloys, obtained by quenching in oil from 550°C, display a decrease in the temperature coefficient of expansion near 120°C.

75. X-Ray Atom Factors for Zn in ZnO. K. LARK-HOROVITZ AND C. H. EHRHARDT, *Purdue University.*—Electron diffraction patterns of zinc oxide show an anomalous intensity distribution as compared with the x-ray pattern.[1] As possible explanations were suggested: A shift of the electron cloud,[2] in respect to the nucleus, a distortion of the crystal lattice,[3] a distortion of the electron cloud and particularly of the valence electrons,[4] or dynamical reflection of the electron waves not taken into account in the kinematic theory. As additional experimental evidence x-ray diffraction patterns from a flat sample of zinc oxide

using monochromatic Cu $K\alpha$-radiation have been obtained photographically, and their relative intensities measured. From these results it is possible to calculate the x-ray atom factors for Zn and thus to construct theoretical electron diffraction curves. These reproduce the essential features of the electron diffraction experiments of K. Lark-Horovitz and H. J. Yearian. Therefore, the change in the value of F in the expression for electron diffraction intensity $[(Z-F)/(\sin^2\theta/\lambda^2)]^2$ must be primarily responsible for the observed intensity anomaly and not application of the kinematic theory. This is also in agreement with the explanation by James and Johnson,[4] since the x-ray intensities calculated from our experiments are in better agreement with the theoretical values obtained by using the distorted charge distribution as calculated by James and Johnson than with the symmetrical distribution of Pauling and Sherman.

[1] H. J. Yearian and K. Lark-Horovitz, Phys. Rev. **42**, 405 (1932).
[2] H. J. Yearian, Phys. Rev. **48**, 631 (1935).
[3] V. A. Johnson and L. W. Nordheim, Phys. Rev. **51**, 1002 (1937).
[4] V. A. Johnson and H. M. James, Phys. Rev. **53**, 327 (1938).

76. LiF Achromats for Covering Large Spectral Ranges. C. HAWLEY CARTWRIGHT, *Massachusetts Institute of Technology*.—LiF corrected by SiO_2 is especially suited for an achromatic lens for covering a broad spectral range. This is due to the small dispersion of LiF and the optical constants of SiO_2 (Ord. ray) combining favorably with those of LiF so as to give relatively long focal lengths to the lens elements and $df/d\lambda=0$ for two wave-lengths instead of for only one, as is usual for a combination of two materials. Working with Professor Stockbarger, a corrected doublet was built which is calculated to be achromatic to ± 0.5 percent from 1800A to about 20,000A. A triplet of SiO_2-LiF-SiO_2 corrected for spherical aberration and coma is being built which should be achromatic to ± 0.25 percent from 2300A to 14,000A. A corrected doublet of LiF and CaF_2 was designed and built for the ultraviolet region between 1300A and 1800A.

77. A New Nitrogen Afterglow Spectrum. JOSEPH KAPLAN, *University of California, Los Angeles*.—An interesting spectrum of a nitrogen afterglow at fairly high pressures (about 10 mm) is presented because every hitherto observed feature of nitrogen afterglows is on the plate, as well as two new characteristics. The first of these is the Goldstein-Kaplan band system of nitrogen. These bands correspond to a transition from a level at 12.05 volts to the $B^3\pi$ level (the level on which the well known first-positive bands originate). Their presence in this afterglow in company with the first-negative bands of N_2^+; the new 3466.3 line of atomic nitrogen, the Vegard-Kaplan bands, the second-positive and first-positive bands, indicates that they too may play a significant role in the spectrum of the light of the night sky and in auroral spectra. The second of these characteristics is the diminution with pressure of the two transitions from metastable states, i.e., the 3466.3 line and the Vegard-Kaplan bands. This too will probably be of some interest in the discussion of problems of the upper atmosphere.

78. A Recording Generating Voltmeter for Lightning Studies. E. J. WORKMAN AND R. E. HOLZER, *University of New Mexico*.—An instrument for recording the surface field intensity under active thunder storms is described. The assembly is contained in a weatherproof iron box (10″×10″×12″ high) which has a false top, above the weather lid, under which a plate rotates at 300 r.p.m. The plate consists of two opposite quadrants of a disk and is insulated from the vertical motor shaft which extends through the weather cover. Water baffles are provided. The top cover is cut out in such a way as to expose the quadrants twice during each revolution in which positive ground contact is made. In intermediate positions contact is made to an electrometer needle. The quartz electrometer is a modified quadrant type with deflections in a vertical plane and plates 22 volts above and below ground. The sensitivity of the instrument is adjusted to record fields from +1000 to −1000 volts/cm on a standard 16 millimeter negative which is sprocket fed past a 0.002″ slit at 15 feet per day from 100-foot magazines. Recorded deflections follow field changes with time resolution appropriate to the slit width. Five of these instruments have been used synchronously on storms, and the performance is demonstrated with prints from the records.

79. A Vacuum Interferometric Dilatometer with Photographic Recording for Measuring Thermal Expansion of Metals and Alloys at Elevated Temperatures. FOSTER C. NIX, *Bell Telephone Laboratories*.—A recording dilatometer especially adapted to the precise measurement of thermal expansion of metals at elevated temperatures has been constructed. The two polished fused silica plates of the interferometer are separated by the three small specimens to be studied, and the lower disk serves also as a refraction thermometer.[1] The fused silica plates with specimens are mounted in a vacuum furnace which is heated at any desired predetermined rate. A vacuum of 10^{-5} mm of Hg is maintained throughout the measurement to avoid any disturbance due to oxide formation. The optical system is essentially a Pulfrich viewing apparatus arranged to permit the photographic recording of the fringes produced by the combination of the two plates as well as the fringe system of the refraction thermometer. The fringes are photographed by means of a 16-mm motion picture camera at intervals varying from 10 seconds to 2 minutes; a small electric motor of adjustable speed is employed to trip the single exposure mechanism. The thermal expansion and temperature can be obtained from a knowledge of the number of fringes which pass the fiduciary marks of the two fringe systems.

[1] J. B. Austin, Physics **3**, 240 (1932).