Proceedings of the American Physical Society

Minutes of the Philadelphia, Pennsylvania, Meeting
December 26–28, 1940

THE 42nd Annual Meeting (the 239th regular meeting) of the American Physical Society was held at Philadelphia, Pennsylvania, on Thursday, Friday and Saturday, December 26, 27 and 28, 1940, in affiliation with Section B—Physics—of the American Association for the Advancement of Science. The regular sessions of the Society were held in the Towne School of Engineering of the University of Pennsylvania.

On Friday afternoon, December 27, at two-thirty o'clock the Society held a joint session with Section B of the American Association for the Advancement of Science and with the American Association of Physics Teachers in the auditorium at the Drexel Institute of Technology. The program consisted of three addresses: "Ions in gases" by Professor John Zeleny of Yale University, President of the Physical Society; "Higher energies" by Professor Ernest O. Lawrence of the University of California, retiring Vice President of Section B; and "Applications of nuclear physics" by Professor Robley D. Evans of the Massachusetts Institute of Technology. Professor A. L. Hughes of Washington University and Vice President of Section B presided.

On Friday morning, December 27, the Society held a joint session with Section E—Geology—of the American Association for the Advancement of Science. The program consisted of four invited papers as follows: "A hydro-physical approach to the quantitative morphology of drainage basins" by Dr. Robert E. Horton, Voorheesville, New York; "Problems of orogeny" by Professor Chester R. Longwell, Yale University; "Physical frontiers in seismology" by Professor L. Don Leet, Harvard University; and "The radio-elements in the water and sediments of the ocean" by Dr. William D. Urry, Geophysical Laboratory, Washington, D. C. Dr. Hugh D. Miser of the U. S. Geological Survey and Chairman of Section E presided.

On Friday evening, December 27, the Society held a joint dinner with the American Association of Physics Teachers at the Benjamin Franklin Hotel. The attendance was two hundred and twenty-two. Professor John Zeleny acted as toastmaster. A special feature of the dinner was the presentation of the Duddell Medal by The Physical Society, London, to Professor Ernest O. Lawrence in recognition of his services in the invention and development of the cyclotron. The presentation, which was to have been made by the late Lord Lothian, was made by Mr. Neville Butler, Counsellor and Chargé d'Affaires of the British Embassy. Before the presentation, Dr. R. H. Fowler, who is a member of The Physical Society, spoke on the importance of the cyclotron in the development of modern physics. Dr. Lawrence spoke briefly in accepting the medal. The other speakers were Dr. Richard M. Sutton, President of the American Association of Physics Teachers, and the President-Elect of the Physical Society, Dr. George B. Pegram.

Annual Business Meeting. The regular Annual Business Meeting of the American Physical Society was held on Friday afternoon, December 27, 1940, at two o'clock, President Zeleny presiding.

Dr. William H. Crew reported for the tellers that the following had been elected as officers for the year 1941:

President, George B. Pegram; *Vice President*, G. W. Stewart; *Secretary*, Karl K. Darrow; *Treasurer*, George B. Pegram; *Managing Editor*, John T. Tate; *Members of the Council*, Joseph C. Boyce and Arthur E. Ruark; *Members of the Board of Editors*, A. C. G. Mitchell, I. I. Rabi and George E. Uhlenbeck.

The tellers reported a vote of 262 to 11 in favor of the amendments to the Constitution, which had been approved by the Council and submitted to the Fellows for balloting in accordance with the provisions of the Constitution, Article X.

Amendments to the by-laws, which had been recommended by the Council for presentation to the Society, were submitted to the Fellows and adopted by a unanimous vote.

The Secretary reported that during the year 269 persons had accepted election to membership. He reported the deaths of 12 members, that 35 had resigned and 57 had been dropped. The membership as of December 24, 1940 was as follows: Fellows: 821; Members: 2802; Honorary Members: 5; Total membership: 3628.

The Treasurer presented a summary of the financial conditions of the Society. 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 1940 would be printed and distributed to the members.

On motion of Dr. A. L. Hughes the Society passed a resolution thanking the Local Committee, particularly Mr. Henry B. Allen, Professor Thomas D. Cope and Professor G. P. Harnwell, for their services in making arrangements for the meeting.

The meeting adjourned at two-twenty-five P.M.

Meeting of the Council. At the meeting of the Council held on Thursday afternoon, December 26, 1940, the deaths of two fellows were reported (William B. Cartmel and T. Russell Wilkins). Seven members were transferred from membership to fellowship and five candidates were elected to fellowship. One hundred and nine candidates were elected members. *Transferred from membership to fellowship:* Donald W. Kerst, Harold J. Kersten, Harry A. Kirkpatrick, Lyle W. Phillips, Norman F. Ramsey, Jr., Robert K. Waring, Martin D. Whitaker. *Elected to fellowship:* J. C. M. Brentano, Peter J. W. Debye, Wilfried Heller, Stanislaw Mrozowski, and Wolfgang Pauli. *Elected to membership:* Felix Adler, Charles O. Ahonen, L. Thomas Aldrich, Henry D. Arnett, Julius Ashkin, Frederick A. Babcock, Roger S. Bender, J. E. Binns, Joseph H. Blickman, John H. Bollman, Richard H. Bolt, Joseph S. Brock, Sidney H. Browne, Robert A. Buerschaper, T. Finley Burke, Thomas D. Carr, Howard A. Christensen, Fred Chromey, E. Lynn Cleveland, Bernard K. Croninger, Sidney M. Dancoff, Kenneth E. Davis, Max Delbrück, J. E. Dinger, Richard W. Dodson, W. Crawford Dunlap, Jr., Alfred A. Ebert, Jr., Lloyd G. Elliott, Victor R. Ells, Herbert F. Engelmann, Lewis I. Estep, Dwight T. Ewing, Robert E. Faires, Francis L. Friedman, Henry H. George, John R. Graham, Jr., Kenneth I. Greisen, Eugene Greuling, Harold H. Grossman, Edith Haggstrom, Maurice B. Hall, David Halliday, Clarence Hammer, Henry Harrison, T. N. Hatfield, Robert H. Hay, Mary S. Hewlett, John M. Hinkle, James M. Hush, Elmer S. Imes, Gene Irish, Arnold A. Jensen, Arthur S. Jensen, Toyozo Kambara, Erwin W. Kammer, J. Warren Keuffel, Joseph M. Kime, Gilbert W. King, Joseph J. Kleimack, Howard R. Kratz, William J. Kroeger, David Lawler, D. C. MacDonald, Charles E. Mandeville, Jordan J. Markham, Albert B. Martin, John H. Martin, Fred M. Mayes, Paul W. McDaniel, Richard P. Metcalf, Tomokuni Mituisi, Kiyotosi Miyazaki, Norman H. Moore, L. Tarver Morris, Byron F. Murphey, Thomas A. Murrell, Basanti D. Nag, Charles F. Otis, William E. Parkins, Clarence M. Parshall, Karl A. Parsons, Simon Pasternack, Gerald M. Petty, Carl B. Post, Jan A. Rajchman, B. P. Ramsay, René G. Rhodes, A. F. Robertson, Glenn M. Roe, Clifford M. Ryerson, Matthew L. Sands, Wayne W. Scanlon, Charles W. Sheppard, J. Oliver Shock, Ralph Simon, Richard L. Snyder, Jr., Lyman Spitzer, Jr., Robert L. Sproull, Guy A. Stone, Richard G. Stoudenheimer, Irvin H. Swift, John W. Trischka, Hirosi Ueda, Francis M. Walters, 3rd, Gerhard L. Weissler, Sherrerd B. Welles, Father Anthony J. Westland, David C. Whitmarsh, Jr., Dexter E. Woodford, and William M. Woodward.

The regular scientific program of the Society consisted of sixty contributed papers of which five, numbers 10, 17, 30, 41 and 44, were read by title. The abstracts of the contributed papers are given in the following pages. An Author Index will be found at the end.

HAROLD W. WEBB, *Acting Secretary*
Columbia University, New York, New York

Abstracts of Contributed Papers

1. Quantum Likelihood. E. C. Westerfield and W. B. Pietenpol, *University of Colorado.*—A statistical formula is developed for the likelihood that an arbitrarily chosen quantity q is a fundamental unit for a given set of data. An experimental datum frequently involves several quanta. When, as in the oil-drop experiment, the number of quanta involved in a single measurement is small and the experimental error is small compared with the value of the individual quantum, the number of quanta in each datum may be easily determined by inspection or by simple arithmetic procedures. However, when the probable error is of appreciable magnitude compared with the value of the quantum, the quantum nature of the phenomenon may be completely masked by the experimental error. Without a previous knowledge concerning the value or even the existence of a possible quantum, any set of data falls potentially into this borderline case. The formula developed for the quantum likelihood weights the data in accordance with their probable errors and hence is applicable only to data for which the probable errors are known or can be estimated. The mathematical quantity involved is a function of two variables and is tabulated graphically in order to apply the theory to a given set of data.

2. The Electron, a Quantum Unit in Nuclear Disintegrations. W. B. Pietenpol, *University of Colorado.*—The previously developed method of analysis for the likelihood that an arbitrary quantity is a fundamental unit is applied to a set of nuclear disintegrations. The data considered are those of the important reactions produced by deuterons and protons with the yielding of charged particles. Use is made of the experimental results summarized by Livingston and Bethe in their article on Nuclear Physics.[1] The 24 listed reactions with the corresponding energy evolutions and probable errors are considered. The results of the analysis are indicated by curves of quantum likelihoods for different energy values. The optimum values indicate that the mass energy of the electron is a possible unit in such nuclear processes.

[1] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 245 (1937), Table LXXII.

3. Proton Distribution in the O. P. Process. Everett C. Smith and Ernest Pollard, *Yale University.*—A recent study by Volkoff[1] of the theoretically expected proton distribution in the O. P. process indicates that a maximum in the yield should occur for proton energies slightly greater than the incident deuteron energies. It is found in studies of the elements of medium atomic weight that a large yield at about this value is always found. This yield can be ascribed to the O. P. process or to carbon contamination of the target. We have shown that very clean surfaces of chromium and nickel do not have appreciable N^{13} radioactivity after deuteron bombardment but give high yields of protons of about 3 to 4 Mev. These are therefore due to the true O. P. process. While group structure is apparent, an examination of the yields shows agreement with Volkoff's theory for chromium in that a maximum occurs at 4.1 Mev of half-width 2.1 Mev (predicted values 4.0 and 2.25, respectively), but apparently no agreement for nickel as the maximum is certainly below 2.5 Mev while the predicted value is 4.1 Mev.

[1] G. M. Volkoff, Phys. Rev. **57**, 866 (1940).

4. Energy Levels of Mg^{26} and Si^{30} formed by Deuteron Bombardment. Ernest Pollard and Richard F. Humphreys, *Yale University.*—In order to answer the question as to whether a final nucleus exhibits the same set of levels if formed in different manners, it is necessary to produce the same nucleus by bombardment of differing target elements. Among the better studied nuclei are Mg^{26} and Si^{30}, produced by alpha-particle bombardment of Na^{23} and Al^{27}, respectively, with emission of a proton. Studies of these protons indicate excited states for Mg^{26} at 2.3 and 4.0 Mev and for Si^{30} at 2.3, 3.6, and 4.9 Mev. The group structure of protons from $Mg^{25}(dp)Mg^{26}$ and $Si^{29}(dp)Si^{30}$ has been observed by coincidence counting. In the case of $Mg^{25}(dp)Mg^{26}$ three definite groups are obtained giving excited states at 1.85 and 3.00 Mev. The yield from silicon is rather less, but the work up to the present shows that the very long range protons occur in several groups, tentatively assigned to excited states at 0.9, 1.9, 2.8, and 3.6 Mev. It can thus be seen that the energy levels found depend on the type of reaction, which suggests a greater density of levels than found in any one transmutation and strong selection rules depending on the manner of formation of the final nucleus.

5. Possibility of Ternary Fission. R. D. Present, *Purdue University.*—Disintegration of the uranium nucleus into three fragments is dynamically possible with the excitation energies available from neutron capture. Such a ternary fission would be highly exothermic; the maximum energy release, occurring for a division into three equal parts, exceeds that for binary fission by nearly 20 Mev. The dynamical course of the fission follows a path over a potential energy surface in the configuration space whose dimensions represent the amplitudes of nth harmonic deformations of the liquid drop. A large positive amplitude deformation of the fourth-harmonic type creates a pair of tropical furrows, which deepen as the drop elongates, forming three collinear droplets connected by liquid necks. The relative sizes of the central and outer droplets depend on the amplitudes and phases of the second and fourth-harmonic deformations. Probable asymmetry causes a droplet to detach itself, leaving a distorted fragment which divides spontaneously. The energy surface shows no obstructions to passage of the configuration point from the saddle region into the region where ternary fission is indicated. The activation energy is the same as for binary fission, but the deviation from the path of steepest descent renders ternary fission less likely than binary fission for low neutron energies.

6. The Internal Temperature-Density Distribution in the Sun.—H. A. BETHE, *Cornell University*, G. BLANCH AND A. N. LOWAN, Mathematical Tables Project, Work Projects Administration, *New York City*, AND R. E. MARSHAK, *University of Rochester.*—An accurate determination has been made of the internal temperature-density distribution of the sun using the point-convective model. Account is taken of the variation of the guillotine factor throughout the star in contrast to all previous calculations on this model. The hydrogen content is adjusted so that the radiative envelope fits onto the convective core where all the energy-production is assumed to take place. The integration is started from the surface of the sun and it turns out that a hydrogen content of 35 percent by weight gives a good fitting of envelope to core, whereas hydrogen contents of 40 percent or 30 percent give evident lack of fitting in opposite senses. The central temperature is 25.7×10^6°C and the central density 110 g/cm^3; values considerably higher than those usually taken for the sun. The carbon cycle now leads to an energy production about 100 times too large. Since 98 percent of the luminosity is contributed by the convective core, the assumptions underlying the point-convective model are self-consistent. The variation of the molecular weight caused by progressive ionization has not been considered. If this correction should fail to lower the central temperature sufficiently and if the carbon-nitrogen concentration is still taken as one percent by weight, the discrepancy has to be explained by the presence of an appreciable amount of helium.

7. Statistical Theory of the Spacing of Nuclear Levels. H. MARGENAU, *Yale University.*—The density of energy levels of a nucleus around a given excitation energy E is determined, aside from factors varying slowly with E, by e^S, where S is the entropy as a function of E and A the number of nuclear particles. In current theories S is calculated with the use of Sommerfeld's asymptotic formulas familiar from the theory of metals, the alleged justification being the high degree of degeneracy (in the Fermi-Dirac sense) of a nucleus for values of E around 10 Mev. As a matter of fact these formulas also involve the assumption, valid in the theory of metals, that the number of energy states of an individual particle be large. For a nucleus (potential well model) of atomic number about 100 there are less than ten such energy states. While this circumstance makes the ordinary theory very inaccurate, it opens the possibility of computing S numerically without much difficulty since the summations encountered have only about ten terms. Such calculations, made on the basis of the model of free particles within a spherical hole, and carried out mainly for atomic numbers around 116 (end of a closed shell), show that the "asymptotic" formula for e^S may be in error by a factor of several hundred in either direction. For $A=116$ it gives too large a density of levels. The effect of shell structure is very pronounced; for instance, for $A=100$ (near middle of a shell) the asymptotic formula errs in the opposite direction.

8. Preliminary Results on Two New Ion Sources. I. A. GETTING,* *Harvard University.*—The gasomagnetron of Vigdorchick[1] and the high frequency ring discharge have been investigated as ion-sources for high voltage tubes. As the name indicates, the gasomagnetron is simply a magnetron filled at low pressure with hydrogen. Its greatest assets are: high ion current (over 2 ma); low power consumption (15 watts excluding cathode heating); and very low gas flow. With a pumping speed of 50 liters per second at the acceleration tube, an increase of only 10^{-5} mm was noted. The gasomagnetron suffers from the short life of the cathode and especially from the low percentage of atomic ions. The high frequency ring discharge possesses some very attractive properties. The discharge tube was built of glass in the shape of a doughnut.[2] It was excited with a coil of ten turns at the center tuned to a 12.8-megacycle 100-watt oscillator. The discharge formed essentially a shorted secondary of one turn of a transformer. The discharge is a positive column of an arc wrapped around itself without a cathode fall. The spectrum showed as many as 17 Balmer lines with little trace of band structure. Currents up to 130 microamperes have been obtained from the source tube. Unfavorable features were the high gas flow and limited ion currents. The discharge runs well at 0.1 mm, but can be maintained at 0.03 mm. The unique feature is that there is no cathode to burn out.

* Society of Fellows.
[1] I. Vigdorchick, J. Phys. Acad. Sci., U.S.S.R. 1, 151 (1939).
[2] Suggested by C. G. Smith.

9. The Mechanism of Proportional Counter Action. M. E. ROSE AND S. A. KORFF, *Bartol Research Foundation of the Franklin Institute.*—In order to clarify the interpretation of porportional counter measurements, we have investigated the operation of counters below the Geiger threshold. A theory of the amplification factor of proportional counters has been made in which the primary assumption is the neglect of fluctuations in energy loss and specific ionization of the secondary electrons. It was found that the energy variation of the ionization mean free path is an essential element which the theory must include. The amplification factor then varies essentially exponentially with counter voltage and depends on one empirical constant, the threshold voltage for proportional amplification. The theory predicts a dependence of amplification on counter geometry, pressure and constitution of gas mixture. The voltage dependence of the size of the pulse produced by alpha-particles has been measured. The amplification has been determined by measuring the range of the particles in the counter and using the known average energy loss per ion-pair. Using various experimental arrangements good agreement with the theory is found. The application of these results to the interpretation of other experiments, for example the exclusion of gamma-ray counts in the observation of neutrons with BF_3 counters, is discussed.

10. Soil Studies with Radioactive Phosphorus: the Phosphate Fixation of Soils.* STANLEY S. BALLARD AND L. A. DEAN, *University of Hawaii Agricultural Experiment Station.*—Methods described elsewhere[1] have been applied to a study of phosphate fixation by soils. To determine this property, measurements were made of the uptake by test

plants—tomatoes, Sudan grass, and radishes—of radio-phosphorus added to soils. These values were then compared with the uptake by plants grown in water and sand cultures, to give a measure of the absolute fixation of the soils. The relative amounts taken up by the thirteen soils varied greatly for the three test plants. Thus, the significance of phosphate fixation depends upon the plant as well as the soil in which it is grown. It was found that for tomatoes this biological measure of fixation obtained with radio-phosphorus agreed with the chemical measure—the recovery of nonradioactive phosphorus in equilibrium with a soil-water system. A full discussion of these results is being submitted for publication. The gift by the Radiation Laboratory of the University of California of the radioactive phosphorus is gratefully acknowledged.

* To be read by title.
[1] S. S. Ballard and L. A. Dean, J. App. Phys. **11**, 366–370 (1940).

11. The Use of Radioactive Materials in Measuring the Thickness of Enamel Coatings. E. P. MILLER AND A. V. COHEE, *Purdue University.*—Thickness measuring devices as used in the synthetic enamel industry are limited in their application by their method of operation. Those working on an electrical or magnetic principle are limited to use on coatings on magnetic or conducting surfaces and all of them require that the coating be completely dry before their operation is satisfactory. In certain types of work with synthetic enamels these are serious limitations. A method of measuring film thickness which overcomes these difficulties would be desirable. Radioactive means have been used with success to answer this need. By mechanically mixing uranyl acetate with the paint pigment in a concentration of 18 grams of acetate to 100 cc of pigment, a series of test samples were sprayed on shim stock and their thickness, when dry, accurately measured with micrometer gauges. The activity per unit area of these samples was then measured with a Geiger-Mueller counter and a scale-of-four circuit. By plotting the counts against the thickness a calibration curve for this radioactive concentration was obtained. This curve is linear up to a coating thickness of 0.0035 inch, the largest value used. With this curve the thickness of unknown coatings can be measured before they are baked or dried to the same accuracy as one can use a micrometer gauge.

12. Solving a Type of Nonlinear Simultaneous Equations with a Mechanical Harmonic Synthesizer. S. LEROY BROWN AND LISLE L. WHEELER, *The University of Texas.*—Consider a pair of nonlinear simultaneous equations that are homogeneous in x and y:

$$a_1x^n+a_2x^{n-1}y+a_3x^{n-2}y^2+\cdots+a_{n+1}y^n=A, \quad (1)$$
$$b_1x^n+b_2x^{n-1}y+b_3x^{n-2}y^2+\cdots+b_{n+1}y^n=B, \quad (2)$$

and substitute $x/y=\cos\theta$. This gives

$$y^n[a_1\cos^n\theta+a_2\cos^{n-1}\theta+\cdots+a_{n+1}]=A, \quad (3)$$
$$y^n[b_1\cos^n\theta+b_2\cos^{n-1}\theta+\cdots+b_{n+1}]=B, \quad (4)$$

or
$$B[a_1\cos^n\theta+a_2\cos^{n-1}\theta+\cdots+a_{n+1}]= A[b_1\cos^n\theta+b_2\cos^{n-1}\theta+\cdots+b_{n+1}]. \quad (5)$$

The powers of $\cos\theta$ may be expressed in cosines of multiple angles [$\cos^2\theta=\frac{1}{2}(1+\cos 2\theta)$, $\cos^3\theta=\frac{1}{4}(3\cos\theta+\cos 3\theta)$, etc.]. The amplitudes of the fundamental and its harmonics in Eq. (5) may be set on a mechanical synthesizer and the value (or values) of θ determined for which this equation is satisfied if there is a ratio (real value of x to real value of y) between -1 and $+1$ for which it is satisfied. Then substitute $y/x=\cos\phi$ in Eqs. (1) and (2) and this gives (instead of Eq. (5))

$$B[a_1+a_2\cos\phi+a_3\cos^2\phi+\cdots+a_{n+1}\cos^n\phi]= A[b_1+b_2\cos\phi+b_3\cos^2\phi+\cdots+b_{n+1}\cos^n\phi]. \quad (6)$$

After Eq. (6) is expressed in terms of cosines of multiple angles, the amplitudes may be set on the synthesizer and solved for angle ϕ. Thus the ratios y/x (between -1 and $+1$) that satisfy Eq. (6) are determined. Consequently, these solutions of Eqs. (5) and (6) give all the ratios (real value of x to real value of y) that satisfy the two simultaneous equations. Substitution of a value of θ_1, as determined by the machine, in Eqs. (3) or (4) determines y_1 and x_1 ($x_1=y_1\cos\theta_1$) that satisfy Eqs. (1) and (2). This method is essentially a machine solution of a polynomial which is obtained from this type of equations, or equations that may be transformed to this type.

13. High Rotational Speed with Small Rotors. L. E. MACHATTIE, *University of Virginia. (Introduced by J. W. Beams.)*—The axial magnetic suspension in vacuum offers small frictional drag to the rotation of the suspended body.[1] With it an attempt has been made to spin small steel rods and balls to as high speeds as possible. An "inductance control" has been substituted for the original light beam photo-cell arrangement for vertical stabilization. Damping of horizontal motion of the rotor is necessary in order to overcome precession in the case of vertically suspended rods and circular motion of increasing amplitude in the case of a spinning ball. Rotors were spun by means of a 112-kilocycle rotating magnetic field. It was found that when a spinning rod reaches a speed approximately equal to the frequency of its first mode of free flexural vibration, it bends double because of the effect of centrifugal force in making the straight shape unstable. A $\frac{3}{16}''$ diameter drill rod $\frac{7}{8}''$ long and tapered at each end reached 36,000 r.p.s. before bending double. A $\frac{3}{32}''$ diameter steel ball such as is used in ball bearings withstood a speed of 110,000 r.p.s. without bursting. On a similar ball two rough-ground faces were made to test the feasibility of use as a rotating mirror. It was spun to over 100,000 r.p.s.

[1] Holmes, Rev. Sci. Inst. **8**, 444 (1937); Nature **140**, 30 (1937); Smith, Rev. Sci. Inst. (in press).

14. A New Analytical Ultracentrifuge. ARTHUR L. STAUFFACHER, J. W. BEAMS AND L. B. SNODDY, *University of Virginia.*—The well-known theory shows that, if the concentration of the material in two regions of a convection-free centrifuge cell at different distances from the axis of rotation can be measured, the molecular weight of the material can be determined. A convection-free centrifuge rotor has been developed in which the material is centri-

fuged in a large number of similar small sector-shaped cells near the periphery of the rotor. The material is injected into the cells through the hollow shaft when the rotor is at full speed. After the centrifuging is completed, the material in each cell is separated into two parts along a surface perpendicular to the radius by a displacement method. From analytical measurements of the concentration in one or both of these parts after the centrifuge is stopped, and that of the original material, the molecular weight is determined. Either the rate of sedimentation or the equilibrium methods for determining molecular weights may be used with this machine. Measurements have been made in the case of proteins and of ordinary inorganic electrolytes.

15. A Lattice Type Acoustic Filter. II. HAROLD K. SCHILLING, *Union College, Lincoln, Nebraska.*—Lattice type acoustic filters were described recently[1] which are built up of parallel grooved slats. They produce sound elimination bands whose positions in the frequency range are determined mainly by the depth of the grooves. This circumstance restricts their suitability to the filtration of high frequencies. They may be adapted to use with low frequencies by covering the slats with plates which are perforated by rows of small holes or by long narrow slits. When the plates are in position, the perforations are parallel with and immediately above the grooves. The perforations are also narrower than the grooves. Hence the plates partially close or cover the grooves. In this manner the filter side branches become Helmholtz resonators, the grooves being the resonator cavities and the perforations the resonator "necks" or channels. These resonators have lower resonance frequencies than do the simple grooves themselves. For such filters, therefore, one obtains attenuation bands at considerably lower frequencies, the cut-offs for any one being determined mainly by the volume of a groove, by the cross-sectional area of a perforation, and by the thickness of a cover plate, i.e., the length of a resonator "neck."

Experimental models of these filters have been constructed whose cut-off frequencies are as low as 700. Their behavior may be understood in terms of theory discussed earlier.[1]

[1] Harold K. Schilling, Bull. Am. Phys. Soc. **15**, Chicago Meeting, 1940, abstract 28.

16. Motion of the Earth's Fluid Core. D. R. INGLIS, *Johns Hopkins University.*—It may be considered probable that the core of the earth has a very low viscosity, such as is typical of molten metals. The earth has a considerable angular acceleration characterized mainly by the 27,000-year precession of its axis about a 24° cone. If the transfer of angular momentum down into the core is not sufficient to cause rigid rotation, the rotation of the interior of the core must lag behind the earth's rotation. The core is so large that its flow is expected to be turbulent, unless there is practically rigid rotation or marked stratification of the core. The turbulent drag has been estimated roughly, on the basis of a semi-empirical relation of von Karman, and it is found that the speed of relative rotation expected on these assumptions is about one percent of the earth's angular speed, in order of magnitude. The axis of relative rotation precesses around the earth daily, so that a particle in the core circulates in a rather small region. The forces of magnetic induction are expected to be less important than those due to turbulence. A direct effect of such a relative rotation on the diurnal variation of the earth's magnetism would be prevented by the shielding of metallic layers outside of the core.

17. Temperature Correction Methods in Calorimetry.* ALLEN KING AND HORACE GROVER, *Rensselaer Polytechnic Institute.*—Temperature correction methods in calorimetry are divided into three categories; namely, those in which a function of the temperature difference between the source of heat and the calorimeter fluid is unspecified but the heating period is limited, those in which this function has a specified analytical form and those in which graphical schemes are employed. A self-consistent method for correcting a temperature rise of the first type is developed and published methods of other investigators are compared with it. Rigorously none of these methods should be used in specific heat, bomb calorimetric, and similar experiments. For such experiments in which the heating period is unlimited, the function mentioned above may be specified in the Rowland manner. Rowland's fundamental assumptions are reexamined and a correct method based on them is deduced. Comparison of this method with those of Regnault-Pfaundler, Rowland-Hoare, and Dickinson by application to a set of data reveals significant discrepancies. A simple approximation of the new method is proposed and a graphical scheme based on this is suggested. Other graphical methods are critically reviewed.

* To be read by title.

18. 27-Day Recurrence Tendency in North American Precipitation. J. W. MAUCHLY, *Ursinus College.*—Most of the numerous attempts to correlate weather phenomena with solar activity have utilized some measure of solar variation as, for instance, the relative sunspot numbers. It is possible, however, to infer the influence of solar variations on terrestrial phenomena if one can discover in the latter approximate 27-day recurrences without strict periodicity. Daily totals of the precipitation reported on the Washington Daily Weather Maps (1927–40) have been converted to a "daily precipitation index," P, in which seasonal and other long period variations are absent. Fourier coefficients have been calculated for the first four harmonics for each 27-day interval in the series. An analysis of variance indicates that, although there is no evidence for persistent periodicity, the coefficients for adjacent 27-day intervals are more alike than would be expected from random data. The usual characteristics of time-series have been considered in connection with these tests. An upper limit for the "probability of chance" is hard to give, but may be taken as 10^{-3} in the opinion of the author. Evidence for solar influence on weather is further strengthened by other work not yet completed.

19. Gamma-Radiation from Airplane Instruments. ROBERT B. TAFT, *103 Rutledge Avenue, Charleston, S. C.*—A recent newspaper article caused much interest among air pilots by stating that the gamma-radiation from the luminous paint used on the instrument dials of a modern air liner would give the pilots a near-lethal dose of radiation in a few years. The author conducted tests in the cockpit of a Douglas DC3 and a Lockheed Electra and while there was a surprisingly large amount of radiation, the total dose was far under that generally accepted as perfectly safe for radium workers. Apparatus and measurements will be briefly demonstrated by colored lantern slides.

20. Correlation between Cosmic-Ray Intensities and Meteorological Conditions over Washington for 1939. NIEL F. BEARDSLEY, *University of Chicago.*—A series of correlation studies has been made between the meteorological conditions over Washington and the cosmic-ray intensities observed at Cheltenham. The air was divided into four layers, three of 4000 meters each and a fourth layer consisting of all the air above 12,000 meters. By multiple correlations between these layers and the surface cosmic-ray intensities, pressures and temperatures, it was found that the variance of the cosmic-ray intensity depends about 15 percent on the total air pressure, 40 percent on the distribution of the air mass and only 10 percent on world-wide magnetic changes. This leaves 30 percent of the variance unaccounted for. In a second computation, the heights of given densities of air at which the mesotrons may be considered as being formed[1] were correlated with the surface cosmic-ray intensities. This gives a method of determining the mean path before disintegration of those mesotrons with sufficient energy to penetrate to the surface from their place of formation. These results are quite in accord with other determinations of the mean path before disintegration.

[1] P. M. S. Blackett, Phys. Rev. **54**, 973 (1938).

21. Fluctuational Effects in Cosmic-Ray Ionization. V. A. LONG* AND R. M. WHALEY,** *University of Colorado.*—Continuous observations of the cosmic-ray ionization have been made at Boulder (alt. 5400 ft., lat. 40°N, long. 105°W). Professor Broxon's[1] high pressure chamber, equipped with five-inch lead shield, radioactive compensation, and an Askania-Werke photographic recorder, was employed in a temperature-controlled room in the basement of a thick-walled stone building. Data for the period June 1, 1938, to Nov. 30, 1939, have been analyzed partially for the various fluctuational effects by the least-squares method. After making the usual barometric corrections, the out-door temperature, magnetic, and humidity coefficients were determined. Both short and long time temperature effects were observed in general agreement with those of Hess[2] and others. A positive magnetic effect is indicated for magnetically undisturbed periods. About 25,000 bursts (some smaller than usually detected) have been observed and classified. Agreement with the usual frequency-magnitude relation is in evidence, and there is indication of diurnal and seasonal periodicities of the very small bursts.

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** Now with G. M. Laboratories, Chicago.
[1] J. W. Broxon, Phys. Rev. **37**, 1320 (1931).
[2] V. F. Hess, Phys. Rev. **57**, 781 (1940).

22. Cosmic-Ray Recurrences. JAMES W. BROXON, *University of Colorado.*—Eighteen-month cosmic-ray measurements by Long and Whaley at Boulder, corrected for bursts and barometric fluctuations, are being analyzed by Chree's[1] method as adapted by Gill[2] and Monk and Compton.[3] Following Monk and Compton, zero-days were selected from the first fifteen months for *subsequent* pulses to $n=135$, and from the last fifteen months for *previous* pulses to $n=-135$. "Positive-pulse" curves have been completed. These display some slight indication of pulses at intervals of about 27 days. It is expected that "negative-pulse" curves will be obtained before the meeting. These and the "difference" curves may bring out more clearly whether or not the data display pulses at definite intervals. Perhaps differences between curves obtained by the same procedure may depend upon locations of observation stations. While the Boulder data show clearly the influence of out-door temperature, Monk and Compton's data were obtained at Teoloyucan, Mexico, where (according to Gill[2]) both temperature range and temperature dependence are small. *Note added in proof.*—The difference curves confirm Monk and Compton.

[1] C. Chree, Phil. Trans. **A212**, 76 (1913).
[2] P. S. Gill, Phys. Rev. **55**, 429 (1939).
[3] A. T. Monk and A. H. Compton, Rev. Mod. Phys. **11**, 173 (1939).

23. Cosmic Rays and the Nature of the Field in Magnetized Iron. W. F. G. SWANN AND WAYNE L. LEES, *Bartol Research Foundation of the Franklin Institute.*—Some time ago one of us showed that in the case of a classical model of a piece of magnetized iron in which the magnetic entities were small in size, while the true average field which would determine the deflection of a cosmic ray in passing through the iron is the magnetic induction B, this average is made up in part of a number of very rare events, with the result that the practically measured average is liable to be $B-2\pi I$, where I is the intensity of magnetization. In view of the subtlety of certain points in the mathematical reasoning, it has been thought advisable to perform an experiment upon a model composed of randomly distributed iron spheres polarized by the magnetic field of a solenoid. By a suitably designed long thin coil, it has been possible to investigate in the space between the spheres the average field which in a practical case would be responsible for deflecting a cosmic ray, and the experimental conclusions have verified the mathematical expectations within the limits of accuracy of the experiments.

24. A Large Wilson Cloud Chamber for Cosmic-Ray Studies. T. H. JOHNSON, J. G. BARRY AND R. P. SHUTT, *Bartol Research Foundation of the Franklin Institute.*—The paper describes the construction of a large cloud chamber in operation at the Bartol Laboratory. The chamber is of the vertical, rubber diaphragm type and is operated by compressed air. It is 23″ in diameter and 6″ deep and its

metal parts are simple rings and disks cut from rolled steel plates. The stops for the diaphragm are grill plates fabricated by winding alternate corrugated and flat steel strips into a flat spiral subsequently dipped in tin. With argon and a mixture of propyl alcohol and water vapors the expansion ratio for good tracks is 1.070. A magnetic field of 12.0 gauss per ampere is produced by simulated Helmholtz coils, series resistance 0.5 ohm. The chamber is illuminated by a capillary mercury arc mounted at the focus of a cylindrical parabolic reflector. The arc tube is maintained at a steady temperature of 240°C and when excited a current of about 55 amperes runs through a 4-mm quartz capillary sleeve 24″ long inserted into the sealed off Pyrex tube. A 5-kw 2200-volt transformer supplies the power for a small integral number of half-cycles. Expansions are controlled by a set of coincidence counters.

25. The Relative Stopping Powers of Carbon and Lead for Slow Mesons. MARTIN A. POMERANTZ AND THOMAS H. JOHNSON, *The Bartol Research Foundation of the Franklin Institute.*—An experimental determination of the relative stopping powers of carbon and lead for slow mesons has been made with an anticoincidence arrangement of G-M counters. For mesons having an average energy of approximately 4×10^7 ev, the experiments revealed that 28.5 g/cm² of carbon is equivalent in stopping power to 24 ± 5 g/cm² of lead. This gives a value for the ratio of the stopping powers of equal masses of carbon and lead, $S_C/S_{Pb}=0.84\pm0.18$, to be compared with the theoretical value of $S_C/S_{Pb}=1.82$ calculated with the ionization theory. However, it is not necessary to invoke a hitherto unknown absorption process to account for this discrepancy, since it may be explained as arising from the scattering and transition effects. The data corrected for these effects show that 28.5 g/cm² of carbon is equivalent in stopping power to 45 ± 7 g/cm² of lead, and $S_C/S_{Pb}=1.6\pm0.3$, in agreement with the theoretical value within the experimental uncertainty. These experiments indicate that in a dense absorber any additional absorption process is unimportant compared with ionization for mesons having energies of about 4×10^7 ev, or higher.

26. On the Scattering of Mesons of Spin $\hbar/2$ by Atomic Nuclei. R. E. MARSHAK AND V. F. WEISSKOPF, *University of Rochester.*—The nonelectric scattering of charged mesons by protons and neutrons is calculated as a first-order effect in the heavy electron pair theory of nuclear forces. The mesons were assumed to be identical with electrons in every respect (spin $\hbar/2$, Dirac "hole" theory, etc.) except that their rest mass was taken equal to the cosmic-ray meson mass μ. It had previously been shown[1] that the meson pair theory gives qualitatively both the correct spin dependence of nuclear forces and the positive quadrupole moment of the deuteron. An upper limit for the scattering cross section has been found: it is less than 5×10^{-30} cm² for mesons of energy $E=\mu c^2$ and less than 2.6×10^{-29} for $E=3\mu c^2$. These values are about 1000 times smaller than the corresponding results obtained on the basis of meson theories of nuclear forces which ascribe to the meson a spin $\hbar$. In contrast to the latter theories the values obtained in the present paper are in agreement with the upper limits of the scattering cross section found experimentally by Wilson[2] and others. For meson energies large compared to the rest energy of the proton or neutron, the scattering cross section increases linearly with the energy; it first attains the value 10^{-26} for meson energies of the order of 10^{11} ev.

[1] R. E. Marshak, Phys. Rev. **57**, 1101 (1940).
[2] J. G. Wilson, Proc. Roy. Soc. **174**, 73 (1940).

27. Slow Protons and Mesotrons at 4300 Meters. WILSON M. POWELL, *Kenyon College.*—In 602 expansions at random of a large Wilson cloud chamber containing five horizontal lead plates each one cm thick 162 tracks appeared which passed through two lead plates or more without producing accompanying particles. 13 of these tracks can be identified as slow mesotrons and 8 can be identified as slow protons. Mesotrons show heavy ionization on one side only of a lead plate or pass through at least two plates and stop in the third showing no heavy ionization. Protons show recognizably heavy ionization on two sides of a lead plate. The energy ranges over which slow mesotrons and slow protons can be recognized by this method will be discussed. This work was done in the Denver University M.I.T. Laboratory on Mt. Evans in Colorado.

28. The Transition Effect for Large Showers of Cosmic Rays. C. G. MONTGOMERY AND D. D. MONTGOMERY, *Yale University.*—The increase in the number of rays in a large shower from the air upon passing through a thin layer of material was measured. The spherical ionization chamber, 40 cm in diameter and filled with nitrogen to 200 lb. pressure, had walls of magnesium only one centimeter thick and so produced a negligible effect. Over the chamber were placed layers of magnesium, iron, and lead and the bursts of ionization in the chamber were recorded photographically. The amounts of ionization corresponded to showers of about 75 rays through the chamber. The increase in shower size depends upon the ratio E/E_c, where E is the energy of a ray of the original shower and E_c the critical radiation energy, which varies inversely as the atomic number. For thicknesses of material corresponding to two radiation unit lengths, it can be estimated from the cascade theory that the number of rays will be increased by the factors 4.4; 1.8; 1.0 for Pb; Fe; and Mg, if we choose $E=2\times10^8$ ev. The observed factors were approximately 1.1; 1.1; 1.0. We must therefore conclude that either (a) the rays in the original shower are not electrons or (b) the variation of E_c with atomic number is incorrectly given by the theory. We believe the second alternative to be correct.

29. The Frequency-Extension Curves for the Soft and Penetrating Components of Extensive Cosmic-Ray Showers. NORMAN HILBERRY, *University of Chicago and New York University*, AND VICTOR H. REGENER, *University of Chicago.*—The frequency *vs.* extension curves for the soft and penetrating components of extensive cosmic-ray showers have been determined at the Mt. Evans high altitude laboratory. One set of three G-M tubes was used

as a "core selector"; the tubes were placed parallel to each other in a horizontal plane with an inter tube separation of 14 cm; the set was permanently shielded with 5 cm of lead and was connected in threefold coincidence. A second set of two G-M tubes was connected in twofold vertical coincidence as the exploring unit. The "extension" of the shower was measured between the center of the core selector and the vertical axis of the exploring pair. The twofold and threefold coincidences were combined and recorded by a mixing circuit. The data obtained are given in the table.

EXTENSION IN METERS		.28	.64	4.0	12.0
Counts per hour	unshielded	10.7 ±1.0	11.1 ±1.0	9.4 ±.9	5.1±.6
	shielded	2.1 ± .4	1.9 ± .3	.67 ±.21	.3±.17

The expected curve for the soft component has been computed using the low energy cut-off value fixed by the 5-cm lead shield over the core selector. The agreement with the present data is satisfactory. A discussion of the penetrating component data will be given.

30. The Diffraction of X-Rays by Liquid Oxygen.*† P. C. SHARRAH AND N. S. GINGRICH, *University of Missouri.*—The x-ray diffraction patterns of liquid oxygen at 90°K and at 62°K have been obtained and analyzed for the atomic distribution. Crystal reflected Mo$K\alpha$ radiation was incident upon a circular thin glass capillary of 7.8 mm diameter filled with liquid oxygen. The camera was evacuated and an exposure of about 30 hours was sufficient to give a pattern of suitable density. The lower temperature, 62°K, was reached by reducing the pressure. At atmospheric pressure, the oxygen was 96 percent pure, and at the reduced pressure it was of approximately the same purity. The intensity patterns showed a strong main peak and two broad peaks more like plateaus. The main peak is at $\sin\theta/\lambda=0.160$ for 90°K and at 0.165 for 62°K. The first plateau has its center roughly at 0.33 and the second plateau has its center roughly at 0.50. At 90°K, these plateaus are not prominent. The distribution curve for the 90°K case shows very nearly one discrete nearest neighbor at about 1.3A, a weak concentration at about 2.2A, a peak at 3.3A and at 4.2A. At 62°K, there is nearly one nearest neighbor at 1.3A, and further concentrations at 2.2A, 3.2A, 4.0A, 5.0A, 5.9A and 6.8A.

* This work was supported in part by a grant from the Elizabeth Thompson Science Fund.
† To be read by title.

31. X-Ray Determination of the Particle Size of Electro-Deposited Coatings. C. H. EHRHARDT, *Universal Oil Products Corp.*, AND E. P. MILLER, *Purdue University.*—The equation developed by Kochendorfer[1] for the x-ray particle size determination for flat samples, reduces to the Scherrer equation for lines which are exactly in focus. It is therefore easily possible to determine the particle size of very thin flat deposits where the number of observable diffraction lines is small. The particle size in nickel coatings plated on brass stampings under commercial conditions has been determined in this way. Using a special camera with a radius of 7.615 cm built to fulfill the theoretical requirements of the method, a number of diffraction patterns of nickel plate have been obtained with copper $K\alpha$ radiation. The particle size of the material was shown to be in the range of 10^{-6} cm. Using a section of the sample which was approximately cylindrical and copper $K\alpha$ radiation reflected from a crystal monochromator, the Scherrer equation could be applied. The particle size determined in this way agreed well with the former evaluation. By using the diffraction lines of the base brass material, the natural breadth of the Scherrer equation could be independently checked. The precautions which are necessary for the successful application of the x-ray method are pointed out.

[1] Kochendorfer, Zeits. f. Krist. **97**, 469–475 (1937).

32. The Atomic Arrangement of Sylvanite. G. TUNELL, *Geophysical Laboratory.* (*Introduced by L. H. Adams.*)—The crystal structure of sylvanite has been determined by röntgenographic analysis of measured faceted crystals from Cripple Creek, Colorado, from Săcărâmbu (Nagy-Âg), Transilvania (Siebenbürgen), and from the Buena Mine, Jamestown district, Colorado. The dimensions of the unit cell, all determined by purely röntgenographic measurements, are $a_0=8.94$A, $b_0=4.48$A, $c_0=14.59$A, all ±0.02A, and $\beta=145°26'\pm20'$. The unit cell contains 2 "molecules" of $AuAgTe_4$, and a small proportion of the silver atoms required by this ideal formula is replaced by gold atoms. The space-group is $P2/c-C_{2h}^4$. The gold atoms are situated in (a) 000, $00\frac{1}{2}$, the silver atoms in (e) $0y\frac{1}{4}$, $0\bar{y}\frac{3}{4}$, with $y=0.43$; and the two sets of tellurium atoms in (g) xyz, $\bar{x}\bar{y}\bar{z}$, $\bar{x},y,\frac{1}{2}-z$; $x,\bar{y},\frac{1}{2}+z$; with $x_1=0.30$, $y_1=0.03$, $z_1=0.00$, and $x_2=0.28$, $y_2=0.42$, $z_2=0.24$. Each gold atom and each silver atom is surrounded octahedrally by six tellurium atoms and each tellurium atom is surrounded octahedrally by three tellurium atoms, two gold atoms and one silver atom, or by three tellurium atoms, two silver atoms and one gold atom.

33. The *L* Emission Band of Sodium. WILLOUGHBY M. CADY AND D. H. TOMBOULIAN, *Cornell University.*—The intensity distribution in the emission band of sodium at about 405A has been determined photometrically. The band is caused by transitions from conduction levels to the L levels. The metal was distilled in vacuum upon a copper target which was operated at −45°C. The sodium surface remained spotless and solid during bombardment. The band "width" appears to be about 3.05 volts, in agreement with the value of O'Bryan and Skinner.[1] A comparative study of the L band of sodium with the L bands of magnesium and aluminum[2] shows, in each case, a low frequency "tail" of which the intensity amounts to some 9 percent of the intensity of the entire band. For each of these elements the ordinary continuous x-ray spectrum was observed. For sodium the peak intensity (as corrected for underlying continuum) is 1.7 times as great as that of the continuum; for magnesium and aluminum the corresponding factors are 7 and 11.

[1] O'Bryan and Skinner, Phys. Rev. **45**, 370 (1934).
[2] Tomboulian and Cady, Phys. Rev. **57**, 1055 (1940).

34. The Auger Effect in the Relative Intensities of X-Ray Lines. JOHN N. COOPER,* *Cornell University.*—The Auger effect should play an important role in determining the relative intensities of x-ray lines, since any atom which leaves an excited state by an Auger (radiationless) transition cannot contribute to the intensities of lines arising from that state. Consequently, as the probabilities of Auger transitions from a given state increase, the relative intensities of lines arising from that state should decrease. It is known (from theoretical considerations,[1] from data on the relative intensities of the $L\alpha$ satellites, and from data on the widths of L-series lines[2]) that the probabilities of the Auger transitions $L_{\mathrm{I}}\rightarrow L_{\mathrm{III}}M_{\mathrm{IV,V}}$ increase rapidly with atomic number in the range $73\leq Z\leq 81$. As a result the intensities of the L_{I} lines relative to the intensities of the L_{II} and L_{III} lines should decrease with atomic number in this range. To verify this prediction, the relative intensities of selected L_{I}, L_{II}, and L_{III} lines were measured with a two-crystal spectrometer. The data obtained are in complete accord with expectations and show strikingly the dependence of the relative intensities of x-ray lines on the probabilities of Auger transitions.

* Now at the University of Southern California.
[1] Coster and Kronig, Physica **2**, 14 (1935).
[2] J. N. Cooper, Phys. Rev. **57**, 1055A (1940).

35. A Timer for Spark Breakdown Studies. E. C, EASTON, *Newark College of Engineering,* AND J. D. COBINE. *Harvard Graduate School of Engineering.*—To aid in the study of the time lag of spark breakdown, a device has been constructed to apply and measure the length of rectangular voltage waves from one to 5000 microseconds in duration. Oscillograms of switching transients and test-gap voltages indicate that many previous investigators have been deceived by assuming a rectangular wave of applied voltage, and that others may have introduced errors by assuming the gap voltage to be influenced by reflections. It has been found possible to apply an essentially rectangular voltage by (1) maintaining the spark which closes the applying switch before the contacts meet mechanically, and (2) by making the test-gap circuit aperiodic. The length of the applied wave is determined by a vacuum tube circuit designed to pass a constant current output as long as the bias to the first tube exceeds a predetermined value. The output current is passed through a ballistic galvanometer whose reading is a measure of the time during which the gap voltage remains above the datum level. A thyratron circuit has been arranged to supply the timer with rectangular waves for the purpose of calibration. Cathode ray oscillograms showing errors of 5 percent to 10 percent indicate that the accuracy of the apparatus is quite sufficient for most breakdown studies.

36. Scattering of Low Velocity Ion Beams. JOHN A. ELDRIDGE, *University of Iowa.*—Rouse has investigated the scattering of potassium ions in passing through certain gases. There were many complicating effects in his experiment: electrons produced by ionization and by emission from electrodes, multiple collisions of ions, effects of slits, etc. These effects have been studied; in the case of scattering by mercury vapor, corrections for these secondary processes can be made without difficulty and the primary scattering determined as a function of angle and voltage. There is a great deal of small-angle scattering; the scattering falls to a minimum at about 110° and increases for larger angles. (This is true either for the center of mass system or for the laboratory system of coordinates.) The large angle scattering varies inversely as the velocity of the ions. Scattering in krypton and xenon has also been studied; here the corrections are larger and definite results have not yet been obtained for these gases.

37. Photoelectric and Electric Properties of Thin Bismuth Films of Measured Thickness. A. H. WEBER AND L. J. EISELE, S.J., *Saint Louis University.*—The photoelectric threshold shift with thickness in thin bismuth films deposited on glass has been further investigated, following a previous report,[1] with some important modifications in apparatus and method including measurement of the film thicknesses[2] and extension of the temperature range in which the DuBridge analysis[3] is applied. The present experiments are in good agreement with the previous preliminary work[1] but show some differences. For example, the threshold shows little change with film thickness below some 100 atomic layers of thickness. In the region of 100 atomic layers thickness there appears a sudden increase in threshold wave-length followed by a more gradual shift in threshold wave-length toward the red with increasing film thickness. The limiting value of the threshold wave-length appears to be about 2785A. Work in progress on the electrical conductivity and the photoconductivity of the bismuth films, measured simultaneously with the photoelectric emission, will be discussed as far as the accumulated data permit.

[1] A. H. Weber, Phys. Rev. **53**, 895 (1938).
[2] A. H. Weber, Phys. Rev. **57**, 1042 (1940).
[3] L. A. DuBridge, Phys. Rev. **39**, 108 (1932).

38. Images Projected from Etched Surfaces of Quartz Crystals. HARRY H. HUBBELL, JR., *Wesleyan University.*—The study reported by W. G. Cady[1] of the patterns formed by a beam of parallel light passing through the surface of a quartz crystal cut normal to the optic axis and etched in hydrofluoric acid has been continued. Following the procedure of Gramont,[2] the beam is focused on a ground glass or photographic film in the focal plane of a lens placed immediately above the etched surface. The three-pointed star patterns formed are quite sensitive to the time of etching and to the previous grinding and cleaning of the surface. A doubling of the patterns often appears, as though a second, fainter, three-pointed star were superposed on the first with its points rotated about 30° counterclockwise. The patterns usually become less diffuse as the microscopic trihedral pyramids formed on the surface become larger with longer etching, but their form becomes more complex. The points of the star make an angle of about 10° with the electric axes of the crystal. A technique of preparation of the surface and of etching is being developed which it is hoped will permit the routine determination of the electric axes of a z cut slab of quartz within about a degree.

[1] W. G. Cady, Proc. I.R.E. **28**, 144 (1940).
[2] A. de Gramont, *Recherches sur le Quartz Piézoélectrique* (Paris, 1935), Chap. 3.

39. Deviations from Ohm's Law at High Current Densities. LEVERETT DAVIS, JR.,* *California Institute of Technology.*—One would expect that a theoretical expression for the deviations from Ohm's law at high current densities could be obtained by considering the higher approximations of a theory whose first approximation gives Ohm's law. A possible method of treatment can be based on the assumption that a relaxation time, $\tau(\mathbf{k})$, can be defined. In this case Boltzmann's equation for the distribution function, $f(\mathbf{k})$, is

$$\mathcal{E}\epsilon\tau(\partial f/\partial k_1)-\hbar[f-f_0]=0,$$

where $\mathcal{E}$, the electric field, is assumed to be in the x direction, $-\epsilon$ is the charge of the electron, $\mathbf{k}$ is the wave vector, and f_0 is the equilibrium distribution function which we will assume to be the Fermi function. If we expand f in a power series in $\mathcal{E}^n$, we find that

$$f=\sum_{n=0}^{\infty}\mathcal{E}^n\left[\frac{\epsilon}{\hbar}\tau\frac{\partial}{\partial k_1}\right]^n f_0.$$

It follows that the current density is

$$J=-\frac{\epsilon}{4\pi^3\hbar}\sum\left(\frac{-\epsilon}{\hbar}\right)^n\mathcal{E}^n\int\frac{\partial f_0}{\partial k_1}\tau\left[\frac{\partial}{\partial k_1}\tau\right]^{n-1}\frac{\partial E}{\partial k_1}dV,$$

where $E(\mathbf{k})$ is the energy and dV is an element of volume in $\mathbf{k}$ space. If τ is assumed to be a constant and the energy that of the free electron case, only the linear term of this series is not zero. Consequently, Ohm's law is exact in this case. Other assumptions as to the dependence of E and τ on $\mathbf{k}$ will, in general, give deviations from Ohm's law. In some cases difficulties concerning the convergence of the series may arise.

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40. Dispersion and Absorption in Dielectrics. ROBERT H. COLE, *Harvard University,* AND KENNETH S. COLE, *Columbia University.*—It will be shown that experimental results on a considerable number of liquid and solid dielectrics are represented by the empirical formula

$$\epsilon^*-\epsilon_\infty=(\epsilon_0-\epsilon_\infty)/[1+(i\omega\tau)^{1-\alpha}]. \quad (1)$$

In this formula ϵ^* is the complex dielectric constant, ϵ_0 and ϵ_∞ are the "static" and "infinite frequency" dielectric constants, respectively, ω is the angular velocity, and τ is a generalized relaxation time. The parameter α can assume values between 0 and 1, the former value giving the result of Debye for polar dielectrics. The expression (1) requires that the locus of the dielectric constant in the complex plane be a circular arc with end points on the axis of reals, and center below this axis. The equivalent three-element electrical circuit requires a complex impedance with the property that the phase angle is a constant independent of the frequency. The significance of the empirical result (1), which is not satisfactorily described by any of the present dispersion theories, will be briefly discussed.

41. Coulomb Wave Functions in Repulsive Fields.* H. M. THAXTON, L. E. BAILEY AND H. E. WEBB, *The Agricultural and Technical College of North Carolina.*—Coulomb wave-functions Φ_L, Φ_L^*, Ψ_L, Ψ_L^*, Θ_L for the differential equation $d^2F/d\rho^2+[1+2\eta/\rho-L(L+1)/\rho^2]F=0$ have been calculated for the region $\bar{1}.0\leqq\ln\eta^{-1}\leqq\bar{2}.0$ and $0.01\leqq\rho\leqq0.10$ at small constant intervals in η and ρ. The values of L used were $L=0, 1, 2, 3$. In this region the series expansions[1] are practicable. These expansions have been used and checked by numerical integration of the differential equation. Many checks have also been made by $\Psi_L\Phi_L^*-\Psi_L^*\Phi_L-\rho^{2L+1}P_L\Phi_L^2=2L+1$. The coefficients A_j, a_j were computed directly, then checked by calculating $B_j=A_j/n_j$ and $b_j=a_j/n_j$. In this region coefficients A_{12} give an accuracy of 0.01 in Φ^* for $L=0$ with higher accuracy for $L=1, 2, 3$ for largest ρ and η. Similarly, a_{15} gives an accuracy of 0.01 in Ψ^* for largest ρ and η. For the region $1\leqq\eta\leqq100$ and $0.1\leqq\rho\leqq1$ the series method converges slowly. Calculations for this region are proceeding by another method.[2]

* To be read by title.
[1] F. L. Yost, G. Breit and J. A. Wheeler, Phys. Rev. **49**, 174 (1936).
[2] J. A. Wheeler, Phys. Rev. **52**, 1123 (1937).

42. Vibration-Rotation Energies of the Planar XY_3 Molecular Model. SAMUEL SILVER AND WAVE H. SHAFFER, *Ohio State University.*—The vibration-rotation energies of the planar XY_3 molecule have been obtained to the second order of approximation. The appropriate Hamiltonian was derived by the method of Wilson and Howard[1] so as to include cubic and quartic anharmonic terms in the potential energy, the dependence of the moments of inertia upon the vibrational states, the centrifugal expansion effects, and the Coriolis interactions between the internal angular momenta arising from the degenerate modes and the total angular momentum. The energy expressions were obtained by a method involving a contact transformation which was developed for this type of problem by Shaffer, Nielsen, and Thomas.[2] The energies are given in the form:

$$E=hc(G_{\text{vib}}+F_{\text{rot}})\pm\frac{\zeta h}{4\pi^2c_0c}(l_2+l_4)K, \quad (1)$$

where

$$G_{\text{vib}}=G_0+\sum_{i=1}^{4}\left(V_i+\frac{d_i}{2}\right)\nu_i+\sum_{i=1}^{4}\left(V_i+\frac{d_i}{2}\right)^2G_{ii}+\sum_{i<k}\left(V_i+\frac{d_i}{2}\right)\left(V_k+\frac{d_k}{2}\right)G_{ik}+(l_2^2-1)g_{22}+l_2l_4g_{24}+(l_4^2-1)g_{44},$$

$$F_{\text{rot}}=J(J+1)B_v-K^2C_v-J^2(J+1)^2D_J-K^4D_K-J(J+1)K^2D_{JK}$$

with

$$B_v=B_e-\alpha_0-\sum_{i=1}^{4}\left(V_i+\frac{d_i}{2}\right)\alpha_i,$$

$$C_v=C_e-\beta_0-\sum_{i=1}^{4}\left(V_i+\frac{d_i}{2}\right)\beta_i,$$

and the third term in (1) representing the Coriolis interactions arising from the doubly degenerate modes ν_2 and ν_4. The parameters G_0, G_{ii}, g_{22}, $\cdots$, D_{JK} have been obtained explicitly as functions of the molecular constants occurring in the Hamiltonian.

[1] E. B. Wilson and J. B. Howard, J. Chem. Phys. **4**, 260 (1936).
[2] W. H. Shaffer, H. H. Nielsen and L. H. Thomas, Phys. Rev. **56**, 895, 1051 (1939).

43. Self-Consistent Field Calculations for Nickel. ROBERT B. GRAY AND MILLARD F. MANNING, *University of Pittsburgh.*—As a preliminary to energy band calculations, self-consistent field calculations for the d^8s^2 configuration have been carried out. The initial estimates were made by the method described by Manning and Millman[1] using previous results for Fe, Cu^+, and Zn. The 3d wave functions proved to be highly sensitive to changes in the assumed initial field. A satisfactory estimate of a new value of Z for the 3d electrons was found by adding to the initial Z one-third of the difference between final field and initial field. The final values of Z are consistent within 0.010 electronic unit.

[1] M. F. Manning and J. Millman, Phys. Rev. **49**, 849 (1936).

44. On the Universal Constants *h*, *c*, and *e*. ALFRED LANDÉ, *Ohio State University.*—The value of e in terms of h and c can be understood on the basis of defining the velocity ratio v/c in two reciprocal ways. First by means of the energy ϵ and the momentum p occurring in Einstein's equation $\epsilon^2-(pc)^2=\epsilon_0^2$, second by means of the time t and the path r traveled during t, occurring in the "signal equation" $t^2-(r/c)^2=t^2$. Just as ϵ_0 is the production energy so t_0 is the critical wave period of a production process. The close analogy between production, annihilation, and scattering leads to identifying t_0 with the time interval of a light signal traveling across the universal scattering cross section σ of Thomson. That is, the light path $a=ct$ is determined either by the equation $a^2=\sigma$ (a=path along the side of a quadratic area σ), or by the equation $a^2=2\sigma$ (a=path along the diagonal of σ). The latter definition of the production period, together with a quantization in the space of Einstein's and the signal equation, leads directly to the value 137.1273.. of Sommerfeld's constant. We do not have a convincing classical theory of the factor 2 in $a^2=2\sigma$, however.

45. The Deflection of Light Rays by a General Anisotropy. PHILIPP FRANK, *Harvard University.*—The refractive index of a medium may be $\mu=\mu_0(\mathbf{r})+\mu_1(\mathbf{r},\mathbf{s})$, the vector $\mathbf{r}$ denoting the coordinates of a point and the unit vector $\mathbf{s}$ the direction of the light ray, while μ_1 may be any function of $\mathbf{s}$. The deflection of a ray pencil $\mathbf{s}=\mathbf{s}(\mathbf{r})$ by the anisotropy μ_1 is defined by the "curvature vector $\mathbf{k}$ of the deflected rays relative to the rays in the isotropic medium μ_0." We find $\mathbf{k}=\mathbf{s}\times\mathrm{rot}\,\mathbf{A}(\mathbf{r},\mathbf{s})$, $\mathbf{s}$ being $\mathbf{s}(\mathbf{r})$ and $\mathbf{A}=\mu_1\mathbf{s}+\mathrm{grad}_s\,\mu_1-\mathbf{s}(\mathbf{s}\,\mathrm{grad}_s\,\mu_1)$, grad_s implying differentiation with respect to the components of $\mathbf{s}$. The simplest case, notwithstanding the anisotropy of crystals, is $\mu_1=\mathbf{sg}(\mathbf{r})$, $\mathbf{g}$ being an arbitrary function of $\mathbf{r}$. This case covers, for example, the deflection of light rays by the motion of the medium. We have only to put $\mathbf{g}=-(1/c^2)\mu_0^2\mathbf{w}(\mathbf{r})$. Here μ_0 is the refractive index and $\mathbf{w}$ the velocity distribution in the medium. A second example is the deflection of electron rays in an electromagnetic field. We have to put $\mathbf{g}=(\epsilon/c)\mathbf{a}(\mathbf{r})$. Here $\mathbf{a}$ is the vector potential of the field.

46. Carbon Isotope Effect in Acetylenes. FORREST F. CLEVELAND AND M. J. MURRAY, *Illinois Institute of Technology.*—Glockler and Renfrew[1] have reported carbon isotope shifts in the triple-bond frequency in the Raman spectra of liquid acetylene and dimethylacetylene. Herzberg[2] has reported a similar isotope effect for $H-C\equiv N$. Since the triple-bond line is very intense, it seemed that it might be possible to observe such shifts for other substituted acetylenes. Assuming a linear, four-mass system and using the force constants listed by Crawford,[3] the isotope shifts for $CH_3-C^{13}\equiv C^{12}-CH_3$, $CH_3C^{13}\equiv C^{12}H$ and $CH_3C^{12}\equiv C^{13}H$ were calculated from the valence force equations to be -33, -50 and -26 cm^{-1}, respectively. Examination of spectrograms of 5-decyne, 3-octyne and 1-phenyl-1-butyn-3-one[4] disclosed the presence of weak lines which would correspond to isotope shifts of -38, -36 and -37, respectively. A long exposure of carefully purified 1-heptyne gave a weak line which would correspond to isotope shifts of -52 and -21 cm^{-1} for the two possible isotopic molecules. Semiquantitative measurement of the relative intensities of the two lines in 1-phenyl-1-butyn-3-one indicated that the intensity of the weak line was one-hundredth to one-fiftieth times that of the strong line.

[1] G. Glockler and M. M. Renfrew, J. Chem. Phys. **6**, 340 and 408 (1938).
[2] G. Herzberg, J. Chem. Phys. **8**, 847 (1940).
[3] B. L. Crawford, Jr., J. Chem. Phys. **8**, 526 (1940).
[4] This compound was synthesized by Mr. R. E. Dineen.

47. Infra-Red Transmission of the Human Body. C. HAWLEY CARTWRIGHT,* JOHN DANIEL† AND ALEX PETRAUSKAS, *Massachusetts Institute of Technology.*—The percentage reflection and transmission of a human cheek were measured as a function of wave-length in the visible and infra-red spectra. Absolute values were obtained to 12,000A by using a special photo-cell and an integrating sphere for collecting all the light. The reflection of the cheek reaches a maximum of about 50 percent in the visible red and gradually decreases for longer wave-lengths. The cheek (10 mm thick) is opaque below 6050A and increases its transmission linearly to about 2 percent of that entering the skin at 7000A. Between 7000A and the water absorption band at 10,000A, the transmission is rather uniform. Beyond 10,000A the transmission rises, reaches a maximum value of about 3 percent at 11,000A and decreases to zero beyond 13,500A, because of the water absorption. Using as a control a bearable discomfort on the outside of the cheek, measurements of the temperature rise inside the mouth were made using various sources of radiation. The best of these was a tungsten lamp with a water filter. An increase in temperature of 3°F was obtained inside the cheek without external discomfort.

* Corning Glass Works.
† U. S. Bureau of Public Health.

48. The Ultraviolet Absorption Spectra of Different Regions of *Trichophyton mentagrophytes* Spores.—PETER A. COLE, *National Institute of Health. (Introduced by F. S. Brackett.)*—The ultraviolet absorption spectrum of various portions of spores of *Trichophyton mentagrophytes* has been determined in the wave-length range 3021A to 2265A using a Zeiss ultraviolet microscope. A photographic method of photometry was employed using a focal plane rotating step-

sectored disk. Absorption maxima of different intensity and wave-length (2800A to 2500A) are observed for different regions within the same spore. Absorption curves and corresponding ultraviolet photomicrographs will be shown for several cells.

49. Afterglows in Nitrogen Rare Gas Mixtures. JOSEPH KAPLAN AND S. M. RUBENS, *University of California at Los Angeles.*—The spectra of nitrogen-helium, nitrogen-neon and nitrogen-argon mixtures have been studied in the auroral afterglow. Similar differences are observed between these and the Lewis-Rayleigh afterglows in rare-gas nitrogen mixtures as are observed when the auroral afterglow in pure nitrogen is compared with the Lewis-Rayleigh glow. The most interesting characteristic of the nitrogen-helium afterglow is the large intensity of forbidden radiations of nitrogen. No helium lines are obtained in either discharge or afterglow. Both the absolute and the relative intensities of the forbidden radiations are high. The argon-nitrogen afterglow closely resembles the afterglow in pure nitrogen at the same total pressure. The Goldstein-Kaplan bands are stronger in argon. The enhancement of the relative intensity of the forbidden radiations late in the afterglow is also observed. The neon-nitrogen afterglow is intermediate between the argon and helium afterglows. There appears to be a connection between the intensity of the first-negative bands in the narrow portion of the tube and the intensity of the forbidden nitrogen line 3467 in the neighboring portion of the tube where the afterglow is observed. This may lead to an understanding of excitation processes in the aurora.

50. On the Molecular-Field Theory of Volume Magnetostriction. R. SMOLUCHOWSKI, *Princeton University.*—In a saturated ferromagnetic substance all elementary magnets are aligned under the influence of the molecular-field proportional to the magnetization. Quantum mechanics relates this field to the exchange forces between electrons of the atoms. Since these forces depend upon interatomic distance we would expect the molecular field to be volume dependent. Interpretation of corresponding magnetostriction data has been given by Becker and Kornetzki who assumed a volume independent saturation magnetization at absolute zero. Since this assumption is questionable a different procedure was adopted: We treat the Brillouin functions in the formalism of the molecular-field theory as known, assuming $j=\frac{1}{2}$ or $j=1$ corresponding to uncoupled or coupled (in pairs) electrons. Using the experimental data on the magnetostriction of iron this method allows us to obtain values for (a) the molecular-field "constant" N; (b) its dependence on the relative change of volume $(1/N)\,(\partial N/\partial\omega)$; and (c) the dependence on volume of the saturation magnetization at 0°K $(1/I_0)\,(\partial I_0/\partial\omega)$. The value of N agrees well with that obtained from magnetocaloric measurements. The dependence of saturation magnetization agrees with the value expected from the change of density. The check of the value of $(1/N)\,(\partial N/\partial\omega)$ is made considering the "magnetic" specific heat caused by the change of the magnetization energy. Thermodynamical considerations lead to an additional term proportional to this magnitude. A comparison with the experimental data provides a good check of the obtained value. All quantitative checks of our theory, including the probable change of Curie point under pressure, are more satisfactory assuming electrons coupled in pairs $(j=1)$ than uncoupled $(j=\frac{1}{2})$.

51. Magnetic Properties of Antimony-Tin Monocrystals. S. H. BROWNE AND C. T. LANE, *Yale University.*—According to the Bloch theory, in metals the energy states of electrons are pictured as falling into zones (Brillouin zones). In particular, Mott and Jones[1] have shown that for bismuth-like structures the first and second Brillouin zones overlap slightly. The magnetic susceptibility of the crystal parallel to the trigonal axis ($\chi_{\parallel}$) is caused by these overlapping electrons while the susceptibility perpendicular to this axis ($\chi_{\perp}$) is due to the vacant spaces (positive holes) in the first zone. We have investigated this theory by measuring $\chi_{\parallel}$ and $\chi_{\perp}$ for monocrystals of antimony-tin, up to eight percent tin. In this range a solid solution is formed, leaving the antimony crystal structure unchanged, but because of the difference in valence each tin atom removes one electron from the crystal. In accordance with expectation $\chi_{\parallel}$ decreases sharply, and eventually (at approximately 1.11 atomic percent tin) changes from diamagnetic to paramagnetic. $\chi_{\perp}$ remains diamagnetic, but decreases slightly (by approximately 15 percent at the inversion point). From the inversion point of $\chi_{\parallel}$ it is estimated that there are approximately 10^{-2} overlapping electrons per atom in the second zone in antimony.

[1] N. F. Mott and H. Jones, *The Theory of the Properties of Metals and Alloys* (Oxford, 1936).

52. Magnetic Susceptibility of Metallic Lithium. C. STARR AND A. R. KAUFMANN, *Massachusetts Institute of Technology.*—The magnetic susceptibility of metallic lithium has been studied as a function of temperature between 300°K and 13.9°K. The experimentally determined volume susceptibility (per cc) is given by the equation $\chi\times10^6=1.90+7.8/T$. The lithium specimen contained more than 99 percent Li, with a remainder of Na, K, N_2 and about 0.01 percent Fe. The major part of the temperature dependent term may be caused by the effect of the dissolved iron impurity. A small amount of iron in solid solution generally behaves as a paramagnetic substance and contributes a Curie law term to the susceptibility. Theoretical study[1] indicates that the paramagnetic susceptibility of pure lithium would be expected to increase with decreasing temperature, but the magnitude of this effect is not known.

[1] J. B. Sampson and F. Seitz, Phys. Rev. **58**, 633 (1940).

53. Hall e.m.f. and Intensity of Magnetization. EMERSON M. PUGH, *Carnegie Institute of Technology.*—The experimental fact that the Hall e.m.f. in the majority of ferromagnetic materials is directly proportional to the intensity of magnetization in the material can be explained by assuming that the Hall electric field $\mathbf{E}_H$ at any point

in the material is given by $\mathbf{E}_H = Ri \times If(I)$ for any function of the intensity of magnetization at that point. This is true since the magnetic domains in the material are always saturated and any $f(I)$ must be a constant throughout the material. Therefore the contribution of any domain to the whole e.m.f. is proportional to its contribution to the macroscopic intensity of magnetization of material. The justification for this assumption will be reviewed. These conclusions probably apply to all of the transverse effects.

54. A Taylor Dislocation Near a Cylindrical Boundary. J. S. KOEHLER,* *University of Pennsylvania.*—It has been suggested by Taylor and others that the low plastic yield strengths of solids are caused by line dislocations. The exact mechanism by which dislocations are created is not known, but there is evidence that they are formed at crystalline surfaces. A solution of the elastic equations for a continuous isotropic solid has been found for the case of a line dislocation near a cylindrical boundary. The elastic energy associated with the dislocation is computed as a function of the distance from the surface. From this result the forces acting on the dislocation near a plane boundary in the absence of an external stress is found and tends to attract the dislocation to the surface.

* Rackham Postdoctoral Fellow of the University of Michigan.

55. Dislocations and the Theory of Creep. FREDERICK SEITZ, *University of Pennsylvania.*—It is pointed out that two different qualitative pictures can be used to discuss creep in single crystals on the basis of the theory of dislocations. One of these is based on the notion that the rate of creep is determined primarily by the relatively slow motion of dislocations present in the solid; the other is based on the notion that dislocations move almost instantaneously and that creep is tied up primarily with the rate of generation of dislocations. The equations associated with each of these pictures are, respectively,

$$\frac{dS}{dt} = \lambda v N, \qquad \frac{dS}{dt} = \lambda L \frac{dN}{dt}.$$

Here dS/dt is the rate of strain, N is the number of dislocation lines per unit area, λ is the slip distance associated with the passage of one dislocation, v is the average velocity of the dislocations, and L is the average distance moved by a dislocation. Examination of the meager available creep data for a quantitative comparison of the merits of these equations indicates that neither furnishes a completely satisfactory correlation of all experimental material. The first meets difficulty because the required velocity v must be unreasonably low for reasonable values of N; the second meets difficulty at low temperatures and stresses because the assumed values of dN/dt are unreasonably high.

56. Damping of Mechanical Vibrations in Copper Crystals. THOMAS A. READ,* *Westinghouse Research Laboratories.*—In a recent paper[1] on the internal friction of zinc crystals it was suggested that the damping of longitudinal vibrations in zinc single-crystal rods results from the production of dislocations by the oscillating stress and their motion under the influence of that stress. Data will be shown which indicate that the internal friction of copper crystals at small strain amplitudes must be ascribed only to the motion of dislocations already present in the crystals. This evidence may be summarized as follows: (1) the decrement of a copper crystal is not changed by the oscillations, (2) the application of a static compressive stress of 100 lb. per sq. in. increases the decrement of a copper crystal, and (3) the internal friction of copper single crystals is only slightly temperature dependent.

* Westinghouse Research Fellow.
[1] T. Read, Phys. Rev. **58**, 371 (1940).

57. Order-Disorder Questions and Certain Spinels. F. C. BLAKE, *Ohio State University.*—It has been previously shown that one of the spinels (lithium ferrite) can be explained as having both long range and short range order of magnitude 100 percent by the method of lattice enlargement from a cube of edge 4.14 angstroms to one of edge 33.2 angstroms. For certain other spinels this method did not work, apparently. However, for one of this latter group, a *smaller* rather than a *larger* lattice gives a unique solution, the space group changing from cubic to tetragonal with the axial ratio equal to $\sqrt{2}$. It is not claimed that a hundred percent short range—and long range—ordered solution can always be found as a substitute for any so-called disordered solution, though less violence is done to our theories of valence by ordered rather than disordered solutions.

58. Phase Transition in Liquid Helium. L. I. SCHIFF, *University of Pennsylvania.*—A method for treating the quantum-mechanical many-body problem at temperatures so low that degeneracy plays a dominant role[1] has been applied to the phase transition in liquid helium. It is shown that the correction to London's free-particle model due to two-body encounters does not affect the transition temperature, or the continuity of either the energy or the specific heat at the transition temperature. Explicit calculations on the basis of the elastic sphere model, considering only S collisions, show that the specific heat is lowered in the neighborhood of the transition temperature. These results suggest the possibility that the observed phase transition in liquid helium is characteristic of a condensed system, and cannot be obtained from gas approximation methods such as the present.

[1] L. I. Schiff, Science **92**, 482 (1940).

59. Description of the Liquid Helium Equipment at Yale University. C. T. LANE, *Yale University.*—A plant for producing liquid helium in quantity has recently been completed, and is in satisfactory operation. The design of the liquefier is based on the work of Kapitza,[1] making use of an expansion engine working adiabatically to bridge the temperature interval between 65° and 10°K. Consequently, the only refrigerant used is liquid air; greatly reducing the cost of the equipment and eliminating the dangers of work with hydrogen. The helium distribution and purifying systems are very simple and compact; the whole plant may

be placed in a room about 18 feet square. For reasons of efficiency the stage from 10°K to liquefaction is accomplished by means of Joule-Thomson expansion between the limits 13 to 1.5 atmospheres. The subsidiary machinery (compressor, vacuum pumps etc.) is composed entirely of commercial equipment. Approximately $1\frac{1}{4}$ hours are required to reach the liquefaction point, and thereafter liquid helium is made at the rate of about $1\frac{1}{2}$ liters per hour. About 10 liters of liquid air are necessary to cool the liquefier to the helium point, and roughly 2 liters per hour thereafter. Photographs of the plant will be shown and an estimate of the cost given.

[1] P. Kapitza, Proc. Roy. Soc. **A147**, 189 (1934)

60. Raman Spectrum of 6-Dodecyn-5-one.* FORREST F. CLEVELAND AND M. J. MURRAY, *Illinois Institute of Technology.*—The Raman spectrum of 6-dodecyn-5-one, $CH_3(CH_2)_4C{\equiv}CCO(CH_2)_3CH_3$, has been obtained. The spectrum is interesting because the triple-bond frequency at 2212 cm^{-1} is single, rather than double or multiple as is the case for most disubstituted acetylenes, and is lower than usual for such molecules. For example, 6-dodecyne, which differs from the above molecule only by the presence of two hydrogen atoms in place of the oxygen atom, has in this region the frequencies 2231(7), 2248(2) and 2294(4). If the multiplicity of lines in this case is caused by resonance interaction, the single line observed for 6-dodecyn-5-one can be understood by supposing that the drop in the triple-bond frequency occasioned by the introduction of the oxygen atom causes it to be no longer in sufficiently exact coincidence with the overtone or combination frequency to permit resonance interaction. Consistent with this hypothesis is the fact that only a single line was observed by the authors for phenyliodoacetylene. The frequency in this case was 2183 which is also considerably less than the usual value for disubstituted acetylenes. Another possibility is that the introduction of the oxygen atom may have changed the value of the fundamental or fundamentals whose overtone or combination frequencies interacted with the triple-bond frequency in the 2200 region. The frequency characteristic of the C=O group is also lower than usual for a ketone as is to be expected for conjugation with a triple-bond.

* To be called for after Paper No. 49.

ABSTRACTS OF INVITED PAPERS

A. A Hydro-Physical Approach to the Quantitative Morphology of Drainage Basins. ROBERT E. HORTON, *Voorheesville, New York.*—The purpose of this paper is to show how fundamental principles of physics, hydraulics and hydrology may be applied quantitatively to the study of drainage basins and their stream systems. As the basis for this study, numerical factors are needed which characterize the physical features of a drainage basin and its stream net quantitatively. Particular stress is laid on two closely related factors, drainage density and infiltration-capacity, as indicative of degree and rate of basin and channel development. Except in regions of karst topography, stream basin development by aqueous erosion is conditioned almost wholly by surface runoff, exclusive of ground-water flow. The independent physical variables controlling surface runoff are: rain intensity, rain duration and intensity distribution, infiltration-capacity, surface roughness, surface slope, length of overland flow and type of overland flow. These factors, in conjunction with the hydraulic laws of sheet flow (Manning's formula for turbulent, Poiseuille's formula for laminar, flow), together with the law of continuity, afford a basis for a complete rational treatment of surface runoff phenomena. Hence the purely hydraulic and hydrologic phases of the subject may be considered as completely solved. The second phase of the subject—determination of the rate of sheet erosion corresponding to a given surface runoff regimen—is almost as completely unsolved. Assuming merely that, for a given drainage basin, sheet erosion is a function of hydrologic conditions, conclusions can be drawn which are helpful in understanding the physiographic characteristics of drainage basins and their drainage nets.

B. Problems of Orogeny. CHESTER R. LONGWELL, *Yale University.*—*Orogeny* is defined as large-scale crustal deformation characterized by folding, thrusting, and other evidences of compression. The chief objectives in the study of orogenic structures are: (1) To determine the geometric pattern of features that record deformation in the several orogenic zones. The first step to this end is accurate mapping of mountain belts; but even if this part of the task were fully accomplished, the third dimension would still present large uncertainties—the depth to which deformation extends, and the nature of deformation at all depths below the zone of observation. Some attempts to calculate depth of deformation from surficial evidence have reached questionable conclusions. (2) To establish the nature of stresses responsible for the several kinds of deformation in orogenic zones. The stresses are to be inferred from the field facts, with the assistance of laboratory experiments, particularly experiments using scale models. (3) To date the orogenic events as closely as possible. The development of any one zone can be understood only after the correct order of events in that zone is determined. Exact dating of all orogenic movements would go far toward settling the controversy as to whether diastrophism is "periodic" and "world-wide" in character. (4) To detect the ultimate forces responsible for diastrophism. This subject is still in the speculative stage, and can be approached only by the method of multiple working hypotheses. A comprehensive study of orogeny must consider its relation to the other kinds of crustal deformation—major warping, or *epeirogeny*, and regional block-faulting, sometimes designated *tafrogeny*.

C. Physical Frontiers in Seismology.—L. DON LEET, *Harvard University.*—Seismology has reached a critical stage where serious discrepancies between observations and current theories have been established. Investigation of these is awaiting the interest and abilities of mathematical and experimental physicists. It is believed that solutions will lead to results of geological importance in connection with data on the structure of the earth's crust, mantle, and core. Over a year ago, the writer reported observations of a new wave form, tentatively called the "coupled wave," which is not explained by the classical theory of elasticity. It was first found in the vicinity of dynamite blasts and in some cases dominated the motion. Subsequent search by Collins on earthquake records at the Harvard Seismograph Station revealed it at certain distances as the wave which had previously been called the shear wave of classical theory. This led further to the discovery that the so-called shear wave is actually compressional in character over certain distance ranges, a coupled wave over others, and shows the characteristics of a true shear wave over only a relatively narrow range. Birch, at Harvard, has made one of the first fundamental attacks on these widening physical frontiers in seismology by investigating the effect of pressure upon elastic parameters of isotropic solids, according to Murnaghan's theory of finite strain. He suggests "that a more rigorous solution of the equations of motion derived from the theory of finite strain might prove of value in interpreting the oscillatory character of seismic records, as well as the direction of the ground motion associated with various wave types."

D. The Radio-Elements in the Water and Sediments of the Ocean. WILLIAM D. URRY, *Geophysical Laboratory, Washington, D. C.*—The radioactive relations existing in the ocean and its sediments are complex in comparison with the simple relations for the igneous and sedimentary rocks that form the continents. This is because neither in the ocean nor in the upper layers of the ocean bottom are elements such as uranium, ionium and radium in radioactive equilibrium. In discussing the distribution of the radio-elements the dimension of time is therefore of prime importance. The sediments underlying the deeper portions of the ocean provide suitable material, correlated with this dimension, for studying the growth and decay of these elements. Glacial and other stratifications in some of these sediments greatly complicate the radioactive relations. These studies indicate the possibility of establishing the rate of deposition of the ocean sediments.

AUTHOR INDEX TO ABSTRACTS OF THE PHILADELPHIA MEETING