Proceedings of the American Physical Society

MINUTES OF THE COLUMBUS, OHIO, MEETING, DECEMBER 28–30, 1939

THE 41st Annual Meeting (the 232nd regular meeting) of the American Physical Society was held at Columbus, Ohio, on Thursday, Friday and Saturday, December 28, 29 and 30, 1939, in affiliation with Section B—Physics of the American Association for the Advancement of Science. All sessions of the meetings were held at The Ohio State University. The presiding officers were Professor John Zeleny, Vice President of the Society, Dr. W. E. Forsythe, Professor R. C. Gibbs, Professor Elmer Hutchisson and Dean Alpheus W. Smith.

On Friday afternoon, December 29, 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. Dr. Herbert E. Ives of the Bell Telephone Laboratories delivered an address entitled "The Measurement of Velocity and Atomic Clocks." Professor I. I. Rabi of Columbia University addressed the session on the subject "Radio-frequency Spectra of Atoms and Molecules." The presiding officer was Dr. Karl K. Darrow of the Bell Telephone Laboratories.

On Friday evening, December 29, the Society held a joint dinner with the American Association of Physics Teachers at the Deshler-Wallick Hotel. The attendance was approximately two hundred. Dr. Karl K. Darrow presided.

Annual Business Meeting. The regular Annual Business Meeting of the American Physical Society was held on Friday afternoon, December 29, 1939 at two o'clock, Vice President Zeleny presiding. Dr. W. H. Brattain reported for the tellers that the following had been elected as officers for the year 1940:

President, John Zeleny; *Vice President*, George B. Pegram; *Secretary*, W. L. Severinghaus; *Treasurer*, George B. Pegram; *Members of the Council*, F. G. Brickwedde and Henry D. Smyth; *Members of the Board of Editors*, Samuel K. Allison, Philip M. Morse and John A. Wheeler.

The Secretary reported that during the year 221 persons had accepted election to membership. He reported the deaths of 14 members, that 40 members had resigned and 51 members had been dropped. The membership as of December 26, 1939 was as follows: Fellows: 788; Members: 2772; Honorary Members: 5; Total Membership: 3565.

The Treasurer presented a summary of the financial condition of the Society. The Treasurer's financial report will be audited, printed and distributed to the members.

Dr. J. W. Buchta, the Assistant 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 1939 would be printed and distributed to the members.

The meeting adjourned at two-twenty P.M.

Meeting of the Council. At the meeting of the Council held on Thursday morning, December 28, 1939, eighteen candidates were elected to fellowship and thirty-four candidates were elected to membership. *Elected to fellowship:* Allen V. Astin, C. Hawley Cartwright, Jacob Clay, Gioacchino Failla, James B. Fisk, William W. Hansen, Serge A. Korff, Henry M. O'Bryan, Arthur L. Patterson, Franco Rasetti, Lynn H. Rumbaugh, Leonard I. Schiff, Theodore E. Sterne, Arthur von Hippel, Milton G. White, Howell J. Williams, John H. Williams, and E. Bright Wilson, Jr. *Elected to membership:* Thomas C. Bagg, F. Meade Bailey, Clifford Beck, Sister Bernarda, Maurice A. Biot, William W. Beeman, Harvey Brooks, Allan L. Burton, Jr., George W. Charles, Vinton C. Fishel, Herbert Friedman, William Garten, Jr., Herbert Goldstein, Roy Goslin, Eugene M. Grabbe, Theodore Jorgensen, Jr., Mother Marion Kent, Kenneth E. Keyes, J. Stewart Marshall, Ralph W. Mann, Karl Martinez, Boyce D. McDaniel, James O. McNally, Eugene McNatt, Park H. Miller, Jr.,

Wilford E. Morris, Jacob Neufeld, H. F. Newhall, E. W. Richmeyer, Charles F. Robinson, Richard Scheib, Jr., Wave H. Shaffer, Erwin F. Shrader, and William Widmaier.

The regular scientific program of the Society consisted of seventy-five contributed papers of which six, numbers 22, 37, 53, 54, 61 and 72, were read by title. The abstracts of the contributed papers are given in the following pages. An Author Index will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

ABSTRACTS

1. Effect of Hyperfine Structure upon the Magnetic Rotation of the Plane of Maximum Polarization of Resonance Radiation. BERTRUND J. MILLER, *St. Ambrose College.*—An equation has been developed for the polarization, and the angle of maximum polarization of resonance radiation as observed along a magnetic field perpendicular to the electric vector and the direction of propagation of the incident beam. Explicit application has been made to the polarization and the angle for the line $^1S_0-{}^1P_1$ for various values of the ratio of the hyperfine separation constant to the natural breadth of the levels, for a nuclear moment of $\frac{1}{2}$. It was noted here that the form of the curves might differ widely from that to be expected from classical considerations. The polarization, and the angle of maximum polarization for the D lines, for several values of the same ratio, were computed and compared with experimental observations. Thus a range of possible values of A was determined, which is not in disagreement with previous figures, and a value for τ established which agrees well with that calculated from optical dispersion data.

2. The Excitation of High Stages of Ionization in Gases. HARRY D. POLSTER AND FRED W. PAUL, *Ohio State University. (Introduced by Harold P. Knauss.)*—Various methods have been employed in an attempt to produce high stages of ionization in gases to make possible the spectroscopic investigation of highly ionized rare gas atoms. Of these the most successful have been the use of a condensed discharge in a quartz or Pyrex capillary and in a Geissler tube. Banks of condensers having capacitances of 0.1 μf, 0.3 μf, and 0.9 μf have been charged with voltages as high as 25 kv and then discharged through the gases. The resulting light is very brilliant and bluish-white in color. The spectra have been recorded with a 3-meter grazing incidence vacuum spectrograph. In testing the set-up oxygen has been used and the spectra of O III, O IV, and O V have been brought out quite strongly. Preliminary observations in the spectra of neon have permitted the identification of a few lines of Ne V.

3. The Spectra of Cb V and Cb VII. GEORGE W. CHARLES AND FRED W. PAUL, *Ohio State University. (Introduced by Harold P. Knauss.)*—Condensed sparks in a high vacuum chamber between electrodes of columbium metal have been used as a source of light on a 3-meter grazing incidence vacuum spectrograph. The resulting spectrograms have been measured and the data have been partially analyzed. Tentative identifications have been made in the spectra of Cb V and Cb VII with the aid of isoelectronic sequence data. The brightness of these spectra and the fact that they can account for only a small part of the lines observed lead to the hope that some identifications may be made in the spectra of Cb VI and Cb VIII.

4. The Zeeman Effect in Krypton. J. B. GREEN, D. W. BOWMAN AND E. H. HURLBURT, *Ohio State University.*—The spectrum of krypton emitted in a magnetic field of about 36,000 gauss has been measured, using a high frequency electrodeless capillary discharge. Preliminary measurements indicate that a revision of Pogány's measurements[1] is necessary, especially for $4p^55s$ ($1s_2$ and $1s_4$) which are found by us to have values much closer to the theoretical values than Pogány's, which seem to be inverted. A much closer agreement with theory is also found for the $4p^55p$ configuration. Rasmussen's[2] reclassifications of some of the levels are checked, and a few further reclassifications suggested.

[1] B. Pogány, Zeits. f. Physik **93**, 364 (1934–5).
[2] E. Rasmussen, Zeits. f. Physik **73**, 779 (1931–2).

5. Sommerfeld's Fine Structure Constant. ALFRED LANDÉ, *Ohio State University.*—The *suggestion*[1] of obtaining the electronic density amplitude $\psi(r)$ and Sommerfeld's constant α from a homogeneous integral equation, which was transformed into a consistent *theory* by M. Born[2] through his idea of a phase retardation inside the electron, is revised by a reciprocal treatment of (p, E) and the distances $(\Delta r, \Delta t)$. The equation $(c\Delta t)^2-(\Delta r)^2=-a^2$ determines the time Δt of a signal traveling Δr. Then $\Delta t=0$ for $\Delta r=a$ means *particles of diameter a*, similar to *Dirac's* theory of the classical electron,[3] with $a=\gamma e^2/mc^2$ and $\gamma=2/3$. If $R=r/a$ we obtain the integral equation

$$\psi(R)=(\gamma\alpha/2\pi)^3\int\psi(R')K(\gamma\alpha, |R-R'|)dV',$$

where dV' is the noninvariant volume element divided by a^3, and K is the symmetric kernel

$$K=\int_0^\infty dP 4\pi P^2\times\sin(AP)/(AP)\times\sin[iB(P^2+1)^{\frac{1}{2}}]/[B(P^2+1)^{\frac{1}{2}}],$$

$$A=\gamma\alpha|R-R'|, \quad B=\gamma\alpha(|R-R'|^2-1)^{\frac{1}{2}}.$$

$1/\alpha$ is calculated to be 136.08.

[1] A. Landé, J. Frank. Inst. **228**, 495 (1939).
[2] M. Born, Proc. Roy. Soc. Edinburgh **49**, 219 (1939).
[3] P. A. M. Dirac, Proc. Roy. Soc. **A167**, 148 (1939).

6. Spectroscopic Comparison of Strengths of Hydrogen Bonds Between CH_3OD and Certain Solvents.* WALTER GORDY, *Mary Hardin-Baylor College*, AND SPENCER C. STANFORD, *The College of Wooster*.—Forty-two different organic liquids are rated according to their proton-attracting power by comparing the strengths of the hydrogen bonds which they form with heavy methyl alcohol. The classes of liquids studied are: aldehydes, ketones, esters, ethers and amines. The amount of perturbation which the different solvents produce in the OD vibrational band of the CH_3OD is taken as a measure of the strength of the deuterium bridges formed with the CH_3OD. The study is a continuation of a previous work in which 26 similar liquids were observed, and the results agree with those of the former study in showing that the proton-attracting power of the different classes of liquids rises in the order: esters<aldehydes and ketones <ethers<amines. From the data gathered it is possible to observe the effects of unsaturation, substitution and other structural variations on the electron donor power of the O or N atom to which the OD group forms a bond. It is shown that the strength of the deuterium bonds formed with CH_3OD bears a close relation to the basicities of the solvents to their reactivities with certain other compounds, and to their solubilities for other proton donor solutes. There appears to be no correlation between the dipole moments of the solvents and the strengths of the bonds formed with the CH_3OD.

* The observations reported here were made in the Mendenhall Laboratory of Physics, Ohio State University.

7. New Measurements on the Vibration-Rotation Bands of Water Vapor. HARALD H. NIELSEN, *Ohio State University*.—The five bands ν_2(1595 cm^{-1}), $2\nu_2$(3152 cm^{-1}), ν_3(3756 cm^{-1}), $\nu_2+\nu_3$(15,332 cm^{-1}) and $\nu_1+\nu_3$(7253 cm^{-1}), using Dennison's notation, have been remeasured under high dispersion. By enclosing the optical parts of the spectrometer with an air-tight box it has been possible almost completely to resolve these bands. Much more detail in the rotational structure is discernible than is possible in the earlier absorption curves,[1] and many separations between lines have been recorded of 0.5 cm^{-1} or less. While the lines observed have not been completely classified, some modifications of the analysis by Mecke[2] appear necessary. This is especially true of $2\nu_2$ where an additional line, not earlier recorded, has been found near the center so that the interval between the two most intense lines nearest the center is reduced to about 40 cm^{-1} as is the case for the fundamental ν_2. Measurements on the spectra of the "heavy" waters are also in progress. High dispersion data on the frequency ν_3 have been completed and the band is almost completely resolved.

[1] Phys. Rev. **37**, 1493 (1931); **39**, 77 (1932).
[2] R. Mecke, Zeits. f. Physik **81**, 313 (1933).

8. The Infra-Red Absorption Spectrum of the Deutero-Acetylenes. ALVIN H. NIELSEN,* *Ohio State University*.—The spectrum of the deutero-acetylenes has been re-investigated from 2.0μ to 10.0μ, using prism and grating spectrometers. The gas was made by allowing high purity D_2O to react with calcium carbide which had been thoroughly baked out. No bands of C_2H_2 were observed. The prism curve revealed the following bands for C_2DH: ν_2 at 3340 cm^{-1}, ν_3 at 2560 cm^{-1}, $2\nu_4$ at 1340 cm^{-1}, and $\nu_4+\nu_5$ at 1202 cm^{-1}. In C_2D_2 the bands observed were ν_3 at 2414 cm^{-1} and $\nu_4+\nu_5$ at 1043 cm^{-1}. By means of a grating having 4800 lines per inch, ν_2 in C_2DH was resolved giving a rotational $\Delta\nu$ of 1.98 cm^{-1}. The rotational $\Delta\nu$ for $2\nu_4$ and $\nu_4+\nu_5$ in C_2DH, determined by means of a grating having 2000 lines per inch, are 1.98 cm^{-1} and 1.96 cm^{-1}, respectively. The moment of inertia calculated from the average of these spacings is 28.0×10^{-40} g cm^2 in agreement with the value 27.9×10^{-40} g cm^2 of Herzberg, Patat and Spinks[2] determined from photographs of near infra-red overtone bands. The lines in $2\nu_4$ and $\nu_4+\nu_5$ appear complex. This may be because of superposition of corresponding bands in $H-C^{12}-C^{12}-D$, $H-C^{12}-C^{13}-D$, $H-C^{13}-C^{12}-D$, and $H-C^{13}-C^{13}-D$. The remaining unresolved bands are being measured and will be reported at a later time.

* University of Tennessee.
[1] E. F. Barker and H. M. Randall, Phys. Rev. **45**, 124(A) (1934); W. F. Colby, Phys. Rev. **47**, 388 (1935).
[2] Herzberg, Patat and Spinks, Zeits. f. Physik **92**, 87 (1934).

9. Infra-Red Absorption Spectrum of Methylphenylacetylene. FORREST F. CLEVELAND AND M. J. MURRAY, *Armour Institute of Technology*.—The infra-red absorption spectrum of methylphenylacetylene ($C_6H_5C\equiv CCH_3$) between 500 and 2300 cm^{-1} has been obtained with a prism spectrometer. The results are compared with the Raman spectrum, previously measured by the authors,[1] and are found to be inconclusive as regards the assignment of the fundamental whose overtone, according to Badger's hypothesis,[2] is responsible for the resonance doubling of the frequency near 2230 cm^{-1}. The frequency near 1100 cm^{-1} which most nearly satisfies the frequency condition for resonance is a weak one at 1095 cm^{-1}. The first overtone of this frequency, 2190 cm^{-1}, has a value even less than that of the smaller frequency of the doublet, 2214, 2254. The second overtone of the 756 cm^{-1} frequency, 2268 cm^{-1}, on the other hand, is greater than the larger frequency of the doublet. The authors wish to express their appreciation to Professor H. M. Randall for the use of his laboratory at the University of Michigan and to Mr. Robert A. Oetjen for his assistance in obtaining the experimental record.

[1] M. J. Murray and Forrest F. Cleveland, J. Am. Chem. Soc. in press.
[2] R. M. Badger, J. Chem. Phys. **5**, 178 (1937).

10. The Absorption Spectra of α, β, γ, δ-Tetraphenylporphine and a Series of Its Metal Complex Salts. V. M. ALBERS AND H. V. KNORR, *Antioch College*.—The absorption spectra of α, β, γ, δ-tetraphenylporphine and the Cd, Ag, Zn, Pb, Ni, Co, FeCl, MnCl and $SnCl_2$ complex salts have been studied over the region from 900 mμ to 370 mμ in benzene solution, using a recording spectroradiometer previously described.[1] No absorption bands were observed for any of these substances between 900 mμ and 700 mμ. They all, however, show characteristic absorption in the visible region. Absorption curves, showing molecular absorption coefficients as a function of wave-length, have

been determined for all of these substances from 700 mμ to 370 mμ.

[1] V. M. Albers and H. V. Knorr, J. Opt. Soc. Am. **28**, 121–123 (1938)

11. The Fluorescence Spectra of α, β, γ, δ-Tetraphenylporphine and Some of Its Metal Complex Salts. H. V. KNORR AND V. M. ALBERS, *Antioch College.*—The fluorescence spectrum of α, β, γ, δ-tetraphenylporphine in anhydrous benzene and under an atmosphere of N_2, has been photographed by a method previously described.[1] The spectra of the Ni, FeCl, and Ag complex salts have also been photographed under similar conditions. A fluorescence band is observed with its maximum at 655 mμ, for each of these substances. This same band was also observed for tetraphenylporphine under an atmosphere of CO_2. Two additional bands have been observed in the near infra-red portion of the spectrum for the tetraphenylporphine.

[1] H. V. Knorr and V. M. Albers, Cold Spring Harbor Symposia on Quantitative Biology **3**, 98–107 (1935).

12. A Constant Current Network for Supplying Power to a Cyclotron Oscillator. A. J. ALLEN, *University of Pittsburgh,* AND R. G. FRANKLIN, *Biochemical Research Foundation of the Franklin Institute.*—A constant current network using 3 phase-4100 v from the power distribution system and supplying from 0.6 to 3.6 amperes up to 12 kv to the plates of a cyclotron oscillator has been developed. The network makes use of a simple resonant circuit for transforming constant voltage to constant current.[1] The capacitors are made variable in steps and the inductor continuously variable to give the desired power output. The voltage, current, and protection requirements for the various parts are given. The network tends to eliminate power surges, provides a convenient method for regulating the power input into the cyclotron, and eliminates the use of transformers for the plate supply.

[1] Elec. Eng. **54**, 102 (1935).

13. The Ohio State University Cyclotron. ALPHEUS W. SMITH AND M. L. POOL, *Ohio State University.*—A brief introduction to the cyclotron here under construction will be made. The salient features to be discussed include the magnet frame, glass-insulated and water-cooled magnet coils, vacuum chamber and system, radiofrequency oscillator system and quarter wave-length transmission line. The relation of the cyclotron to other departments in the University will be pointed out.

14. Performance of Westinghouse Electrostatic Generator up to 3.7 mv. W. H. WELLS, R. O. HAXBY,* W. E. SHOUPP* AND W. E. STEPHENS,* *Westinghouse Research Laboratories.*—The voltages attained as a function of pressure up to 80 pounds per sq. in. are limited with the present belt arrangement by sparking, mainly along the surfaces of the belts. Voltages are measured with a generating voltmeter which has been calibrated against gamma-ray resonance values determined at the University of Wisconsin. Molecular hydrogen ions of masses two and three are used to determine the linearity and calibration constant of the voltmeter when used as a null instrument. Voltages in the region of 3 mv are constant for observing times of several minutes to less than 0.5 percent and can be read during these time intervals to 0.2 percent.

* Westinghouse Research Fellow.

15. Coincidence Measurements in As^{76}. L. M. LANGER, A. C. G. MITCHELL AND P. W. MCDANIEL, *Indiana University.*—Using a strongly activated source of As^{76} (26 hours), prepared by irradiation of As by slow neutrons from the Berkeley cyclotron, gamma-gamma and beta-gamma coincidences have been investigated. The maximum energy of the beta-rays was measured by absorption in Al, using a single counter. The end point was found to be 3.24 mv. The number of gamma-gamma coincidences was found to be 0.28 ± 0.02 per thousand gamma-rays detected. Beta-gamma coincidences were measured as a function of the thickness of aluminum absorber placed between the source and the beta-ray counter. The number of beta-gamma coincidences per thousand beta-rays detected was found to vary with the energy of the beta-rays. The shape of the curve suggests that there are at least two groups of beta-rays present, both of which go to an excited state of Se^{76}.

16. Investigation of Beta- and Gamma-Rays from Sb^{122} and Sb^{124}. A. C. G. MITCHELL, L. M. LANGER AND P. W. MCDANIEL, *Indiana University.*—The beta- and gamma-rays emitted by Sb, irradiated by slow neutrons, have been studied by the method described in the previous abstract. In Sb both beta-rays and gamma-rays were observed to be associated with each of the two periods of 70 hours and 60 days. The energy of the gamma-rays was measured by the coincident method of absorption of Compton electrons. The radiation was found to be inhomogeneous. The highest energy gamma-ray, which is associated with the long period, has an energy of 1.7 mv as determined from the range of the Compton recoils. Gamma-gamma coincidences decay with the long period, indicating more than one gamma-ray associated with this period. Absence of gamma-gamma coincidences with the short period indicates that only one gamma-ray of measurable intensity is associated with it. The maximum energy of the beta-rays of the long period was found, by absorption in Al, to be 1.53 mv. That of the short period is not greater than and probably equal to the same value. Beta-gamma coincidences, measured as a function of the energy of the beta-rays, show that there is only one group of beta-rays associated with the long period and this leads to an excited state of Te.

17. The Disintegration of N^{14} and N^{15} by Deuterons. M. G. HOLLOWAY, *Cornell University.* (*Introduced by R. F. Bacher.*)—The study of the disintegration of N^{14} and N^{15} has been continued using a gas mixture having much higher concentration (70 percent) of N^{15}. A search has been made for alpha-particle and proton groups in the region between 7 cm and 3 cm range. A new alpha-group of 3.48 cm range

was found at the end of the very intense distribution of alphas below 3.2 cm. This 3.48-cm alpha-group is attributed to the $N^{14}(d\alpha)C^{12}$ reaction in which the C^{12} is left in an excited state at 7.78 Mev. There is some indication of a proton group of about 3.5 cm range, which would arise from the $N^{15}(dp)N^{16}$ reaction.

18. Lithium and Carbon (p,n) Thresholds. R. O. HAXBY,* W. E. SHOUPP,* W. E. STEPHENS* AND W. H. WELLS, *Westinghouse Research Laboratories.*—Using high energy protons from the Westinghouse pressure electrostatic generator,[1] we have bombarded targets of lithium hydroxide and graphite and measured the thresholds for the production of neutrons. The neutrons were detected by a boron trifluoride ionization chamber surrounded with paraffin and connected to a linear amplifier and counter. The linearity and constant of the generating voltmeter was determined by measuring the 0.862-Mev gamma-ray resonance[2] from $F(p,\gamma)$ at 1.724 Mev and 2.586 Mev using H_2^+ and H_3^+. Hence our voltages depend on the Wisconsin voltage calibration of the fluorine resonances. The $Li^7(p,n)Be^7-Q_1$ threshold occurred at a proton energy $Ep=1.86\pm0.02$ Mev. This gives $Q_1=1.62\pm0.02$ Mev and $Be^7-Li^7=0.86\pm0.03$ Mev. This difference is somewhat lower than the estimate of 1.0 Mev made by Rumbaugh, Roberts and Hafstad[3] from the fraction of K-electron captures accompanied by gamma-rays, but is within their limits of error. This threshold is also smaller than that measured by Hill and Valley[4] due, perhaps, to our use of a more sensitive neutron detector. The $C^{13}(p,n)N^{13}-Q_2$ threshold was measured at $Ep=3.20\pm0.03$ Mev giving $Q_2=2.97\pm0.03$ Mev and $N^{13}-C^{13}=2.21\pm0.03$ Mev. So $N^{13}=C^{13}+e_+ +\mu+1.19\pm0.03$ Mev. This agrees well with Lyman's observed value of the maximum energy of these positrons $=1.198\pm0.006$ Mev.[5]

* Westinghouse Research Fellow.
[1] W. H. Wells, Phys. Rev. **55**, 599(A) (1939); J. App. Phys. **9**, 677 (1938).
[2] Bernet, Herb and Parkinson, Phys. Rev. **54**, 398 (1938).
[3] Rumbaugh, Roberts and Hafstad, Phys. Rev. **54**, 657 (1938).
[4] J. E. Hill and G. E. Valley, Phys. Rev. **55**, 678(A) (1939).
[5] E. M. Lyman, Phys. Rev. **55**, 234 (1938).

19. Radioactive Isotopes of Sr, Y and Zr. L. A. DUBRIDGE AND JOHN MARSHALL, *University of Rochester.*—Bombardment of Rb, Sr and Y with protons, deuterons and neutrons produces eleven radioactivities whose assignments, periods, properties and methods of formation are as follows:

Sr^{85}: isomers, 60 min. and 65 days, x-rays and gamma-rays only, 0.8 Mev γ-ray accompanying long period; $Rb^{85}(p,n)$.

Sr^{87*}: 2.7-hr. isomeric state, 0.37 Mev γ-ray internally converted;[1] $Rb^{87}(p,n)$, $Sr^{87}(n,n)$ and Y^{87}(85 hr.)$+e_k^-$. Cross section for $Sr^{87}(n,n)Sr^{87*}$ is of the same order of magnitude as for $In^{115}(n,n)In^{115*}$.

Sr^{89}: 55 days, e^-, $Sr^{88}(d,p)^2$.

Y^{85}: 15 days, K capture, $Sr^{84}(d,n)$.

Y^{86}: 80 days, K capture, 2 Mev γ-ray, $Sr^{86}(p,n)$.

Y^{87}: isomers, 85 hr. and 14 hr. 85-hr. activity, but not the 14-hr., decays by K capture to Sr^{87*}(2.7 hr.). Over 95 percent of the equilibrium activity of this period is due to conversion electrons of Sr^{87*}. Both periods formed by $Sr^{87}(p,n)$ and $Sr^{86}(d,n)$.[2]

Y^{88}: 2 hr., e^+, $Sr^{88}(p,n)$ and $Sr^{87}(d,n)$.[2]

Zr^{89}: isomers, 4 min. and 70 hr. Short period emits only x-rays and gamma-rays in isomeric transition, 70-hr. period emits 1-Mev positrons. $Y^{89}(p,n)$.

[1] L. A. DuBridge and J. Marshall, Phys. Rev. **56**, 706 (1939).
[2] Reported also by D. W. Stewart, Phys. Rev. **56**, 629 (1939).

20. The Production of Radium E and Radium F from Bismuth. J. M. CORK, J. HALPERN AND H. TATEL, *University of Michigan.*—It was shown by J. Livingood that on bombarding bismuth with 22-cm deuterons, neutron capture resulted in the formation of radium E. When the energy of the incident deuterons is increased it is now shown that both radium E and radium F (polonium) are made during bombardment. The latter process is associated with a proton capture. By observing the subsequent alpha-activity, making use of a linear amplifier and cloud chamber, data are obtained showing the yield of each product at varying excitation energies. At 10 Mev about four atoms of radium E are formed for each one of polonium. An apparent threshold energy for radium F exists at about 6.8 Mev. The atomic cross sections at 10 Mev are 9×10^{-29} cm^2 and 4×10^{-28} cm^2 for the formation of radium F and radium E, respectively.

21. Nuclear Excitation by Charged Particles Which Do Not Penetrate the Potential Barrier. EUGENE FEENBERG, *Washington Square College, New York University.*—A charged particle passing near a nucleus may lose some of its kinetic energy without actually penetrating the potential barrier.[1] The mechanism for the energy transfer is the Coulomb interaction between the particle and the protons in the nucleus. In the inhomogeneous and rapidly changing Coulomb field of the particle, the nucleus is subjected to forces which tend to produce distortion without change in volume. The momentary distortion resolves itself into a superposition of surface vibrations which persist until the excitation energy is lost in radiation or transferred to other types of motion in the nucleus. The coupling energy between a charged particle and the surface vibrations of a uniformly charged liquid drop has been determined and applied to compute the cross section for inelastic collision. In contrast to the more general formula given by Weisskopf, the expression for the cross section obtained from the liquid-drop model contains no undetermined nuclear matrix elements. Most of the cross section arises from the excitation of the surface wave with two units of orbital angular momentum. In very heavy nuclei this type of surface vibration has an excitation energy of about 0.8 Mev.[2] For particle energies greater than 3 Mev the cross section varies as the square of the momentum of the incident particle and in the case of 6-Mev alpha-particles on lead has a value greater than 10^{-26} cm^2.

[1] V. F. Weisskopf, Phys. Rev. **53**, 1018 (1938).
[2] N. Bohr and J. A. Wheeler, Phys. Rev. **56**, 426 (1939).

22. Scattering and Polarization of Electrons. M. E. ROSE,* *Yale University.*—The possibility of accounting for the observed small polarization of electrons in double scattering[1] and the anomalously small scattering of fast electrons ($E \gtrsim 500$ kv) in heavy elements[2] by assuming non-Coulomb forces near the nucleus is examined. Without any assumptions as to the nature of the forces it is found that due to the small range, *in general* either $s_{\frac{1}{2}}$ or $p_{\frac{1}{2}}$ waves can be scattered but not both. With the correct polarization the scattering of $s_{\frac{1}{2}}$ waves yields too small an intensity at low energies ($E \lesssim 300$ kv). Scattering of $p_{\frac{1}{2}}$ waves results in a correct polarization and scattering at low energies but the scattering at high energies cannot be made less than 70 percent Coulombian whereas about 15 percent Coulombian scattering is required. Under special conditions both $s_{\frac{1}{2}}$ and $p_{\frac{1}{2}}$ waves may be scattered. A necessary condition for this is that the logarithmic derivatives of both inside wave functions at the boundary be nearly equal to $-(1+(1-\alpha^2Z^2)^{\frac{1}{2}})/\text{range}$. This requires a very large interaction at small distances. The sufficient conditions for correct polarization and scattering are found in the form of a special energy dependence of the logarithmic derivatives of the inside wave functions at the boundary.

* Sterling Fellow.
[1] For example, E. G. Dymond, Proc. Roy. Soc. **A145**, 657 (1934).
[2] A. Barber and F. C. Champion, Proc. Roy. Soc. **A168**, 159 (1938).

23. The Crystalline Electric Field in $CuSO_4 : 5H_2O$. O. M. JORDAHL, *Northwestern University.*—With the publication of data on the principal magnetic susceptibilities of $CuSO_4 : 5H_2O$,[1] it becomes possible to study in detail the symmetry and magnitude of the crystalline electric field around the cupric ion. According to the analysis by Krishnan and Mookherji,[1] both for the crystal as a whole and for the single ion in the crystal, two of the principal magnetic susceptibilities should be the same. The value of the third principal susceptibility is less than the other values by about 20 percent in the crystal but is greater by about 40 percent in the case of a single ion. Using methods previously employed[2] we assume a predominant crystalline electric field of cubic symmetry and superpose a smaller field of tetragonal symmetry suitably oriented. The very large asymmetry in the magnetic susceptibilities means that the departure from cubic symmetry is considerable. Nevertheless it is the cubic field (fourth degree term) which primarily determines the mean magnetic susceptibility. The potential term in the Hamiltonian is

$$V=D(x^4+y^4+z^4)+A(x'^2-2y'^2+z^2) \text{ where } D>A.$$

Excellent agreement is secured between the computed and "observed" values of the principal magnetic susceptibility of the cupric ion if the $x'y'$ axes of the tetragonal field make angles of 45° with the x,y axes of cubic field and the splittings of the energy levels produced by the cubic and tetragonal fields are, respectively, 18,300 cm^{-1} and 2550 cm^{-1}. A tetragonal component whose axes coincide with the cubic field axes is unsatisfactory. The relation between this assumed field and the crystal structure of $CuSO_4 : 5H_2O$ [3] will be discussed.

[1] K. S. Krishnan and A. Mookherji, Phys. Rev. **50**, 860 (1936); **54**, 533 and 841 (1938).
[2] O. M. Jordahl, Phys. Rev. **45**, 87 (1934).
[3] C. A. Beevers and H. Lipson, Proc. Roy. Soc. **A146**, 570 (1934).

24. Interaction of Electrons with Nuclei. E. GUTH, *University of Notre Dame.*—The deviations from theory of observed fine structure of H_α and D_α, isotope displacements and electron scattering by nuclei can be explained by assuming that Coulomb's law for the interaction between electrons and nuclei breaks down at a certain distance r_0. The experimental results indicate that inside the nucleus there exists either a small negative potential ($\sim Ze^2/r_0$) with a large nuclear radius, or a big positive potential with a small radius ($\sim e^2/mc^2$). The effect of such deviations from Coulomb's law on the scattering of electrons is calculated, and it is shown that observable effects may result for electron energies of about 1.5 Mev and higher. Scattering experiments might distinguish between the two types of nuclear potentials mentioned. An interpretation of isotope displacement data over the whole periodic system is made by using a two-parameter nuclear potential. The displacements can be interpreted partly as the outcome of an additional electron-proton (and electron-neutron) interaction. The specific effects expected to result from such deviations from Coulomb's law will be discussed for various phenomena e.g. polarization of electrons in double scattering etc.

25. Calculation of Transmission Coefficients and Explanation of the Periodic Deviations from the Schottky Line. CHARLES J. MULLIN AND E. GUTH, *University of Notre Dame.*—In order to calculate transmission coefficients by the W.K.B. method for certain potential barriers, especially for those with sharp boundaries, approximations higher than the first (hitherto not used) are considered. The necessary formulae are developed. Former calculations using the first W.K.B. approximation are shown to be inconsistent. Interference effects in the transmission coefficient can explain the recently discovered periodic deviations from the Schottky line.[1] Both exact and W.K.B. calculations for simplified potential barriers account fairly well for the observed deviations.[2]

[1] D. Turnbull, *et al.*, Phys. Rev. **56**, 652, 663 (1939).
[2] Cf. also H. M. Mott-Smith, Phys. Rev. **56**, 668 (1939). However, with the special fields that he considered, he did not show this effect.

26. Some Properties of Retarded and Advanced Potentials. BORIS PODOLSKY AND KAISER S. KUNZ, *University of Cincinnati.*—The general solution of inhomogeneous wave equations of the type $\nabla^2\varphi-(1/c^2)\partial^2\varphi/\partial t^2=-4\pi\rho$, for the case of a charged particle moving in an external field, with the total field assumed known at the time $t=0$, can be written in either of the two forms: $\varphi=$retarded potential$+\psi_1$, or $\varphi=$advanced potential$+\psi_2$, where ψ_1 and ψ_2 are suitably chosen complementary functions. To study the properties of the complementary functions, and to obtain physical interpretations, space-time is divided into three regions: (1) the absolute past of the particle at $t=0$, (2) the absolute future of the same, and (3) the remaining region. It is then found that: first, in region (3) φ is independent of the shape of the world line of the particle; second, in region (1) ψ_2 is independent of the shape of the world line; third, in region (2) ψ_1 is independent of the shape of the world line. Application of this result leads to the conclusion that the retarded

potential gives the field produced by the particle, while ψ_1 gives the effects of the external field. The corresponding statement cannot be made for the advanced potential and ψ_2.

27. Magnetic Forces. F. W. WARBURTON, *University of Kentucky.*—The force of one electron on another developed from Riemann's potential is attractive because of its symmetry, action-reaction and propagation. The induced e.m.f., computed from the force of protons and electrons in a primary circuit acting on electrons in the secondary circuit, contains explicitly the relative velocity of the secondary element and the field-producing apparatus and the acceleration of the primary electrons. It satisfies the unipolar induction experiments with a rotating solenoid, the acceleration term canceling the motional term. However, when applied to the orbital electrons in the magnet acting on electrons in the secondary wire the results are not so favorable. This force and other similar symmetrical expressions, as well as the nonsymmetrical conventional magnetic force, obey constancy of field momentum plus mechanical momentum.

28. Analysis of B_2H_6 with a Mass Spectrometer. JOHN A. HIPPLE, JR.,* *Westinghouse Research Laboratories.*—A mass-spectrometer of the magnetic analyzer type has been constructed by platinizing the inside of a glass tube bent in the form of a semicircle. This is simpler and more convenient than the customary method of inserting a curved metal shielding tube inside the glass, and appears to function as well. The tube may be baked out in the same manner as before. A sample of B_2H_6 has been analyzed using 90-volt electrons. As this has the same structure as C_2H_6, a comparison of the relative intensities of the corresponding products is given in the following table (corrected for the isotope effect in B_2H_6):

	X_2H_6	X_2H_5	X_2H_4	X_2H_3	X_2H_2	X_2H	X_2	XH	X
B	0	100	44.8	21.7	63.7	2.9	2.2	0	40
C	100	76	360	105	62	12	2.5	2.5	1

Peaks at the mass numbers 11.5, 12 and 13 with intensities relative to B_2H_6 of 4.9, 12.6, and 17.7, respectively, were not included in the table because the interpretation is not clear due to the effects of the isotopes and doubly charged ions. The most striking feature of the analysis is the absence of the ion corresponding to the simple ionization of the parent molecule. There was a small peak at mass 28, but it seems likely that this is a slight N_2 impurity. In any case, B_2H_6 is less than 1/1000 of B_2H_5.

* Research Fellow.

29. Collisions of Negative Atomic Ions with Molecules. PAUL F. DARBY AND WILLARD H. BENNETT,* *Ohio State University.*—A method for the analysis of the particles derived from the collisions of negative atomic ions with molecules has been developed. The ions are produced in a glow discharge and formed into a beam in high vacuum by electron lenses. A narrow velocity range is selected by passing the beam through a magnetic field. It is then focused into a collision chamber where it passes through a unidirectional beam of molecules proceeding at right angles to the ion beam. The ions thus formed are collected into a beam and separated by a magnetic field in the same manner as the initial ion beam. This procedure makes for clear cut results and easier handling of the colliding ions although the resolving power of the system is not great. Details of design and experimental results will be given.

* Now with Electronic Research Corporation.

30. Electrical Discharge on Liquid Surfaces. L. B. SNODDY, HUGH F. HENRY AND J. W. BEAMS, *University of Virginia.*—The study of electrical discharges on surfaces of conducting liquids previously reported[1] has been extended to include surfaces of soap bubbles, bubbles of air in liquids, and the surface of water covered with oil. The discharges in each case are produced by a high potential impulse from a Marx circuit (maximum potential about 80 kv). The soap bubbles were formed between two metal pipes which formed the discharge electrodes. The discharge path follows the surface of the bubbles, although this distance is approximately 1.5 times the straight sparkover distance. This occurs with the bubble filled with H_2, air, or illuminating gas and does not seem to depend appreciably on the film thickness. The same results are obtained for bubbles passing between two electrodes in the interior of a viscous slightly conducting liquid. The discharge in most cases follows the surface of the air cavity. In the case of water covered with oil, the discharge follows the water oil interface.

[1] L. B. Snoddy and J. W. Beams, Phys. Rev. **55**, 663 (1939).

31. Progressive Breakdown in a Long Discharge Tube. F. H. MITCHELL, *University of Virginia.* (*Introduced by L. B. Snoddy.*)—Negative impulsive potentials were applied to an electrode in one end of a glass discharge tube 12 meters long and 14 cm in diameter, containing dry air. By means of a high speed cathode-ray oscillograph, a family of curves was obtained expressing the average speed of the discharge between two electrodes 6.4 meters apart as a function of applied potential (25 to 115 kv) and pressure (0.006 to 8.0 mm Hg). With increasing potential and pressure the speed reached a maximum, which varied from 3×10^9 cm/sec. (at 0.3 mm and 25 kv) to 1.0×10^{10} cm/sec. (at 1.5 mm and 115 kv). At higher pressures the speed for all potentials decreased approximately exponentially, with increasing pressure, becoming 1×10^9 cm/sec. at values ranging from 1.0 mm and 25 kv to 8 mm and 115 kv. The luminous column completely filled the tube at all pressures used, in contrast to the previously noted[1] contraction when positive potential was applied.

[1] Dietrich, Snoddy and Beams, Phys. Rev. **53**, 923 (1938).

32. Dielectric Properties of the Rutile Crystalline Modification of TiO_2. L. J. BERBERICH AND M. E. BELL, *Westinghouse Electric and Manufacturing Company.*—Most materials have dielectric constants in the range 1–10. Notable among the exceptions is rutile, the crystalline modification of TiO_2 which is stable at high temperatures. Three samples of this material have been investigated in the form of disks pressed from powdered crystals, then

sintered. Curves of dielectric constant against frequency show a rise at very low frequencies, probably attributable to interfacial polarization, with a uniformly high value of approximately 100 extending through the highest radio-frequencies, falling off only in the infra-red region. With increasing temperature the dielectric constant decreases with an average coefficient of 8.2×10^{-4}/°C in the temperature range of 20 to 120°C. Only a very few of the materials investigated so far, including TlCl, TlBr and rutile, show this negative coefficient of dielectric constant. The conductivity of rutile is well represented in the high temperature region by a straight line on the semi-log plot against the reciprocal of the absolute temperature. The dielectric constant of typical mixtures of rutile with low dielectric constant materials shows agreement with the empirical logarithmic mixture formula,

$$\ln \epsilon_m = x_1 \ln \epsilon_1 + x_2 \ln \epsilon_2.$$

A qualitative explanation of the high dielectric constant and negative temperature coefficient can be made in the light of published work on weakly ionic crystals, assuming that the degree of ionic binding varies with the distance between titanium and oxygen atoms, resulting in a large electric moment being formed for a relatively small movement of the mass points.

33. Nonlinear Resistance Elements in Circuit Networks. PETER I. WOLD, *Union College.*—Graphical methods for treating circuit networks containing nonlinear resistance elements are found to be particularly powerful, and application of such methods to vacuum tube circuits has proved highly effective. If linear resistance loads are used in the latter, the form of the I_p-E_g curve, is set by the characteristics of the tube; and the voltage curve taken over the output load, will be of the same form. By using properly chosen nonlinear elements in the load, there arises the possibility of modifying the I_p-E_g characteristic in a desired manner. In this case also, the output voltage curve will, in general, be of a different form from the output current curve. Nonlinearity of the output curves, because of the tube nonlinearity, can be reduced very substantially.

34. Another Criterion in the Identification and Prediction of Half-Lives. G. DICKSON, P. W. MCDANIEL AND E. J. KONOPINSKI, *Indiana University.*—By taking care to eliminate the effects of fast neutrons, we have minimized the intensity of the 4-min. V^{52} activity usually produced strongly when chromium is bombarded by Ra-Be neutrons and have obtained evidence for a weak activity of 2.27 hours half-life. This we identified chemically as due to chromium and assign to Cr^{55}. This finding is of interest as a confirmation of a method of predicting and identifying half-lives based on the treatment of nuclei differing by an alpha-particle as analogous. The logarithms of known half-lives of such analogous nuclei were plotted as a function of atomic number. For most series with odd isotopic number fairly smooth behavior is thus obtained. There is a continuous rise up to the stable isotopes of each series and a subsequent falling off. The 2.27-hour half-life we found fitted in well with the series for Cr^{55} (we had predicted 3 hours) whereas Cr^{51} should have a half-life longer than 10 years. Other assignments heretofore made on questionable grounds can now be made more definitely; for example, the 2.5-hr. Ni activity is thus Ni^{65} rather than Ni^{63}. A total of about 80 predictions of yet unknown half-lives with varying degrees of reliability have been listed by us on the basis of this method.

35. Positron Energy Distribution of Si^{27}. R. L. MCCREARY, G. KUERTI AND S. N. VANVOORHIS, *University of Rochester.*—An induced radioactivity produced by the bombardment of aluminum with protons has previously been reported.[1] The half-life of this activity was found to be 3.7 seconds and the observed threshold 6.0 ± 0.1 Mev, giving a value for the minimum reaction energy of 5.8 ± 0.1 Mev. The assignment was made to Si^{27} by the reaction, $Al^{27}(p,n)Si^{27}$, since no other reaction could account for the large yield. Further experiments have been made with a cloud chamber in a uniform magnetic field to check the sign of the emitted particles and to measure their energy distribution. Because of the short half-life, the sample was mounted on the end of an arm which could be moved alternately into the proton beam and in front of a window in the side of the cloud chamber. At the same time switches attached to the arm turned on the cyclotron filament in the first position and set off the cloud chamber expansion in the second. The bombardment of the sample lasted 3 seconds and the time between the end of bombardment and the expansion of the cloud chamber was $1\frac{1}{2}$ seconds. The tracks produced in the cloud chamber were those of high energy positrons and over 1000 of these tracks have been measured. By inspection the upper energy limit of the distribution is found to be 3.74 Mev. A Fermi plot, following the method of Kurie *et al.*,[2] yields the same value. This is smaller than the value of 4.0 ± 0.1 Mev expected from the reaction energy and larger than the value 3.4 Mev calculated on the basis of the Coulomb energy.[3]

[1] G. Kuerti and S. N. Van Voorhis, Phys. Rev. **56**, 614 (1939).
[2] F. N. D. Kurie, J. R. Richardson and H. C. Paxton, Phys. Rev. **49**, 368 (1936).
[3] M. G. White, L. A. Delsasso, J. G. Fox and E. C. Creutz, Phys. Rev. **56**, 512 (1939).

36. Experiments with Mono-Energetic Slow Neutrons. C. P. BAKER AND R. F. BACHER, *Cornell University.*—The arc ion source employed in the cyclotron has been operated at 400 cycles with thyratron control which gave an on-time of 50 to 150 microseconds. It has been found that the deuteron beam starts and stops in a few microseconds and thus gives rise to well-defined bursts of neutrons from the beryllium target. Control of an amplifier used with BF_3 ionization chamber by a method different from that used by Alvarez,[1] made possible the detection of those neutrons which had a predetermined time of flight from the source.[1,2] Preliminary results indicate that the work can be carried to energies well above the Cd cut-off which has been found to occur at approximately 0.15 ev. Present evidence also indicates that the Cd resonance is resolved from the absorption which occurs at lower energies and that the maximum resonance absorption occurs at 0.1 ev.

[1] L. W. Alvarez, Phys. Rev. **54**, 609 (1938).
[2] Fertel, Moon, Thomson and Wynn-Williams, Nature **142**, 829 (1938).

37. The Scattering of Resonance Neutrons in Paraffin. V. W. COHEN, H. H. GOLDSMITH, *Columbia University*, AND M. HAMERMESH, *New York University*.—In view of the importance of the neutron-proton scattering cross section, we have extended our previously reported work[1] by measuring the scattering in paraffin of Ag and In neutrons. These have the advantage of a smaller $\Delta E/E$ value than the Rh resonance neutrons. Ag has the additional advantage of having a larger resonance energy. The result for both Ag and In neutrons is $\sigma = 20 \pm 2 (10^{-24})$ cm^2, agreeing with the value obtained by us for Rh. Simons[2] has recently reported a value of 14.8 ± 5 percent for the scattering of Ag and I neutrons in water. However, due to the poor geometrical arrangement he employed, the corrections in Simons' experiment are both large and difficult to evaluate. Until he has stated what corrections he made we cannot consider his value in disagreement with ours.

[1] Cohen, Goldsmith and Schwinger, Phys. Rev. **55**, 106 (1939).
[2] L. Simons, Phys. Rev. **55**, 792 (1939).

38. The Elastic Scattering of Fast Neutrons. R. F. BACHER, *Cornell University*.—Experiments[1] with the neutrons from the $Be^9(d,n)B^{10}$ reaction as detected by the fast neutron reaction $Al^{27}(n,p)Mg^{27}$ have been continued and extended to C and Cu as scatterers. The accuracy of the experiments has been somewhat increased and is believed to be about 5 percent. Surrounding detector and source with carbon gave no increase in activity while the similar experiment for copper gave a 6 percent increase which may just possibly be real. There is no evidence of appreciable "elastic" scattering. Since the above experiment is most affected by large angle scattering, a further experiment has been carried out with and without a hollow cylinder of the scattering material between source and detector and with the detector at greater distance (12 cm) from the source. Increases of activity in the detector of 15, 30 and 36 percent for C, Cu and Pb, respectively, were observed indicating definite evidence of "elastic" scattering at small angles.

[1] R. F. Bacher, Phys. Rev. **55**, 679 (1939).

39. The Magnetic Moment of the Neutron. LUIS W. ALVAREZ, *University of California*, AND F. BLOCH, *Stanford University*.—The magnetic resonance method of determining nuclear magnetic moments in molecular beams, recently described by Rabi and his collaborators, has been extended to allow the determination of the neutron moment. In place of deflection by inhomogeneous magnetic fields, magnetic scattering is used to produce and analyze the polarized beam of neutrons. Partial depolarization of the neutron beam is observed when the Larmor precessional frequency of the neutrons in a strong field is in resonance with a weak oscillating magnetic field normal to the strong field. A knowledge of the frequency and field when the resonance is observed, plus the assumption that the neutron spin is $\frac{1}{2}$, yields the moment directly. A new method is described which permits the magnetic moment of any nucleus to be determined directly in absolute nuclear magnetons merely by a measurement of the *ratio* of two magnetic fields, (1) that at which resonance occurs in a Rabi type experiment for a certain frequency, and (2) that at which protons are accelerated in a cyclotron operated on the nth harmonic of that frequency. The final result of a long series of experiments during which 200 million neutrons were counted is that $\mu_n = 1.93_5 \pm 0.03$ absolute nuclear magnetons.

40. The Radiofrequency Spectra of Atoms. P. KUSCH, S. MILLMAN AND I. I. RABI, *Columbia University*.—The ground states of many atoms possess hyperfine structures whose intervals range from about 0.005 to 0.4 cm^{-1}. The usual optical methods are limited in precision and resolution by line widths and instrumental factors. For many questions it is of interest to possess more precise measurements of these intervals, whether large or small, than exist in the literature. We utilize the absorption and stimulated emission of electromagnetic waves of appropriate frequency (several hundred megacycles) by atoms in an atomic beam. The lines represent transitions within a hyperfine structure multiplet. The transitions are observed by the effect on the atom rather than on the radiation. The resonance lines are so narrow that they exhibit clearly resolved Zeeman patterns in a field of only 0.2 gauss. Some lines are 10^{-6} cm^{-1} wide. The precision of frequency measurement in this region is very high and an accuracy of 0.01 percent was obtained with little difficulty. The hyperfine structure of the ground states of Li^6 and Li^7 was measured with the purpose of comparing the resultant ratio of nuclear moments with the moment ratio obtained directly, and to see how well hyperfine structure can be explained by the effect of nuclear magnetic moment alone. The results agree to one part in 2000. It is possible to utilize this method even when the available electromagnetic frequencies are only a portion of the hyperfine structure interval by observations on the Zeeman pattern at high magnetic fields.

41. The Problem of the Scattering of Fast Electrons. JOHN A. WHEELER, *Princeton University*.—Recent electron deflection experiments of Fowler and Oppenheimer and Oleson, Chao, Halpern and Crane have given results which disagree quite strikingly with theoretical predictions, such as those of Williams, based on present theory. The investigation whose results are reported here shows that the discrepancy can be accounted for on the theoretical side neither by possible uncertainties in the screening of the atomic field, nor by the influence of the polarization of the electron spin, nor by any fault in Williams' method of treating multiple scattering, nor by any first-order effect of interference of the scattered electron waves coming from different atoms. However, for crystals above a critical size t_c given by $n\lambda\sigma^{\frac{1}{2}}t_c \sim 1$ (n atoms per unit volume, λ de Broglie wave-length, σ scattering cross section), higher order interference effects become important (as in the Darwin-Ewald x-ray theory) and reduce the predicted scattering to a value which is, within the probable limits of error, in accord with the observations cited. We thus have no reason based on *these* experiments to

doubt that we can represent the interaction between electrons and nuclei in a collision process in terms of simple electrostatic forces.

42. On the Applicability of Quantum Theory to Mesotron Collisions. J. R. OPPENHEIMER, *University of California.*—The application of quantum mechanics to Yukawa's theory of mesotrons gives a cross section for mesotron-electron collisions which agrees with the classical result for energy transfers under 10^{10} v.; for higher energies the probability of a given fractional energy transfer becomes independent of mesotron energy; these anomalous terms in the cross section correspond to the sesquipole moment of the mesotron spin. The complete result agrees quantitatively with the magnitude and variation with material and filtration of the soft component of cosmic radiation, with the dependence of shower and burst production on shower size, and with the absolute probability of burst production. Parallel calculations for nuclear collisions and for *bremsstrahlung* give cross sections too large to be reconciled with experiment. In all cases momentum transfers large compared to μc (μ the mesotron mass) occur; only for the electron collisions is the coupling energy small compared to the proper energy of the fields (and then only for energies under 10^{12} v.). This condition, and not the smallness of the momentum transfer, would thus seem to limit the applicability of present theory.

43. A Simple Calculation of Disintegration by Mesons. J. F. CARLSON, *Purdue University.*—The collision of a meson with a nucleus in which the meson is absorbed by one of the nuclear particles should give rise to energetic protons or neutrons. For any but the simplest nuclei this process is quite complicated. For the simplest nucleus, a deuteron, the calculations have been carried out and the dependence of the cross section of this collision on the meson energy and the binding energy of the deuteron has been obtained. Both the scalar and vector models of the meson have been used. The cross sections for meson energies are found to be quite sensitive to the model used. The cross section for the scalar model goes to zero directly as the velocity of the meson, while for the vector model this dependence is as the cube of the meson velocity. In both cases the dependence on the binding of the particles is as the square root of their binding energy.

44. Calcite Diffraction Patterns and X-Ray Line Widths. LEONARD T. POCKMAN, *Cornell University.*—Probably our most direct knowledge of the calcite diffraction pattern comes from Miller's[1] recent calculations based on double spectrometer work of L. G. Parratt. Some important assumptions demanded in Miller's calculations are not required in a similar calculation based on curves obtained with a single spectrometer of high geometrical resolving power. This is a preliminary report of work undertaken to obtain such curves. A secondary objective is to obtain further evidence bearing on the large discrepancy between line widths measured with the double spectrometer and with the focusing spectrograph. Two adjustable slits of novel design have been constructed. The jaws of each slit are of lead glass, optically flat on faces (1 cm×0.7 cm) forming the slit. Parallelism, secured by forcing the movable jaw against the stationary jaw and retained by frictional forces, was found good with slit width of 10^{-3} cm by an optical method and 10^{-4} cm by x-rays. The zero reading of the slit micrometer is determined photographically with x-rays. For the present work the total reflection from the faces causes no complication. Preliminary photographic width measurements of Mo $K\alpha_1$, with a spectrometrically good calcite, give uncorrected results only a few percent wider than the narrowest (1, +1) widths reported with the double spectrometer.

[1] F. Miller, Phys. Rev. **56**, 757 (1939).

45. *K* Emission and Absorption: Fine Structure of Copper. S. T. STEPHENSON, *State College of Washington.*—The Kronig type fine structure in the absorption spectrum of many elements is well known. Several authors have also reported emission structure lying as much as a hundred volts on the short wave-length side of various $K\beta_{2,5}$ lines. This structure might be (1) Kronig type absorption in the target of the emitter or it might be (2) real emission due to lattice electrons in permitted energy zones of the target returning to vacant K levels. For (2) to be possible one would have to have: first, vacant K levels caused by electron bombardment of the copper target; second, electrons in the higher permitted energy zones of the copper crystal due again to the continual electron bombardment of the copper target; and third, transition probabilities which allow this type of transition. A careful study of the positions of the emission bands from copper as compared with the absorption structure appears to decide, contrary to some preliminary results,[1] against this latter hypothesis. Absorption in the target is the source of most if not of all the emission structure observed in these experiments for copper. A similar study is carried out for some other elements.

[1] S. T. Stephenson, Phys. Rev. **56**, 856 (1939).

46. *K*-Absorption Edges of Kr (36) and Br (35).* C. H. SHAW AND T. M. SNYDER, *Johns Hopkins University.*—The K-absorption edges of krypton and bromine have been measured with a double crystal spectrometer. An argon-alcohol Geiger counter was used to measure the x-ray intensities. The absorption edge of krypton is practically without structure, due to the relatively great width of the K level. A rough estimate of the width of the K level may be made and is 2.6 volts. For bromine the structure is confined to a single intense region of transmission on the high frequency side of the absorption edge in agreement with the results of Cioffari.[1] The present results indicate that any other structure in the curve is less than 2 percent of the intensity of the first absorption minimum. The structure for bromine to be expected from theory was calculated in a manner similar to that used by Petersen for his calculations on chlorine.[2] The scattering phases were determined by extrapolating from those for krypton as calculated by Faxén and Holtsmark.[3] The theoretical results agree with experiment in predicting a region of transmission at the observed position. The predicted dis-

tance of the absorption minimum from the edge is 5.4 volts, while the observed distance is 5.6 volts. The theory, however, indicates that there is more than one maximum, in disagreement with the experimental results. It was thought possible that predicted structure farther from the edge than the observed minimum is washed out by the varying interatomic separation due to molecular vibrations. Present calculations indicate, however, that such is not the case.

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[1] B. Cioffari, Phys. Rev. **51**, 630 (1937).
[2] H. Petersen, Zeits. f. Physik **80**, 258 (1933).
[3] Faxén and Holtsmark, Zeits. f. Physik **45**, 307 (1927).

47. Secondary X-Ray Diffraction Maxima From Tobacco Mosaic Virus. I. FANKUCHEN,* *Birbeck College, University of London.*—A preliminary account[1,2] has been given by Bernal and the writer of x-ray studies of tobacco mosaic virus. Briefly the x-ray patterns from oriented specimens consist of two quite distinct parts. The small angle scattering varies with the virus concentration while the large angle scattering is quite independent of it. These parts are termed the inter- and intramolecular patterns, respectively. The reflections forming the intramolecular pattern of an unusually well oriented solution of virus could be measured accurately. The unit cell dimension (68A) along the particle length could be determined directly from the layer line separation. The cell dimensions at right angles presented difficulties in their determination. The diameter of the particles (152A) was known from intermolecular patterns[1] and the observed reflections could all be explained only by assuming a unit cell within the particle of greater size than the known particle diameter itself. This difficulty is removed however if the reflections are indexed on the basis of an hexagonal unit cell, $a=88$A, $c=68$A. Some reflections cannot then be given integral indices and are attributed to secondary maxima which occur because of the small number (3) of unit cells within the individual particle. If this explanation is correct, it is interesting as being the first occasion on which secondary maxima have been observed for x-rays.

* Now National Research Council Fellow in Protein Chemistry, Physics Department, Massachusetts Institute of Technology.
[1] J. D. Bernal and I. Fankuchen, Nature **138**, 1051 (1936).
[2] J. D. Bernal and I. Frankuchen, Nature **139**, 923 (1937).

48. A Study of the Changes Produced in Metals by Hammering. RAYMOND G. SPENCER AND J. WALLACE MARSHALL, *Albion College.*—A small cylinder, fitted with two accurately ground solid pistons, was used to hold the specimens while they were hammered. X-ray diffraction patterns show the crystallites in malleable iron are first markedly strained and then broken up into fine fragments and, in so doing, are partially relieved of strain. When a major portion of the crystallites are powdered, the sample has very little strength. This is in agreement with one of the conclusions drawn by Spencer[1] from his studies of fatiguing. The diffraction patterns of aluminum can be explained by assuming that some of the crystallites are strained and then broken up after which another portion is strained and broken up. In the case of Dow metal, some of the lines are displaced, some increase in intensity, some decrease in intensity and some completely disappear. In order to explain this, it seems necessary to assume that the hammering has partially relieved the original strain in some sets of planes in the crystallites, has introduced strain in other sets of planes and has caused gliding of others.

[1] R. G. Spencer, Phys. Rev. **55**, 991 (1939).

49. Emission and Absorption Processes Involving the 3*d* and 4*s* Bands of Copper and Nickel.* H. FRIEDMAN AND W. W. BEEMAN, *Johns Hopkins University.* (*Introduced by J. A. Bearden.*)—Neither the shapes nor the wave-length positions of the K-absorption edges of copper and nickel are changed when these elements are alloyed together. This indicates either that the constituents of the alloy do not share a common band system or that the ionization of the K shell of the absorbing atom so perturbs its outer levels that they do not mix with the levels of adjacent atoms. The $K\beta_{2,5}$ lines which arise from transitions of conduction electrons into the K shell have been measured for these alloys and considerable evidence has been found for a shared band system. Structure on the high frequency side of the Cu $K\beta_{2,5}$ line, which has been interpreted[1] as emission from the 4*s* band of Cu, disappears in the low percentage copper alloys. In such alloys the 4*s* electron of copper is shared with the nickel.

* This work was supported by a grant made to Professor J. A. Bearden from the Penrose Fund by the American Philosophical Society.
[1] W. W. Beeman and H. Friedman, Phys. Rev. **56**, 392 (1939).

50. Order in the Copper-Gold Alloy System.[1] L. H. GERMER AND F. E. HAWORTH, *Bell Telephone Laboratories.*—A high temperature electron diffraction camera has been developed in which diffraction patterns of alloy films have been obtained by the transmission method. Studies have been made of copper-gold alloys containing 25, 50 and 75 atomic percent copper. Results of many of the experiments are in approximate agreement with those of x-ray investigations upon quenched alloys. For example, films of the alloy containing 25 atomic percent copper have been found to have a face-centered cubic structure in which ordering is not developed by any heat treatment; films of 50 atomic percent copper develop a simple tetragonal structure upon heating to temperatures below 375°C, above this temperature the structure is face-centered cubic and disordered, and in films which have been slowly cooled from temperatures above 375°C crystals have been discovered which have a complex orthorhombic structure together with other crystals which are tetragonal;[2] films of 75 atomic percent copper develop the well-known cubic superstructure. In the course of the investigation many observations have been made regarding atomic diffusion in these alloys and regarding the corrosion of the alloys at various elevated temperatures.

[1] Continuing work reported in Phys. Rev. **56**, 212 (1939).
[2] See C. H. Johansson and J. O. Linde, Ann. d. Physik **25**, 1–48 (1936).

51. Astigmatism, Aberration and Coma of Concave Gratings. H. BEUTLER, *University of Chicago.*—For 15,000 lines/inch gratings of six to twenty feet curvature, the effects of higher order terms in the grating formula are

masked by the graininess of the photographic plate. These effects were revealed in adjusting some large 30,000 lines/inch gratings on a 67″-circle and on a 30-foot circle. The grating theory has been developed for the extension of slit, of rulings and of images perpendicular to the Rowland plane. The general results are represented by a set of graphs, which show for any angle of incidence and of reflection: (1) the wave-length and the dispersion; (2) the astigmatism in (a) the length of the spectral lines from a point source on the slit and (b) the slit length necessary for giving the optimum intensity on the plate; (3) the allowed grating width (limited by aberration), restricting the attainable resolving power and brightness of the spectrum; (4) the coma arising from the extension of the rulings and of the slit, limiting the length of the rulings for a permissible loss in resolving power. From these diagrams, it is possible to determine, for any desired wave-length range, the angles at which the optimum brightness and resolving power are obtained, provided the grating considered has a uniform reflectivity, as is true for most 30,000 line gratings.

52. A High Power Tungsten Light Source. N. METROPOLIS AND H. BEUTLER, *University of Chicago.*—The usual type of tungsten ribbon lamp (carrying about 16 amp.) proved too weak for absorption spectra under high dispersion (0.4–0.2A/mm); the same difficulty arose with the conventional hydrogen discharge tube (especially with an astigmatic grating). Some attempts were made with graphite rods electrically heated in argon at atmospheric pressure, but graphite evaporates too rapidly at 3000°C. In the present form, we use a tungsten ribbon $3''\times\frac{1}{8}''\times 0.02''$ carrying 150 amp. a.c. in argon at atmospheric pressure. The tungsten ribbon is clamped to monel leads, which screw into two concentric, water-cooled brass cylinders. They form with an insulating layer a compact unit that is sealed with Picein into a three-liter Pyrex bulb. The lamp has an additional quartz window diametrically opposite to facilitate alignment. The tungsten temperature is kept near its melting point (3600°K). The lifetime is limited to about 50 hr. by the evaporation. The deposit of *W* on the exit window is rendered negligible by interposing a double slit system. At λ3000A the brilliancy of *W* at 3600°K is 80 times greater than that of a commercial ribbon lamp kept at 2600°K; at λ5000A the gain is twenty-fold.

53. Spectral Transmission of Glucose Glass in the Near Infra-Red. WILLI M. COHN, *El Cerrito-Berkeley, California.*—The transmission of samples of glucose glass varying in thermal history was previously investigated.[1] This work covered the visible part of the spectrum. Transmission data in the near infra-red are presented now as far as could be obtained photographically (12,000A). No limit of absorption was found at long wave-lengths as far as tested. The possible use of organic glass for investigations in the near infra-red is discussed.

[1] Willi M. Cohn, "A Spectral Investigation of Glucose Glass," J. Chem. Phys. 6, 65–67 (1938).

54. Radio-Phosphorus in Soil Studies. STANLEY S. BALLARD AND L. A. DEAN, *University of Hawaii.*—The use of radioactive phosphorus has been found to have certain advantages over the conventional chemical methods ordinarily employed in soil studies. Among the problems that have been investigated are measurements of the rate of sorption of phosphorus by soils, fertilizer placement studies, and measurements of the movement of applied phosphorus through a soil. A satisfactory technic has been developed for making quantitative measurements with a Lauritsen electroscope of the radioactive strength of soils, plant materials, and solutions such as soil extracts. The average deviation from the mean of several determinations was approximately 1 percent when either soils or solutions were being tested, indicating that the technic is sufficiently accurate for such use. A description of the technic and some applications has been submitted to the *Journal of Applied Physics.* In progress is a study using radio phosphorus for measuring the phosphate fixation of different soil types, in terms of the phosphate uptake of tomato plants. Grateful acknowledgment is made to the Radiation Laboratory of the University of California for the gift of several samples of radio phosphorus.

55. Activation of Indium by Alpha-Particles. J. R. RISSER, K. LARK-HOROVITZ AND R. N. SMITH, *Purdue University.*—The activation of indium by alpha-particles as recently[1] described leads to a capture process with formation of radioactive Sb^{118} and the excitation of In^{115}. By using very short activation periods, the capture process alone can be observed, leading to a lifetime of 3.6 min. for the end product. The cross section of this process is of the order 10^{-26} cm². The excitation of indium has been studied with different energies of alpha-particles and can be observed from 16 Mev down to about 11 Mev, at energies about 5 Mev smaller than the potential barrier. At 16 Mev the cross section of the excitation process is about 3×10^{-28} cm². This cross section is higher by a factor of about 10 than the one observed for the excitation of In^{115} with protons,[2] but is much smaller than the corresponding capture cross section, again analogous to the results obtained in the proton activation[2] of indium. The cross section is smaller by a factor of 1/1000 than the one predicted from the theory of excitation of nuclei by electric fields,[3] but much higher than the theoretically predicted excitation of In^{115} by inelastic *collision.**

[1] Lark-Horovitz, Risser and Smith, Phys. Rev. **55**, 878 (1939)
[2] S. W. Barnes, Phys. Rev. **56**, 414 (1939).
[3] V. F. Weisskopf, Phys. Rev. **53**, 1018 (1938).
* Private communication of V. F. Weisskopf.

56. Absorption Measurements of Beta-Rays. B. L. MOORE, *Cornell University.* (*Introduced by R. F. Bacher.*)—The comparison method developed by Sargent[1] has been applied to the beta-ray spectra of C^{11}, N^{13}, Na^{24}, Mg^{27}, P^{32} and the isomers of Rh^{104}. The absorption end points are found by comparing the upper region of the spectrum with that of RaE. Energy end points are then found using Sargent's range energy relation which was obtained from the extrapolated end points of the absorption curves for homogeneous high energy electrons. The measurements were made with an argon-filled ionization chamber and Edelmann electrometer. End points in Mev so obtained are: $C^{11}(e^+)1.03\pm0.03$; $N^{13}(e^+)1.24\pm0.03$; $Na^{24}(e^-)1.36$

± 0.05; $Mg^{27}(e^-)1.74\pm 0.05$; $P^{32}(e^-)1.72\pm 0.03$; $Rh^{104}(e^-)$ (both the 42 sec. and the 4.3 min. periods) 2.46 ± 0.10. For N^{13}, Na^{24} and P^{32} a comparison with more accurate values from magnetic spectrograph measurements indicates agreement within the estimated errors except for N^{13} for which Lyman[2] found 1.198 ± 0.006 Mev. Uncertainties in the end points by absorption appear to be considerably reduced by the use of the comparison method. The main advantages of this method are that strong sources are not necessary and the end points may be obtained with a relatively small amount of work.

[1] B. W. Sargent, Can. J. Research **A17**, 82–102 (1939).
[2] E. M. Lyman, Phys. Rev. **55**, 234 (1939).

57. Energy Spectra of Radioactive Indium. J. L. Lawson and J. M. Cork, *University of Michigan.*—The energy spectra of several of the indium isotopes have been obtained by means of a magnetic spectrometer. It was originally reported by Cork and Lawson[1] that a 0.39-Mev gamma-ray was associated with the 1.73-Mev beta-radiation ascribed to In^{117} because of their rather similar half-lives of about two hours. Barnes,[2] however, showed that this gamma-ray was present in indium separated from long-lived radioactive tin, and was therefore probably due to In^{113}. It is now shown that this gamma-radiation is not associated with the 1.73-Mev beta-radiation. The half-lives of these activities have been determined in the spectrometer to be 104 ± 2 min. and 117 ± 3 min., respectively, for the 0.39-Mev gamma-ray and the 1.73-Mev beta-ray. The spectrum of the 0.336-Mev gamma-ray ascribed to In^{115*} has been more precisely determined, and its half-life as obtained in the spectrometer is 272 ± 3 min. The long-lived indium shows two activities, one of 65-hours half-life and the other of approximately 50-days half-life. The spectra of both of these activities have been obtained in the spectrometer. The 65-hour activity apparently consists only of two internally converted gamma-rays of energies 172 ± 2 kev and 247 ± 2 kev, respectively. The very long-lived radioactive indium displays a continuous beta-ray spectrum whose upper limit is 1.98 ± 0.03 Mev, and an internally converted gamma-ray of energy 0.192 ± 0.002 Mev.

[1] J. M. Cork and J. L. Lawson, Phys. Rev. **56**, 291 (1939).
[2] S. W. Barnes, Phys. Rev. **56**, 414 (1939).

58. Some Improvements in Geiger-Müller Counter Systems. Harold McMaster and M. L. Pool, *Ohio State University.*—A complete scale-of-sixteen Geiger-Müller counter with a maximum speed of 140,000 random counts per minute has been constructed. A fast choked multivibrator vacuum tube relay drives the Cenco recorder. A 0.01-mf mica condenser placed between the control grid of the high voltage regulator tube and ground reduced the sixty-cycle ripple to 0.1 volt without further filtering. The interpolation meter of the scale-of-sixteen is coupled directly to one tube in each scale-of-two. The direct coupling eliminates one tube per scale-of-two previously used to actuate the meter.[1] A direct-current coupled multivibrator quenching circuit is used which has most of the desirable features of both the Neber-Harper and alternating-current coupled multivibrator. The quenching circuit is set to deliver a maximum of 140,000 random counts per minute to the scaling and recording circuits in which there are no losses at this speed. Corrections for losses due to randomness need be applied only to the quenching unit, and correction charts reliable up to speeds of 25,000 random counts per minute have been prepared.

[1] Harold Lifschutz, Rev. Sci. Inst. **10**, 21 (1939).

59. Positive Excess and Electron Component in the Cosmic-Ray Spectrum. Donald J. Hughes, *University of Chicago. (Introduced by Arthur H. Compton.)*—In obtaining the energy distribution of mesotrons, H. Jones found an excess of positive particles throughout the energy spectrum, the ratio of positives to negatives amounting to 1.29. This work has been continued to determine whether this positive excess occurs in the particles striking the apparatus or is caused by a greater absorption of the negative particles in the 10-cm lead filter. Care has been taken to reduce any instrumental asymmetry by careful temperature control and frequent reversals of the magnetic field. A total of 1339 tracks was measured. With the lead filter the positive-negative ratio is 1.21 ± 0.083 (standard error), while with no lead the value is 1.18 ± 0.083. This confirms Jones' finding and further indicates a real positive excess in the incident particles. The lead absorbs 11 percent of the cosmic rays that traverse the magnetic field. Comparison of the spectra taken with and without lead shows that this absorption is entirely in the energy range $2\times 10^8 - 10^9$ ev, where 26 percent of the rays are absorbed. This shows that there are very few absorbable particles (electrons) of energy greater than 10^9 ev but a considerable number in the range $2\times 10^8 - 10^9$ ev.

60. Time Variations in Cosmic-Ray Intensity at High Altitudes. William P. Jesse, *University of Chicago.*—During the past year twelve balloon flights with a recording ionization chamber have been carried out at Chicago to observe any possible time changes in cosmic-ray intensity at high altitudes. The same apparatus was carried in ten of the flights. In each flight a height was attained sufficient to define clearly the maximum of the cosmic-ray intensity curve. The minimum pressure recorded was 1.6 cm. During the period of observation, time changes in the peak value of the cosmic-ray intensity curve of over 14 percent have been observed. These changes have a distinct correlation with the intensity variations observed at the mountain station of the Carnegie Institution at Huancayo, Peru. The variations at this station correspond to the "world-wide" variations observed by Forbush. When the high altitude values are somewhat arbitrarily corrected for such "world-wide" variations on the basis of the Huancayo data, a residual variation remains with a maximum in the early spring and a minimum in the late summer. Further measurements will be necessary to determine whether this represents a true seasonal effect.

61. Collision Energy Loss of Low Energy Cosmic-Ray Electrons. J. K. Boggild, I. C. Kuo, S. H. Neddermeyer and C. D. Anderson, *California Institute of Technology.*—The direct energy loss measurements of cosmic-ray electrons have heretofore been made largely in heavy elements where radiation accounts for the major part of the loss in

energy, and the results have been found in approximate agreement with theory. In order to study the energy loss of electrons due to direct inelastic atomic collisions, 5000 cloud-chamber photographs were taken in which a carbon plate of 4 mm thickness was placed across the chamber. For this purpose only electrons of low energy (20 Mev to 60 Mev) are suitable. These occur infrequently and only 36 cases suitable for accurate measurement were found. In the table the observed average values of energy loss in Mev/cm are compared with the theoretical average values.

Energy range in Mev	Average energy in Mev	Observed total energy loss	Calculated collision loss	Calculated radiation loss	Calculated total energy loss
10–20	16.8	4.3	4.3	0.5	4.8
20–40	30.3	5.0	4.6	1.1	5.7
40–60	47.8	6.7	4.8	1.9	6.7

These preliminary experiments show that in the energy range studied the theoretical formulae for energy loss of electrons (no heavy tracks were included) by direct collisions are in approximate agreement with observation. An experimental test of these formulae is important since they have been assumed correct in the mass estimates of the mesotron which have been made so far.

62. A Device for Viewing of Slow Rotary Motions. RICHARD M. SUTTON, *Haverford College.*—Stroboscopes and rotascopes which permit intermittent observation of rotating systems for periodic short elements of time are ideal for "stopping" motions at speeds greater than 20 r.p.s.; but, because of flicker, they are not suitable for lower speeds. An optical mechanism is designed for the steady observation of bodies in rotation. It consists of a reversing prism arranged to rotate about a longitudinal axis at one-half the speed of the observed rotation, in which case the observer sees what is essentially a stationary mirror image of the rotating object. In order to see the object in the correct relationship in all respects, a second reversing prism is mounted axially beyond the first but is not revolved, and the eye-prism is revolved at half the speed of the motion but in the opposite sense. The observer then has the point of view of a person revolving with the motion but unaware of his own rotation, in which case stationary objects appear to revolve in an opposite sense. The motion must be observed along the axis of rotation; the field of view is limited by the solid angle subtended by the far end of the second prism.

63. The Lubrication of Plane Sliders. F. MORGAN, M. MUSKAT, AND D. W. REED, *Gulf Research & Development Company.*—A machine has been designed and built for measuring the friction torque between plane sliders or thrust bearings and a rotating table. It provides means for variations in lubricant viscosity, bearing load, and slider speed. It also permits the study not only of sliders of various shapes, but also of such as have fixed wedge angles, or which are pivoted and self-aligning. Experiments performed in the thick film region with both fixed angle and self-aligning sliders have confirmed recent extensions of the hydrodynamic theory of such lubrication systems. The machine also permits a study of the thin film region of lubrication under carefully controlled conditions.

64. The Vapor Pressure of Bismuth between 603° and 638°C. ALFRED H. WEBER, *Saint Louis University.*—The vapor pressure of liquid bismuth at temperatures between 603° and 638°C has been measured by the molecular effusion method used by Rudberg[1,2] and others. The masses of the evaporated bismuth deposits were obtained by direct weighing with a microbalance. Seven values of the vapor pressure obtained fall fairly well on the straight line plot ($\log_{10} p$ *vs.* $1/T$) of the empirical equation

$$\log_{10} p(\text{in mm}) = -52.23(205)/T + 9.03. \qquad (1)$$

This equation is in very good agreement with the expression[3]

$$\log_{10} p(\text{in mm}) = -52.23(200)/T + 8.876, \qquad (2)$$

which is stated to apply in the range 1210–1420°C. Apparently expression (2) has not been tested hitherto in the temperature range of the present experiments. The author acknowledges the assistance of S. C. Kirsch, S.J., of St. Joseph's College, Philadelphia, who calibrated the Kovar-tungsten thermocouple used in these experiments. He also expresses his thanks to the Physics Department of the University of Pennsylvania for the loan of the microbalance used in the weighings.

[1] E. Rudberg, Phys. Rev. **46**, 763 (1934).
[2] E. Rudberg and J. Lempert, J. Chem. Phys. **3**, 627 (1935).
[3] *International Critical Tables*, Vol. III (1926), p. 205.

65. Vitrification of Water. B. J. LUYET, *St. Louis University.*—The author reported previously that by the sudden immersion in liquid air of small quantities of aqueous solutions of various inorganic or organic substances he obtained these solutions in the vitreous state. Vitrification was impossible when the concentration was not higher than about 20 percent, that is, when the proportion of water exceeded considerably that of the other component. This impossibility was attributed to the high rate of formation of crystalline nuclei in subcooled water, to the high velocity of growth of the crystals of ice, and to the enormous quantity of heat produced by the growing crystallization centers in freezing water, which kept the local temperature from dropping. A cooling velocity sufficient to vitrify pure water was finally obtained in the following manner. A fine stream of water, falling vertically from a pipette, was flattened between two metal disks previously cooled in liquid air, one of which was fastened behind the stream while the other was thrown against the stream and against the first disk by the propelling action of the spring of a toy pistol. The thin layers of solid water so obtained, transported to a cooled polarizing microscope, stayed dark between crossed Nicols until the temperature was high enough for devitrification to occur.

66. An Anomalous Effect in the Viscosity of Glass. W. B. PIETENPOL AND D. E. BILLINGS, *University of Colorado.*—A method for determining the surface tension of molten glass, by which under static conditions the pressure difference between the inside and outside of a bubble is balanced by the surface tension of the liquid, has been previously published.[1] Later the theory for the viscous forces present when the bubble is expanding was deduced.[2]

This theory has now been applied to the experimental determination of the viscosity of glass throughout a limited temperature range above the softening point. Contrary to all previous results a rapid increase in viscosity with increase in temperature is found slightly above the softening region. For example, the viscosity of a typical lime glass increases from approximately 2.5 to 6×10^8 poises with an increase in temperature from 678° to 686°C. This should not be interpreted as the previously suggested "transformation temperature" which "corresponds to a viscosity of from 10^{13} to 10^{14} poises." The expanding bubble is very sensitive to temperature equilibrium conditions of the glass. The significance of this change in viscosity in the annealing of glass is pointed out and it is suggested that it may have an important bearing on the theory of glass structure.

[1] W. B. Pietenpol, Physics **7**, 26 (1936).
[2] E. C. Westerfield and W. B. Pietenpol, Phys. Rev. **55**, 306 (1939).

67. The Hardness of Rubber and Other Highly Elastic Materials. LEWIS LARRICK, *The B. F. Goodrich Co.*—The penetration of vulcanized rubber by spherical indentors follows the laws of classical elasticity for indents as large as 10 percent of the diameter of the indentor, and at depths of penetration as great as 30 percent the deviation is not great. This makes possible a new, convenient method for measuring the elastic moduli of such materials. Values of Young's modulus so obtained range from about 200 pounds per square inch for soft rubber compounds to over 1000 pounds per square inch for heavily pigmented compounds. Since hardness is customarily defined as resistance to penetration, the elastic modulus can be used as a measure of hardness. The laws of penetration are derived from the conventional problem of the contact of two elastic spheres. Inasmuch as vulcanized rubber is generally treated as an incompressible material (Poisson's ratio is $\frac{1}{2}$), the equation for the penetration of a rectangular block of rubber by a rigid sphere reduces to: $d=(K/E^{\frac{2}{3}})L^{\frac{1}{3}}D^{\frac{1}{3}}$ (where K is a geometric constant, E Young's modulus, L the load, and D the diameter of the indentor). Criteria for: (1) Similar test conditions (relative depth of indent), (2) Minimium size of face of sample, (3) Minimum thickness of sample, follow from the general theory. The values of the principal stresses are easily derived in certain special cases.

68. The Variation of the Principal Elastic Moduli of Cu_3Au with Temperature. SIDNEY SIEGEL,* *Westinghouse Research Laboratories.*—Single crystal rods of the copper-gold alloy Cu_3Au were prepared in a vacuum furnace. The specimens were annealed according to the procedure described by Sykes and Evans[1] to produce the best possible degree of order at room temperature. A dynamical method —that of the composite piezoelectric oscillator—was used to measure Young's and the rigidity moduli of several crystals of different orientation. Measurements were made over the temperature range 20° to 450°C, and the principal moduli S_{11}, S_{12}, and S_{44} calculated over this interval. All three moduli increase linearly with temperature up to about 250°. From 250° to 388° the slope becomes increasingly large, and at the order-disorder transformation temperature T_c, 388°, each modulus undergoes an abrupt change. The increase in S_{11} at T_c amounts to about 15 percent of its value there, 1.8×10^{-12} cm²/dn. The increase in S_{12} is also about 15 percent of its value there, -0.8×10^{-12} cm²/dn. The increase in S_{44} is about 3 percent of its value at T_c, 1.75×10^{-12} cm²/dn. The elastic constants of such initially well ordered crystals were found to be single-valued functions of the temperature, except very close to T_c, where steady final values were obtained only after 50 hours at constant temperature.

* Westinghouse Research Fellow.
[1] Sykes and Evans, J. Inst. Metals **58**, 255 (1936).

69. Camera Lenses with Low Reflecting Films. C. HAWLEY CARTWRIGHT, *Massachusetts Institute of Technology.*—Several fast camera lenses were treated with evaporated metallic fluoride films to reduce the reflection from the air-glass surfaces. Two results were produced by diminishing the reflection in fast lenses: (1) the ghost images that normally occurred under adverse lighting conditions were entirely eliminated and (2) the effective speed of a lens was about doubled. The first result is due to ghost and flare being caused by at least two internal reflections (thus, reducing the reflectance of each surface ten times results in ghost images and flare being reduced a hundred-fold). The second result is somewhat subjective because the increase in exposure due to the added transmission of the lens is accompanied by more contrast, due to the absence of flare, and also an observable increase in detail.

70. Optical and Magnetic Properties of a Magnetite Suspension. C. W. HEAPS, *The Rice Institute.*—A suspension of magnetite powder in oil acts in a limited way as a light shutter. When a magnetic field is parallel to the light direction more light is transmitted than when the light is transverse. Microscopic examination shows that the particles form elongated groups. Each particle probably consists of relatively few magnetic domains, magnetized to saturation, and hence it attracts neighboring particles. The theory of the phenomenon, assuming the groups to be uniform and cylindrical, gives for the fraction of the incident light transmitted, $l/l_0=1-A(2L/a)^{\frac{1}{2}}+BL$, where A and B are structure constants, L is the Langevin function of a, and a is $\mu H/(kT)$ with the usual meaning for the symbols. If we assume the groups to behave like the molecules of a paramagnetic gas in the standard Langevin theory the function L is equal to I/I_0, where I is the intensity of magnetization of the suspension and I_0 is the saturated intensity. Thus the magnetization curve of the suspension may be determined by measurements of light intensities made in various fields. Experimental tests indicate that the theory is satisfactory provided the groups are not all assumed to be identical in shape.

71. The Concentration of Carbon 13 by Thermal Diffusion. ALFRED O. NIER, *University of Minnesota.*—A Clusius and Dickel[1] thermal diffusion column employing methane gas has been constructed for the purpose of concentrating C^{13}. The length of the column was 730 cm, the separation of the hot and cold walls 0.71 cm, and the mean circumference of the annular gas space 13.2 cm. For a

temperature difference of 300°C between walls and the outer wall water-cooled, the power consumption was 2750 watts. When the column was used without reservoirs at pressures of 21.7, 40.0 and 65.6 cm, the separation factors were 2.25, 6.25, and 4.25, respectively. These results are in *quantitative* agreement with the theory of Furry, Jones and Onsager[2] provided one: (a) employs the experimentally determined value of D_T/D for methane[3] rather than the arbitrary value assumed by Furry, Jones and Onsager, and (b) assumes the existence of a convection loss term, such as is given by Eq. (70) in reference 2, having a numerical value of approximately 0.6. When a reservoir having a volume of 20 liters was connected to the top it was possible to produce methane having a concentration of over 4 times the normal amount of $C^{13}H_4$. The pressure in this case was 46 cm, the value corresponding to greatest separation factor. With an infinite reservoir the concentration would have been over 6 times.

[1] K. Clusius and G. Dickel, Naturwiss. **26**, 546 (1938).
[2] W. Furry, R. C. Jones, L. Onsager, Phys. Rev. **55**, 1083 (1939).
[3] A. O. Nier, Phys. Rev. **56**, 1009 (1939).

72. Concentration of Isotopes by Thermal Diffusion: Rate of Approach to Equilibrium. J. BARDEEN, *University of Minnesota.*—The time-dependent partial differential equation involved in the theory[1] of the operation of a Clusius thermal diffusion column[2] is solved for various assumed boundary conditions at the ends of the column. The solutions give the concentration of molecules of a given species at any point in the column as a function of time. Among the cases treated are: (1) both ends of the column closed, (2) reservoir at the upper end, lower end closed, and (3) reservoir connected to upper end by a tube along which a concentration gradient can exist. Numerical calculations made for several cases are compared with experimental results of Nier,[3] who studied the operation of a column containing methane gas. (The column is to be used for the separation of the carbon isotopes.) In the calculation, use is made of the value of the thermal diffusion coefficient for methane obtained by a direct experiment,[4] and of the empirical values of the equilibrium separation factor. The theoretical curves giving the rate of approach to equilibrium agree well with the experimental.

[1] W. H. Furry, R. C. Jones, and L. Onsager, Phys. Rev. **55**, 1083 (1939).
[2] K. Clusius and G. Dickel, Naturwiss. **26**, 546 (1938).
[3] See preceding abstract.
[4] A. O. Nier, Phys. Rev. **56**, 1009 (1939).

73. Thermal Separation of Gases and Isotopes. ARTHUR BRAMLEY, *Swarthmore, Pa.*—The thermal method for the separation of gases and isotopes[1] depends for its success on the simultaneous action of a number of different processes. These can be divided conveniently into three groups: (a) A difference in the thermal behavior of the gases or isotopes depending on their difference in mass, e.g. thermal or initial diffusion. (b) A mass motion of the gas, such as a convection current up a hot wall and down a cold wall or in tubes with larger wall clearance turbulence or swirls, either of which plays an important part in transferring the heat across the intervening gas space. (c) A slight concentration of one of the components over the others exists in the Langmuir film[2] surrounding wires heated directly or indirectly. There is a definite motion of the gas in this film along the wire which arises from the swirling motion of the gas outside this film. An interchange of molecules occurs between the swirls themselves and between them and the Langmuir film on account of process (a).

[1] Bramley and Brewer, Science **90**, 165 (1939). Bramley and Brewer, J. Chem. Phys. **7**, 553 (1939). Brewer and Bramley, J. Chem. Phys. **7**, 972 (1939).
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74. Concentration of Chlorine Isotopes by Centrifuging at Dry Ice Temperature.* F. C. ARMISTEAD AND J. W. BEAMS, *University of Virginia.*—The concentration of the chlorine isotopes obtained experimentally at room temperature (300°A) by the evaporative centrifuge method has been shown previously to be in accord with the theory of Lindemann and Aston and Mulliken. In the present paper the same theory has been checked at dry ice temperature (approximately 200°A). The centrifuge was of the air-driven vacuum type. The hollow rotor (8 cm effective I.D.) was spun inside an evacuated enclosure maintained at dry ice temperature. The tubular shaft (gauge 15) was 15″ long and made of stainless steel to increase heat insulation. Standing vibrations in the shaft were prevented by guides mounted in Bakelite. After placing 10 cc of liquid ethyl chloride in the rotor, it was spun to 1240 r.p.s. and evacuated through the shaft. The ethyl chloride vapor was drawn off very slowly through the shaft and a glass capillary, so that approximate equilibrium could exist in the rotor, and was collected in 2 cc (liquid) samples in traps cooled by liquid air. The isotopic ratio measured by the mass spectrometer in the first and in the last samples differed by 12 percent, which is in fair accord with the theory.

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75. Interparticle Separations for Tobacco Mosaic Virus at Varying Concentrations, *p*H, and Ionic Concentrations. I. FANKUCHEN,† *Birkbeck College, University of London.*—In a preceding paper, a brief description of the x-ray patterns obtained from tobacco mosaic virus has been given. The intermolecular patterns obtained from all oriented specimens permit the direct computation of the interparticle distances. These distances have been determined for virus preparations (a) of varying water content, (b) gels at varying *p*H, (c) gels in solutions of varying ionic concentration. From (a), it is shown that as the water content increases the particles are displaced only in a direction at right angles to their lengths, maintaining their hexagonal arrangement in cross-section. The interparticle distance in A can be expressed by $\text{I.P.D.} = 1700/\sqrt{C}$ where C is concentration in grams of vacuum dried virus in 100 cc of specimen. For (b), it is found that the I.P.D. is a minimum at the isoelectric point. From (c), it is found that as the ionic concentration increases I.P.D. steadily decreases, reaching a stationary value for the stronger concentrations. It is believed that measurements of this character may help the arrival of a more quantitative theory of colloids than now exists.

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