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MINUTES OF THE WASHINGTON D. C. MEETING, APRIL 25–27, 1940

THE 234th regular meeting of the American Physical Society was held at Washington D. C. at the National Bureau of Standards on Thursday and Friday, April 25 and 26, 1940, and at the National Academy of Sciences on Saturday, April 27, 1940. There were three parallel sessions for the reading of contributed papers on Thursday morning and afternoon and on Friday morning and afternoon. On Saturday morning and afternoon there were two parallel sessions. The attendance at the meeting was over nine hundred.

On Friday evening the Society held a dinner at the Wardman Park Hotel attended by three hundred members and guests. President John Zeleny presided. The guest speaker was Professor George Gamow of George Washington University.

Meeting of the Council. At its meeting held on Thursday, April 25, 1940, the death of one fellow (A. deF. Palmer) was reported. One candidate was reinstated to fellowship, one candidate elected to fellowship, and five candidates transferred from membership to fellowship. Fifty-one candidates were elected to membership. *Reinstated to Fellowship:* Ernest Blaker. *Elected to Fellowship:* Gleb Wataghin. *Transferred from Membership to Fellowship:* Felix Cernuschi, George B. Collins, Elbe H. Johnson, J. K. Knipp, and R. S. Krishnan. *Elected to Membership:* Hiroo Aoki, C. E. Barthel Jr., Grant S. Bennett, V. E. Bottom, Arnold E. Bowen, Eleazer Bromberg, Ralph H. Caston, Robert L. Chasson, John W. Coltman, Rudolf Drenick, Alexander J. Ferguson, S. Phillips Frankel, George R. Gamertsfelder, Edward Gerjuoy, Lee W. Gildart, William E. Good, Harold D. Green, William C. Hahn, Oscar L. Hay, J. Richard Haynes, Hugh F. Henry, Marshall G. Holloway, George A. Hornbeck, Paul S. Johnson, Charles B. Jordan, Howard R. Kelly, John G. Kirkwood, Robert T. Lagemann, Joseph Lempert, Cyril E. McCellan, Donald B. McNeill, Charles R. Mingins, T. H. Mueller, Koju Noguchi, Shuzo Odajima, Anton Petrovich, Joseph B. Platt, Frederick Reines, Philip S. Riggs, George B. Salmons, Chalmers W. Sherwin, Arnold J. F. Siegert, Milton M. Slawsky, E. Howard Smith, Gail P. Smith, Maurice R. Smith, Arthur L. Stauffacher, Franz S. Veith, David P. Wheatland, Gerald A. Wrenshall, and Violet Wu.

The regular scientific program of the Society consisted of 179 contributed papers of which five, numbers 2, 19, 20, 55 and 57, were read by title. The abstracts of these papers are given in the following pages. An author index will be found at the end.

HAROLD W. WEBB
Acting Secretary

ABSTRACTS

1. The Diffraction of X-Rays by Liquid Argon. A. EISENSTEIN AND N. S. GINGRICH, *University of Missouri.*—The x-ray diffraction pattern of liquid argon has been obtained using crystal reflected Mo$K\alpha$ radiation. Argon gas under a gauge pressure of 50 lb. per sq. in. was cooled to 90°K in a thin-walled Pyrex glass capillary of about 1.7 mm diameter and under these conditions the argon became liquid. An evacuated camera of 9.53 cm radius was so constructed that the film could be placed outside the vacuum, with entrance and exit windows of aluminum. Exposures of 140 hours were required to give patterns of satisfactory density. Of six pictures taken, three could be used. Microphotometering the films showed three peaks: a very strong peak at $\sin\theta/\lambda=0.154$, a medium peak at $\sin\theta/\lambda=0.280$ and a weak peak at $\sin\theta/\lambda=0.415$. No evidence of another peak could be found beyond this and up to $\sin\theta/\lambda=0.75$. Keesom and de Smedt[1] observed peaks at 0.159, 0.231 and 0.371 using Mo filtered radiation and at 0.151 and 0.269 using Cu filtered radiation. A preliminary Fourier analysis of our diffraction pattern results in an atomic distribution curve ($4\pi r^2\rho(r)$ *vs.* r) showing approximately 7 atoms at 3.90A and 5 atoms at about 5.05A. A third broad peak occurs at over 7A. This indicates that the distribution of atoms in liquid argon does not follow closely that in crystalline argon, since in the crystal there are 12 nearest neighbors. Further experimental work is in progress toward improving the experimental determination of the diffraction pattern, to give the basis for this conclusion a more critical examination.

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[1] Keesom and de Smedt, Proc. Amst. Acad. 12, 1 (1923).

2. The Diffraction of X-Rays by Indium, Cadmium, Zinc, and Chlorine in the Liquid State.[*] CARL GAMERTSFELDER, *University of Missouri.*—The x-ray diffraction patterns of the liquid elements indium, cadmium, zinc, and chlorine were obtained at different temperatures, using strictly monochromatic Mo$K\alpha$ x-rays and a camera of 9.20 cm radius. Atomic distribution curves were obtained in the usual manner. Three diffraction maxima were obtained for indium at 160°C and 390°C. The main peak for 160°C was at $\sin\theta/\lambda = 0.179$ and for 390°C was at $\sin\theta/\lambda = 0.177$. The distribution curves show a concentration of 8 atoms at 3.30A for 160°C and 3.36A for 390°C; also a concentration of 4 atoms at slightly more than 4A in each case. In the crystal there are twelve nearest neighbors at an average distance of 3.32A. Cadmium at 350°C had three diffraction maxima, with the main peak at $\sin\theta/\lambda = 0.202$. The distribution curve shows a concentration of 8 atoms at 3.06A with a secondary concentration of 4 atoms at about 4A. In the crystal there are twelve nearest neighbors at an average distance of 3.16A. Zinc at 460°C had three diffraction maxima the second of which, at $\sin\theta/\lambda = 0.228$, was most intense. The distribution curve has a concentration of 11 atoms at 2.94A. In the crystal there are twelve nearest neighbors with an average distance of 2.8A. For chlorine the distribution curve shows that there is one nearest neighbor at 2.0A.

[*] Read by title.

3. A Comparison of Liquid Diffraction Patterns Using Crystal-Reflected and Filtered X-Rays. N. S. GINGRICH AND R. Q. GREGG, *University of Missouri.*—X-ray diffraction patterns of liquids are used for the determination of the structure of liquids through the use of a theoretical treatment that presupposes monochromatic incident x-rays. Monochromatic x-rays of sufficient purity can readily be obtained by crystal reflection, but the intensity of the reflected beam is so low that exposures of great length are required. A comparison has been made between diffraction patterns of liquid sodium at 117°C taken (1) with crystal reflected x-rays and (2) with x-rays filtered in several different ways. With a Mo target tube operated at 37 kv all filtered radiation patterns show a spurious peak at small angles due to continuous radiation, and they all show larger background over the whole pattern relative to the main peak intensity. If filtering with double thickness of ZrO_2 and narrow slits are used the resolution of the first two true peaks approaches that of the crystal reflected case. But the exposure time for the filtered case is then greater than the crystal reflection. Using a tube voltage of 29.5 kv and the usual filtering reduced the spurious peak greatly, but the exposure time was again greater than with crystal-reflected x-rays. Thus, for reliable patterns from which quantitative conclusions are to be made it appears to be both desirable and expedient to use crystal reflected x-rays.

4. The L Emission Band of Aluminum. D. H. TOMBOULIAN AND WILLOUGHBY M. CADY, *Cornell University.*—The emission band due to transitions from conduction to L levels has been photographed on Q plates in a vacuum grating spectrograph with a dispersion of 1.2 A/mm and a resolving power of 300. For homochromatic photometry two unequal exposures were obtained on each spectrogram by raising or lowering the plate holder through an externally controlled mechanism. The effect of light fog was compensated. This procedure also serves as a convenient means for obtaining the calibration curve of the plate in the region of the band (170–240A). The x-ray technique resembled that of O'Bryan and Skinner.[1] During an exposure (1–2 hours) the surface of the target was renewed every few minutes by evaporation. A plot of the relative intensity of radiation as a function of the energy of the emitted x-ray photons shows a more marked minimum near the band head and a band width comparable to those reported previously.[1, 2] The present measurements give a band width of 10.2 ev.

[1] O'Bryan and Skinner, Phys. Rev. **45**, 370 (1934).

[2] Siegbahn, Ergebnisse der exakten Naturwissens. **16**, 104 (1937).

5. Decrease of Skin Damage by Deflecting Secondary Electrons from a Beam of One Million-Volt X-Rays. G. FAILLA AND EDITH H. QUIMBY, *Memorial Hospital.*—Previous experiments in this laboratory have shown that the biological effectiveness of gamma-rays can be reduced considerably by removing from the beam many of the associated secondary electrons. The thickness of tissue in which this obtains is of the order of one millimeter for one million-volt x-rays. Skin erythema results largely from injury to cells situated close to the surface. Accordingly it should be possible to reduce skin damage of this type by the suggested method. Tests have been made by covering with rubber (entirely material of low atomic number) one-half of the skin surface exposed to one million-volt x-rays. The skin area irradiated through rubber shows a distinct erythema, whereas the other half shows no reddening at all. In these tests the x-rays traversed a considerable thickness of air between the last collimating diaphragm and the patient's skin, for the purpose of scattering many of the secondary electrons out of the beam. No magnetic field was used. The simplicity of the method makes it readily applicable to the treatment of patients.

6. The Auger Effect in X-Ray Line Widths. JOHN N. COOPER, *Cornell University.*—The Auger (radiationless) transition $L_{\mathrm{I}} \rightarrow L_{\mathrm{III}}\ M_{\mathrm{IV,V}}$ is believed to be responsible for the curious variation of the intensity of the satellites of the x-ray lines $L\alpha_1$ and $L\beta_2$ in the range of atomic numbers $70 < Z \leq 81$. This Auger transition is forbidden (conservation of energy) for $Z < 73$, but its probability increases rapidly with atomic number from Ta (73) to Tl (81). When present, this transition provides a process alternative to photon emission by which an atom may leave the L_{I} state, and the additional process should be accompanied by an increase in the width and a decrease in the intensity of every line originating from the state of L_{I} ionization. In the present work, widths of selected lines arising from L_{I}, L_{II}, and L_{III} initial states for elements in the range $73 \leq Z \leq 81$ have been measured with a two-crystal spectrometer. The L_{I} line widths relative to the $L_{\mathrm{II,III}}$ line widths are observed to increase with atomic number. Qualitative comparison of intensities further shows that the L_{I} lines relative to the $L_{\mathrm{II,III}}$ lines become less intense as the atomic number increases. These observations are in accord with the expected influence of the Auger transitions.

7. New X-Ray Laboratory of The National Bureau of Standards. Lauriston S. Taylor, *National Bureau of Standards.*—A combined x-ray and high voltage laboratory has just been completed at the National Bureau of Standards and a brief description of the x-ray part will be given. The laboratory consists essentially of a large transformer bay 132′×65′×60′ high and five laboratory floors 30×132′. The space is about equally divided between high voltage testing and x-ray investigations. The new equipment consists of a 1.4 million-volt 15-ma direct-current end ground generator (0.08 percent ripple per ma) in which the polarity may be reversed. This supplies either of two x-ray tubes now being installed or an ion tube to be installed in the future. For the protection of the operators x-ray targets are located behind heavy concrete protective barriers, where the physical measurements will be made. Voltage is measured with a potentiometer voltmeter operating through a wire resistance of 1.4×10^9 ohms. A generating voltmeter will be used for control purposes. On the second floor is a 400-kv center ground d.c. generator with connections to any one of three tubes. On the third floor is a 220-kv 30-ma half-wave rectifier set for use with liquid ionization measurements. On the same floor is a 180-kv d.c. set for low power exploratory work. The laboratory will be open for inspection during the meeting.

8. Critical Phenomena. E. F. Mueller, Edward O. Sperling and D. C. Ginnings, *National Bureau of Standards. (Introduced by R. S. Jessup.)*—An apparatus, designed to exhibit particularly the large changes in density occurring below the critical temperature in both liquid and vapor, will be exhibited. The changes occurring in the apparatus will also be shown with lantern slides.

9. New Measurements on the Dielectric Constants of Eight Gases. L. Grant Hector and Donald L. Woernley, *The University of Buffalo.*—The heterodyne beat frequency method of determining dielectric constants of gases previously described by Hector and Schultz[1] has been improved and the equipment rebuilt to increase the sensitivity of the apparatus and to improve the reliability of the data. So far eight gases have been measured (helium, neon, argon, hydrogen, oxygen, nitrogen, carbon dioxide, and air). The value for air is found to be somewhat lower than that previously reported from this laboratory, but it is in very close agreement with that computed from the values for its constituents as individually determined with the new equipment.

[1] Hector and Schultz, Physics **7**, 133–136 (1936).

10. The Electrical Breakdown Strength of Glasses *Versus* Crystals as a Function of Temperature. A. von Hippel and R. J. Maurer, *Massachusetts Institute of Technology.*—The breakdown strength of alkali halide crystals increases with temperature in the lower temperature range.[1] This effect was interpreted in analogy to the temperature coefficient of the resistance in metals: the probability for scattering of electron waves is increased by the thermal disordering of the periodic structure. If this explanation is right, the effect should be absent in materials without periodicity. Glasses have therefore been studied, and especially quartz glass has been compared with quartz crystals. The result is, that not only the increase of the breakdown strength is absent in glasses but even a decrease has been observed over the whole temperature range measured. A slow decay at low temperatures is probably due to polarization phenomena, while a rapid decrease at higher temperatures is produced by thermal breakdown.

[1] R. C. Buehl and A. von Hippel, Phys. Rev. **56**, 941 (1939).

11. Dielectric Research at Ultra-High Frequencies with a New Method. S. Roberts and A. von Hippel, *Massachusetts Institute of Technology.*—In the course of a larger research program about the sources of dielectric loss the authors have developed a new method for measuring the dielectric properties of solids and liquids in the ultra-high frequency range. The material is inserted in the closed end of a rectangular metal pipe or a coaxial line. A detector with a probe pointing into the pipe through a slot travels parallel to the axis, driven by a precision screw arrangement. A standing electric wave is generated in the pipe and its position and the relative amplitudes at node and antinode outside the dielectric material are measured with high accuracy; ϵ' and ϵ'' can be calculated from these data. Some results for $\lambda=5.9$ cm are given. Adaptability to any kind of material, avoidance of boundary difficulties, and high precision while using small amounts of the dielectric are special advantages of the method.

12. Air Friction on a Centrifuge Rotor as a Function of Pressure and Rotor Speed. J. M. Cranford, *University of Virginia. (Introduced by J. W. Beams.)*—An inverted type ultracentrifuge[1] was surrounded by a concentric ring suspended between two guard rings by a steel fiber. The frictional torque on the ring was measured by its angular deflection. Pressures of air were from 0.1 cm to 10 cm. Linear peripheral speeds of the centrifuge rotor were from 15 m/sec. to 420 m/sec. Plotting torque against rotor speed at constant pressure, the dependence for smaller speeds was approximately linear, the slope being independent of the pressure. When the critical Reynolds' number is reached, an abrupt decrease in torque is noted. The critical Reynolds' number is constant (about 1500). For speeds above this point the initial slope of the curve is smaller, but shows a steady increase with speed. At the critical Reynolds' number the suspended ring is very unstable, but measurements immediately above and below this point are reliable.

[1] Beams and Linke, Rev. Sci. Inst. **8**, 160 (1937).

13. A Quantity-Type Rotor for the Ultracentrifuge. A. Victor Masket, *University of Virginia.*—The fixed angle quantity-type rotor[1,2] for the ultracentrifuge has been modified so that the holes are inclined at 10° to the axis of rotation (vertical). The rims of the Lusteroid tubes which are used to hold the centrifugate are flared to serve as gaskets. Duralumin plugs are screwed into the rotor over the tubes and serve to prevent loss of material and maintain a vacuum seal. Advantages of the new design are (1) greater efficiency, (2) collapse of the tubes is prevented, (3) fewer and longer tubes can be used with equivalent capacity, (4) reduction in diameter of the rotor. A rotor of this design has been used successfully for the differential concentration of proteins in undiluted blood serum.

[1] Bauer and Pickels, J. Exp. Med. **64**, 503 (1936).
[2] Beams, Linke and Sommer, Rev. Sci. Inst. **9**, 248 (1938).

14. An Electric Ultracentrifuge Motor. C. SKARSTROM AND J. W. BEAMS, *University of Virginia.*—The a.c. electric motor drive and magnetic support for ultracentrifuges[1] have been improved and their operation simplified. The motor armature comprises a solid steel cylinder ($1\frac{1}{2}''$ dia.) and a magnetic support core ($\frac{13}{16}''$ dia.) mounted coaxially on a stainless steel tubular shaft ($\frac{1}{8}''$ O.D.). Cooling water passes through the hollow armature shaft. A two-phase salient pole stator produces the rotating magnetic field when fed from the output of a "transitron"[2] oscillator and power amplifier. Condensers in series with the motor field windings split the phase and match the load to the power amplifier. With 1-kw motor input at 1180 cycles per sec. the rotating magnetic field develops 600 g cm torque throughout the starting period up to about 10 percent slip ($\frac{1}{2}$ hp. at 1000 r.p.s.). A $7\frac{1}{2}$-lb. rotor $6\frac{1}{4}''$ dia. of 81,000 g cm^2 moment of inertia has been accelerated to 1000 r.p.s. in 18 minutes. At this speed a slip-speed control actuated by a magnetic pick-up on the motor shaft sharply reduces the power input to the motor to about 450 watts and automatically maintains the speed of the ultracentrifuge within $\pm\frac{1}{8}$ r.p.s. Synchronous household electric clocks with rewound field coils measured the drive frequency and slip speed.

[1] Beams and Black, Rev. Sci. Inst. **10**, 59 (1939).
[2] Brunetti, Rev. Sci. Inst. **10**, 85 (1939).

15. The Aerodynamics of Golf Balls. J. M. DAVIES, *The B. F. Goodrich Company.*—The aerodynamic forces on a golf ball were studied by dropping a spinning ball through a horizontal wind-stream having a velocity (V) of about 105 feet per second. The lift (L) and drag (D) were calculated from the drift of the ball at rotational speeds (N) up to 8000 r.p.m. For a standard golf ball weighing 0.1 lb., the lift varied with the rotational speed as $L=0.064$ (1-exp.—$0.000260N$) with a maximum observed value of 0.055 lb. The drag increased nearly linearly from about 0.06 lb. for no spin to about 0.1 lb. at 8000 r.p.m. For a nonrotating standard ball the results are consistent with the equation $D=22.7\times10^{-6}V^{5/3}$. The most surprising result was that with a smooth ball the lift was negative below 5000 r.p.m. Above this speed it was normal in direction but less than for the standard ball. The drag was nearly constant at about 0.08 lb. Balls with shallower dimples gave intermediate results. The negative lift can be explained on the basis of negative pressure at the surface above the critical speeds for turbulent flow. Driving tests were consistent with the wind tunnel data. These results explain why long drives cannot be obtained with a ball having a smooth surface, and why the standard dimple or mesh surface gives the golfer much greater distance and better control of the ball.

16. Ultrasonic Velocity and Absorption in Liquids. GERALD W. WILLARD, *Bell Telephone Laboratories.*—An ultrasonic light-diffraction cell was used for measuring the velocity and absorption of sound in some fifty transparent liquids at frequencies 6, 10, 18 and 30 mc. Velocity was obtained from diffraction spectra spacing. Absorption was obtained from sound radiator voltages required to produce certain color transmission effects at measured distances along the sound beam. The velocity was found to be independent of frequency, within experimental error of several tenths percent. This in itself indicates absence of anomalous absorption within the frequency range covered. The absorption, where measurable at all four frequencies, was not found to differ from the expected proportionality to frequency squared. There appears to be no correlation between measured absorptions and those calculated from viscous and thermal losses. Absorption measurement error runs from 5 to 50 percent, depending on material and frequency. Typical values of the amplitude absorption per centimeter divided by the frequency squared, $10^{15}\ \alpha/f^2$, are: carbon disulfide, 74; glycerine, 26; benzene, 8.3; chloroform, 3.8; chlorobenzene, 1.7; nitrobenzene, 0.9; acetone, 0.6; water, 0.33.

17. Calculation of Acoustic Waves with Irregular Boundaries. RICHARD H. BOLT,* *Massachusetts Institute of Technology.* (*Introduced by P. M. Morse.*)—The nature of normal modes in an enclosure of arbitrary shape is of practical concern in the development of room acoustics theory. For certain types of boundary irregularities, a modification of the net-point method[1] is applied to the calculation of wave functions. In this method, "arbitrary" values are first assigned to lattice points covering the region, and then improved by successive application of a difference equation. To obtain states higher than the fundamental, orthogonality conditions must be imposed. This would make the method cumbersome for acoustics, in which higher modes are of chief interest. It is found, however, that the approximate orthogonality obtained by inserting appropriate nodal lines and changes of sign in the initial guess appears to yield convergence directly on any desired mode. For minor irregularities on the walls of a rectangular room, the unperturbed wave function may be used for the first guess. As an example, some cases are calculated for a rectangular beam on a wall, with several ratios of beam width and depth to wave-length. For major distortions of shape, experimental plots giving at least the nodal lines are useful for obtaining initial values. Examples are calculated for comparison with recent experiments[2] and found to be in good agreement. Some of the practical implications are mentioned.

* National Research Fellow.
[1] G. E. Kimball and G. H. Shortley, Phys. Rev. **45**, 815 (1934).
[2] R. H. Bolt, J. Acous. Soc. Am. **11**, 184 (1939).

18. A Method for Solving the Wave Equation in a Region with Perturbed Boundaries. H. FESHBACH AND A. M. CLOGSTON, *Massachusetts Institute of Technology.*—A description is given of an application of perturbation methods to the solution of partial differential equations with particular boundary conditions on a surface slightly deformed from some regular shape for which the exact solutions are known. If the original boundary is $f(x,y)$ and the deformed boundary is $F(x',y')$, a transformation $x'=x'(x,y)$, $y'=y'(x,y)$ is found such that the transformed function $\phi(x,y)=\psi(x',y')$ satisfies the same boundary conditions on $f(x,y)$ as ψ does on $F(x',y')$. In the new coordinate system, perturbation terms are introduced into the original differential operator, and the usual methods of perturbation theory are applied. The first-order change in the eigenvalue, which vanishes when no volume change is involved, agrees with the result obtained in a different manner by H. Froelich.[1] The method is applicable to acoustic and electromagnetic problems. For the acoustic case the velocity potential ψ obeys the equation $\nabla^2\psi+k^2\psi=0$ with $\partial\psi/\partial n=0$ on the boundaries. Formulae are given for the matrix components of the perturbation terms which allow the computation of the distorted wave patterns arising from certain deformations. Comparison is made with recent experiments in acoustics on standing waves in enclosures of irregular shape.[2]

[1] H. Froelich, Phys. Rev. **54**, 945 (1938).

[2] R. H. Bolt, J. Acous. Soc. Am. **11**, 184 (1939).

19. The Classical Theory of Shock and the Theory of a Propagated Discontinuity.* L. THOMPSON, *Naval Proving Ground.*—Rayleigh and others approached the problem from the standpoint of a condensation cycle of concurrent, continuous changes of pressure, density, and velocity of air particle. The formula

$$V_r=\left(\frac{dp}{d\rho}\right)^{\frac{1}{2}}$$

is the wave velocity relative to the velocity of flow within the wave. Hugoniot's theory of a discontinuity of the second order does not involve discontinuous change of particle velocity when the surface is penetrated by a particle. Finite time is required to accumulate finite change of velocity under a finite (jump of) acceleration. Or we may say no finite proportion of molecules will experience collision precisely at instant of passing shock surface, though there is a jump in density. The equation between p and wave velocity so defined with respect to undisturbed medium $v=(dp/d\rho)^{\frac{1}{2}}$,[1] gives pressures of the order of those by Rayleigh. Differences are reasonable as being effect of dealing in one case with a true discontinuity and in the other (through continuous processes) with an approach to perfect abruptness. Both procedures are faulty in employing at some point the thermodynamics of equilibrium. The theory of discontinuity seems less vulnerable in this respect.

* Read by title.

[1] L. Thompson, J. Acous. Soc. Am. **11**, 245 (1939).

20. Solution of Laplace's Equation in Application to the Artificial Drainage of Waterlogged Land Overlying an Impervious Layer.* DON KIRKHAM, *Utah State Agricultural College.*—Drainage is to be effected by circular drains of radius r buried in equispaced horizontal lines distance a apart and d deep. The water table, in keeping with field experiments, is assumed horizontal and is distance h above the impervious layer. Laplace's equation is solved for the velocity potential subject to the boundary conditions that at the water table and drains the pressure is atmospheric, and that the impervious layer is a streamline. From the velocity potential the quantity of water flowing into unit length of drain per second is found to be

$$Q=-\frac{2\pi K\gamma gd}{\log_e\dfrac{\sinh\dfrac{\pi r}{a}}{\sinh\dfrac{2\pi d}{a}}+\sum\limits_{n=1}^{\infty}(-1)^{n-1}\log_e\left[1-\left(\dfrac{\sinh\dfrac{2\pi d}{a}}{\sinh\dfrac{2\pi nh}{a}}\right)^2\right]},$$

where, besides the symbols already defined, $K=k/\mu$, k is the soil permeability, μ the viscosity of water, γ the density of water, and g has its usual meaning. This equation exhibits a maximum for Q when d is somewhat smaller than h. For the case $r=4.5$ in., $h=6$ ft., $a=50$ ft., Q is a maximum when $d=4.5$ ft.; whereas, when $d=5.62$ ft. (drains next to impervious layer), Q is about the same as for $d=3$ ft. These results indicate that the present-day practice of placing drains immediately next to the impervious layer should be modified.

* Read by title.

21. Characteristics of a Low Cost Hydrogen Liquefier. CHARLES F. SQUIRE, *University of Pennsylvania.*—The general features of this type liquefier have been described by Ahlberg, Estermann, and Lundberg.[1] Simon[2] has suggested the use of such a liquefier for precooling a helium liquefier of his design. In our liquefier the experimental chamber (it could also be a helium liquefier) is an integral part; thus we avoid a second cryostat with the accompanying transfer losses and liquid nitrogen consumption. Operation characteristics are discussed with slides. We are using this cryostat for studies in antiferromagnetism.

[1] J. E. Ahlberg, I. Estermann and W. O. Lundberg, Rev. Sci. Inst. **8**, 422 (1937).

[2] A. H. Cooke, B. V. Rollin and F. Simon, Rev. Sci. Inst. **10**, 251 (1939).

22. Abundance of Molybdenum Isotopes. G. E. VALLEY, *Harvard University.*—An analysis of the relative abundance of the molybdenum isotopes has been made, using a mass spectrometer of the magnetic analyzer type. Mo^+ ions were formed by the intersecting of a beam of molybdenum vapor and a stream of electrons of sufficiently low energy so that no Hg^{++} ions were formed. The ion currents were measured by a d.c. amplifier of the usual type, operating at a sensitivity of 46,700 mm/volt and employing a grid resistor of 2×10^{10} ohms. The values found are:

Mo	92	94	95	96	97	98	100
	14.9	9.40	16.1	16.6	9.65	24.1	9.25

The accuracy is 1.0 percent. These values lie between those of Aston[1] and of Mattauch and Lichtblau[2] which were obtained photographically.

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[1] F. W. Aston, Proc. Roy. Soc. **A130**, 302 (1931).

[2] J. Mattauch and H. Lichtblau, Zeits. f. physik. Chemie **B42**, 288 (1939).

23. The Weber-Fechner and Granit-Harper Laws for Heat Sensation. L. P. Granath, *New York University*, C. M. Herget and J. D. Hardy, *Russell Sage Institute of Pathology, New York Hospital.*—Investigations were made to test the validity of the Weber-Fechner and Granit-Harper Laws for heat sensation. Heat radiation from a 1000-watt tungsten lamp was used to irradiate the blackened forehead of the subject. This radiation was interrupted by a rotating half-sector; the frequency of interruption was adjusted by the subject until the flicker of heat on the forehead was smoothed out into a sensation of continuous warmth. This critical frequency was regarded as representing the S (sensory response) of the Weber-Fechner and Granit-Harper Laws. Readings were taken in this manner for intensities ranging from 145×10^{-6} to 2720×10^{-6} gram cal. sec.$^{-1}$ cm^{-2}, and areas of exposed forehead from 27.3 to 1.0 cm^2. The plots of log of intensity of heat stimulus *vs.* critical frequency for constant area, and log of area *vs.* critical frequency for constant intensity, gave in general straight lines, indicating conformity to the Weber-Fechner and Granit-Harper Laws over most of the range. Possibilities of deviations at the extremes will be discussed.

24. A New Direct Reading Densitometer. Charles E. Buchwald, *Haskins Laboratories, Inc.*, and Franklin S. Cooper, *National Photocolor Corporation.*—The authors have designed a densitometer for the measurement of the density of photographic plates. This instrument has incorporated in it several novel features which are worthy of description. The range of density covered is from 0–3 (i.e., transmission of 1 to 0.001). The scales are practically linear and the over-all accuracy is greater than 0.005 density unit. The circuit consists of two vacuum photoelectric cells arranged in a bridge circuit so that line fluctuations have an insignificant effect on the reading. Balance is indicated by means of a cathode-ray indicator. The light falling on the photo-cell in the known arm of the bridge is controlled by means of a circular logarithmic wedge and a triangular wedge working together to give a range of illumination of 1 to 1/1000. Because of inherent difficulty in making the circular logarithmic wedge and triangular wedge the instrument has to be calibrated for accurate work. This, however, does not present any difficulty. Details of the circuit, construction, and operating characteristics will be given.

25. A Fast Recording Spectrophotometer. J. B. H. Kuper, *Washington Biophysical Institute*, and F. S. Brackett, *National Institute of Health.*—A spectrophotometer recording transmission curves in the visible region from 4300 to 7200A in four minutes has been constructed. This instrument has an effective slit width of about 10 angstroms, which is practically constant throughout the spectral range covered. The slits are operated by a cam shaped to correct for the spectral sensitivity of the photocell, transmission and dispersion of the instrument, and the emission curve of the lamp, giving an almost flat line for 100-percent transmission. The optical system is of the Littrow type, employing a large 60° and a 30° prism of dense flint glass and an off-axis parabolized mirror. The definition permits resolving the D lines. The recording system consists of an electrometer tube amplifier and Moll galvanometer, period 0.2 sec. The stability attained is such that zero points need only be introduced by occultation at intervals of a half-minute. A pneumatic device places the sample and reference cells alternately in the beam, making a complete interchange in less than a second. Hence, no appreciable error is introduced by fluctuations in the source. The unknown and reference curves are thus built up of about three hundred points each, or on the average one point per 10 angstroms.

26. Quartz Double Monochromator with Single Wave-Length Control. F. S. Brackett, *National Institute of Health*, H. T. Wensel, *National Bureau of Standards*, and J. B. H. Kuper, *Washington Biophysical Institute.*—A quartz double monochromator has been developed which provides a single control for all wave-length adjustments, thus facilitating automatic registration. The instrument consists of two complete constant deviation monochromators, one of $f/4$ and the other $f/5$ relative aperture so that no field lenses are required for tandem arrangement. A common base permits use of the units independently, or coupled to deviate in the same or opposite directions. The dispersive systems each consist of two symmetrical tilting 30° prisms. All lenses (30 cm focal length at 4000A) including condensers are displaced by worm drives, gear coupled to a single motor. Each prism is rotated by a toggle connection to the adjacent lens. A family of curves have been obtained relating prism rotation to lens displacement for a wide range of deviations. This required curvilinear relation is fitted by a selection of a simple toggle with unequal arm lengths. It is shown that such a linkage may be described by curves depending upon scale and shape parameters, the former being determined by focal length and the latter by the geometry of the system. A two-point agreement is obtained yielding critical definition from 7000 to 2000A.

27. An Improved Method for Obtaining a Long Optical Path in a Limited Space. Howard R. Kratz and J. E. Mack, *University of Wisconsin.*—A new method has been devised for obtaining a long optical absorption path by repeated traversal of a tube. Light is reflected at one end of the tube by a spherical mirror, and (twice) at the other end by a totally reflecting prism placed at the center of curvature of the mirror. The prism is truncated to allow the light to enter and leave the system. The source is placed close to the prism. The system is especially well suited to a capillary source such as the H-6 mercury lamp. For using the mirror to greatest advantage the optimum prism angle, a few minutes less than 90°, has been calculated as a function of the mirror radius, the width of the source or prism truncation, and the desired (even) number of traversals n. The principal advantage over other methods, aside from simplicity of adjustment, is that by imaging the light at the prism after each double traversal the emergent beam is kept almost as bright as the source except for the loss at $n/2$ reflections and n refractions, with an angular divergence limited principally by the mirror aperture (except for large n). The small number of metallic reflections makes for great speed in the ultraviolet.

28. Durable Low-Reflecting Films on Glass. C. HAWLEY CARTWRIGHT, *Massachusetts Institute of Technology.*—Evaporated films of magnesium fluoride on glass are considerably hardened by heat treatment and the effective hardness can be further increased by applying an oil or soap film, which serves as a lubricant and also makes the magnesium fluoride waterproof.[1] Such films are practically as durable as the glass itself. The reflection of ordinary glass is reduced to about 25 percent of its former value; the reflection of higher index glass is reduced much more. A further decrease in reflection is obtained for these rugged films by first applying a very thin film of TiO_2 to the glass, to increase effectively its index of refraction, and then applying a hard film of evaporated magnesium fluoride which is oiled to make the magnesium fluoride hydrophobic and withstand abrasion. The effects outlined in this respect will be presented in some detail.

[1] Dr. A. F. Turner found baking at about 400°C most effective.

29. Optical Constants of Quartz for the Extreme Ultraviolet. RICHARD TOUSEY, *Tufts College.*—Specular reflecting powers of polished specimens of crystalline and vitreous quartz have been measured at 45°, 60°, 75°, and 85° from 1608A to 910A. For crystalline quartz the reflecting power at 45° varies between limits of 26 percent and 9 percent within this wave-length range. There are two bands of selective reflection, at 1190A and at 1070A. Specimens with different orientations of the optic axis were tested and showed small differences in reflecting power near the 1190A reflection maximum. Vitreous quartz gave reflecting power curves a little lower than crystalline quartz but of the same type, with selective reflection at the same wave-lengths to within 20A. Dispersion and absorption curves were calculated from these data using the reflection equations for an isotropic medium. These curves show for all specimens a strong, narrow absorption band at 1190A and a weaker and broader band at about 1060A. The transmission limit for crystalline quartz was found to be 1436A even for pieces as thin as 0.02 mm. Published dispersion formulae fit the new data to within experimental error as far as about 1400A, but for shorter wave-lengths inside the absorption bands they do not fit.

30. The Attenuation of Infra-Red Light by Fog. J. A. SANDERSON, *Naval Research Laboratory.*—The infra-red absorption spectra of clean natural fogs have been measured over the wave-length range 1–12μ by means of an infra-red spectrometer, using as a source of light two 600-watt Globar heaters in a 65-cm metal mirror placed 244 meters from the point of observation. The spectral transmission curves, obtained for fog densities corresponding to visibility ranges of 0.6 to 2 km, show fairly uniform transmission for all wave-lengths and lead to the result, in accordance with previous measurements and theory, that there is no important advantage in employing long wave-length infra-red light in seeing through fog. Additional measurements with a residual ray apparatus lead to the same conclusion. It was further observed that falling snow scatters all wave-lengths equally.

31. Velocity of Light Measurements. WILMER C. ANDERSON, *Harvard University.*—This is a continuation of previous work. A discussion of the changes made in the apparatus during the past year will be given. The changes include a recorder enabling 400 records to be taken with a single loading, a new modulator cell, a new type of diaphragm for matching the intensities of the two light beams, a new fluctuation stabilizer, and devices for correcting or minimizing the electron transit time factor. A summary of results up to the date of the meeting will be given. Certain correction factors will be discussed.

32. Absorption Spectra of Microscopic Structures. P. A. COLE AND F. S. BRACKETT, *National Institute of Health.*—Ultraviolet photomicrograms of human erythrocytes (red blood cells) have been taken at 19 selected wave-lengths in the range 4358 to 2265A. The intensity of absorption of the cells at each wave-length has been determined by an adaptation of standard photometric methods. A rotating step sectored disk is placed directly in front of the plate, thus making possible calibration of each exposure by subsequent densitometry. An ultraviolet absorption curve of the cell has been obtained which compares favorably with the ultraviolet absorption spectrum of hemoglobin, the chief absorbing constituent, as obtained by means of a "Spekker" photometer. This provides a test of the practicability of the method for determining the absorption properties of the materials within microscopic living cells.

33. A Comprehensive Theory of Light. PETER FIREMAN, *Magnetic Pigment Company.*—We have today two theories of light, a theory of waves and a theory of corpuscles. They are both firmly grounded. Between them they account for all light phenomena so far observed but each only for a part of them. We thus have a sharply dualistic doctrine of light. It is attempted here to construct a unitary theory of light. Let us envisage light corpuscles as endowed with vibratory motion, as vibrating while moving with the velocity of light, as vibrating transversely to the path of propagation. Such corpuscles on passing over a diffraction grating would produce light spectra on a screen. We would then have light corpuscles capable of accounting for phenomena of interference and diffraction, and also of polarization. Thus we would have a wave theory of light without ether, we would have a corpuscular theory accounting for all light phenomena. Obviously the concept of vibrating corpuscles can be extended to apply also to electrons, protons, heavy nuclei; and so we attain to unity of light and matter.

34. On the Fine Structure Pattern of Cosmic Rays. E. J. Schremp, *Washington University.*—Surveys of directional cosmic-ray intensity at St. Louis[1] and Columbia,[2] Missouri, have yielded concordant evidence for a fine structure pattern in the intensity distribution. This work has been continued in order to map the pattern exhaustively throughout the sky. The present revised coincidence counter telescope possesses a reduced aperture of 5° in zenith angle and 15° in azimuth angle, and an increased areal aperture of 6 square feet, provided by 72 counters in a double coincidence array. Operating automatically, the apparatus records up to 4000 counts per point per day for an arbitrary 10-point curve within a given azimuthal plane. By selecting angular intervals of as little as 1°, it has been possible to improve the relative magnitudes of some of the observed prominences to as much as 10 percent of the total intensity. In a long-time pattern the magnitude of the prominences seems to be inherently restricted, by positional fluctuations, to this value or less; but in short-time patterns this magnitude is frequently over 20 percent of the intensity. With the high counting rate of the present apparatus, one may now follow such short-time patterns day by day. In this way it is hoped that there may be extracted a correlation of the pattern fluctuations with magnetic and barometric disturbances.

[1] E. J. Schremp and H. S. Ribner, Rev. Mod. Phys. **11**, 149 (1939); H. S. Ribner, Phys. Rev. **56**, 1069 (1939).

[2] D. M. Cooper, Phys. Rev. **57**, 68(A) (1940).

35. Cosmic-Ray Showers Produced by Mesotrons. Wilson M. Powell, *Kenyon College.*—Five hundred and three penetrating particle tracks traversing 5 lead plates 1 cm thick were observed for shower particles in a very large counter controlled Wilson cloud chamber. The sensitive area measures 10.2 × 30.5 × 61 cm with the largest dimension vertical. The horizontal plates were approximately 6 cm apart. The two controlling G-M counters were placed above and below the chamber. The chamber was located in the basement with 80 cm of concrete above. The top and bottom of the chamber are cold-rolled steel 1.27 cm thick. Letting n be the number of rays accompanying the penetrating particle and p be the number of the plate starting from the top where the rays occur we have:

n p	1	2	3	4	5
1	29	5	0	1	0
2	19	4	1	0	0
3	27	1	1	2	1
4	28	5	0	0	2
5	17	6	1	2	0
Average	24	4.2	0.6	1	0.6

This will be compared with W. F. G. Swann's results[1] and H. J. Bhabha's calculations.[2] One particle stopped in the third plate. Its mass was calculated from the increase in ionization and was found to lie in the range of 75 to 200 times the electron mass. Another calculation based on the two scattering angles and the increase in ionization gave a mass of 200. Twenty shower particles occurred in an upwards direction. Three large bursts were observed with many particles fanning out under each plate. Two heavy tracks occurred in one of these.

[1] W. F. G. Swann, Rev. Mod. Phys. **11**, 242 (1939).

[2] H. J. Bhabha, Proc. Roy. Soc. **A164**, 257 (1938).

36. Use of Counters with Equalized Voltage Pulses in the Study of Cosmic-Ray Showers. W. E. Ramsey, *Bartol Research Foundation of the Franklin Institute.* (*Introduced by W. F. G. Swann.*)—The basic units in the systems to be described are trays, each consisting of 25 Geiger-Mueller counters. The counters are 20 cm in length and 1 cm in diameter and are so constructed that the sensitive areas may be placed very close together in the plane of the tray. Each counter in a tray is coupled to a terminal common to all by a variable condenser. The condensers are adjusted until single pulses from the separate counters are equal. The terminal common to the tray now experiences a succession of voltage pulses, each of which is proportional to the number of counters discharging simultaneously. Such counter tray units have been used alone, with recording vacuum tube circuits, for detecting and measuring multiplicity of rays through their surfaces. They have been used in groups to form coincidence telescopes capable of automatically recording the number of rays through the various surfaces subject to the restriction that the rays lie in a specified solid angle. They are very efficient detectors and have been used for cloud-chamber control. Discussion and illustrative results of these various applications will be given.

37. Further Evidence of Mesotron Showers. W. F. G. Swann and W. E. Ramsey, *Bartol Research Foundation of the Franklin Institute.*—With a sextuple coincidence set of Geiger counter sensitive areas, shower production was observed for cases where at least one ray had passed through 18 cm of lead. In 2300 events there were two cases in which a single entering ray gave rise to a pair in the 18-cm block, which pair recorded on each occasion after passing through four separate centimeters of lead. In one case a single entering ray recorded on each occasion after passing through three individual centimeters of lead. Taking into account inefficiency of the counter areas, it is estimated that in the 2300 events there were 6 cases of pairs capable of passing through several centimeters of lead without shower production. There were 7 cases where two entering rays showed as two rays without multiplication after passing through additional individual 1 cm lead slabs. There were several cases in which 10 or more rays entering passed through the 18 cm of lead and 4 individual 1-cm slabs with no more reduction than was to be expected from counter inefficiency, and without multiplicative electron shower production. These results, indicating mesotron showers, are in harmony with data already presented by one of us before the Cosmic-Ray Symposium held in Chicago on June 27–30, 1939.

38. Fluctuations in Cosmic-Ray Showers. W. T. Scott and G. E. Uhlenbeck, *University of Michigan.*—W. H. Furry[1] has given an expression for the probability $P(N,x)$ of finding N particles in a multiplicative shower, at depth x. His calculations are based on a model in which photons and electrons are treated identically. However, Furry's expression only applies to the case of no ionization. We have shown that, for the same model with ionization included, $P(N,x)$ can be rigorously determined if $F(E,x)$, the average number of particles of energy E at depth x, is known. Difficulties arise in the application of this formalism even when the expression for $F(E,x)$ obtained by the so-called cut-off method is employed. However, as has been shown previously, the dispersion, $\overline{N^2}-(\bar{N})^2$, can be computed. We have extended these calculations to the complete cosmic-ray shower model, using the cut-off method. In accordance with the predictions of Furry, we find again that the dispersion is much larger than that for a Poisson distribution.

[1] W. H. Furry, Phys. Rev. **52**, 569 (1937).

39. On the Production of Secondary Ionizing Particles by Non-Ionizing Agents in the Cosmic Radiation. B. Rossi,* L. Jánossy, J. D. Rochester and M. Bound, *University of Manchester, England.*—Previous experiments have shown that the number of coincidences recorded with a vertical counter arrangement is a few percent larger when some absorber is placed above the counters than with the same absorber between them. The effect is also present when the experimental conditions do not allow interpretation as shower production by photons. It has been, therefore, ascribed either to penetrating non-ionizing particles (neutrettos) producing ionizing secondary rays, or to ordinary photons producing penetrating secondary particles (mesotrons). In order to test these hypotheses, experiments were performed with an anticoincidence counter arrangement. A cloud chamber was also used to investigate the origin of the observed anticoincidences. These experiments proved that only a minor part, if any, of the previously reported differences could be due to secondary effects of neutrettos or to the production of mesotrons. The major part of them arises from the interference of already known phenomena like scattering, ionization showers, showers from the air, etc. This conclusion applies only to experiments performed near sea level.

* Now at the University of Chicago.

40. On the Occurrence of Associated Mesons. T. H. Johnson, R. P. Shutt and J. G. Barry, *The Bartol Research Foundation of the Franklin Institute.*—In a vertical cloud chamber 23 inches in diameter and 3 inches effective depth we have obtained 350 coincidence-counter controlled photographs (not stereoscopic) in which a penetrating ray passed through 15 cm of lead placed between the counters immediately above the chamber and through at least one lead plate in the chamber. The chamber contained three horizontal lead plates 1 cm, 5 cm and 1 cm thick, respectively, and spaced ten cm apart. Ten percent of the photographs showed an additional penetrating ray which appeared to emerge from the lead above the chamber simultaneously with the principal ray. About half of these additional rays appeared to intersect with the principal ray in the lead block. Although giving the appearance of being associated with the principal ray these additional rays occurred with just the frequency to be expected by chance if the rays were all independent and the sensitive time of the chamber has the reasonable value of 1/20 sec. The fraction of the additional rays which appeared to intersect in the upper lead block with the principal ray was also in agreement with the chance expectation. In 600 photographs we have observed 518 mesons traversing the 5-cm lead plate and 773 traversals of the 1-cm lead plates in the chamber. Forty-six possible knock-on electrons were found but except for two doubtful cases in the upper and middle plates and three undetermined secondaries from the lower plate no penetrating secondaries were seen.

41. On the Theory of Cascade Showers. H. A. Bethe, *Cornell University.*—It is often important to know the maximum number N_{max} of electrons in a shower for given energy E_0 of the primary. In previous theories,[1–4] N_{max} was calculated numerically, the result being rather uncertain because of (a) the inaccurate definition of the critical energy ϵ at which radiation and ionization loss are equal, (b) the neglect of ionization losses for energies $>\epsilon$, (c) the unsatisfactory treatment of the electrons below ϵ. However, N_{max} can be calculated quite accurately from the fact that ultimately all the energy must be transformed into ionization. The ionization energy loss of an electron does not depend much on its energy E if $E>mc^2$, especially in condensed materials.[5] We define ϵ as the ionization energy loss per radiation length[2] for an average electron (energy $\approx\epsilon$). Then, if $N(t)$ is the number of electrons in the shower, t radiation lengths from its origin, we have

$$\int N(t)dt=E_0/\epsilon. \tag{1}$$

Using the theory and notation of Landau and Rumer,[3] N has a maximum for $t=\eta/\lambda'(1)=1.01\log(E_0/\epsilon)$ and we have, approximately,

$$\int N(t)dt=N_{\text{max}}[2\pi\eta\lambda''(1)]^{\frac{1}{2}}\lambda'(1)^{-\frac{3}{2}}\approx 3.3\sqrt{\eta}N_{\text{max}}, \tag{2}$$

so that N_{max} can be calculated. The result is accurate to quantities of the relative order $1/\eta$ and could be further improved by a closer investigation of the length of the shower (cf. 2). The value of N_{max} is considerably greater than previous theoretical estimates[4] but of the same order as that used by Montgomery.[6]

[1] H. J. Bhabha and W. Heitler, Proc. Roy. Soc. **159**, 432 (1937).
[2] J. F. Carlson and J. K. Oppenheimer, Phys. Rev. **51**, 220 (1937).
[3] L. Landau and G. Rumer, Proc. Roy. Soc. **166**, 213 (1938).
[4] H. Euler and W. Heisenberg, Ergeb. Exakt. Naturwiss. **17**, 1 (1938).
[5] E. Fermi, Phys. Rev. **56**, 1242 (1939).
[6] C. G. and D. D. Montgomery, Rev. Mod. Phys. **11**, 255 (1939).

42. On Space Closure of Periodic Orbits in the Field of a Magnetic Dipole. O. Godart,* *Massachusetts Institute of Technology. (Introduced by M. S. Vallarta.)*—Periodic orbits play an essential role in the qualitative solution of dynamical problems. Periodic trajectories of charged particles in the field of the earth's magnetic dipole and their asymptotic orbits determine the distribution of cosmic rays on the earth. Moreover these orbits play an important role in the theory of the aurora polaris[1] and magnetic storms.[2] Some authors have supposed that the latter are due to periodic motions in a ring surrounding the earth. These periodic trajectories have been computed[3] for several values of the initial conditions. We have been able to express all periodic orbits as a function of a parameter μ

related to the initial moment of momentum with respect to the dipole. For each value of the parameter, the periodic orbits are situated on a surface of revolution. For a set of measure zero of this parameter, the periodic orbits form a simple infinity of closed orbits in space. For the other values, the surface of revolution is filled by one orbit only, quasi-periodic in space. All the neighboring orbits can be expanded as a function of the same parameter. For a given value of the energy, all the periodic solutions form a toroidal volume around the dipole. A decrease of energy produces a dilatation of this ring. The knowledge of this ring offers the hope of making some advances in the ring theory of magnetic storms and a more exact determination of the distribution of cosmic rays on the earth.

* Fellow of the Belgian American Educational Foundation.

[1] C. Störmer, Zeits. f. Astrophys. **1**, 237 (1930).

[2] O. Godart, Phys. Rev. **55**, 875 (1939).

[3] C. Störmer, reference 1; G. Lemaître, Ann. de la Soc. Sci. de Bruxelles **54**, 194 (1935); O. Godart, *ibid.* **57**, 27 (1938); A. Banos, H. Uribe and J. Lifshitz, Rev. Mod. Phys. **11**, 137 (1939).

[4] Forthcoming paper to appear in the *Journal of Mathematics and Physics.*

43. The Effect of Shielding on the Scattering of Fast Electrons by Heavy Elements. J. H. BARTLETT, JR. AND T. A. WELTON, *University of Illinois.*—The scattering amplitudes, for a central field, on the Dirac theory have been expressed by Mott[1] as series of Legendre polynomials, the coefficients of the series being functions of phase shifts η_j, where j is the Dirac angular momentum quantum number. We have determined these phase shifts for mercury, using a Hartree field and the Massachusetts Institute of Technology differential analyzer, for an energy of 100 kv and for values of j up to $j=29$. The W.K.B. method has also been used, and the results are in very good agreement with those from the differential analyzer, but not with those calculated on the basis of the Born approximation. At $j=29$, the phase shift is about 22°, and the W.K.B. method has been used to find higher phase shifts, which fall off exponentially. Preliminary summing of the series indicates that the scattering is larger for large angles than the Coulomb scattering, and that the polarization is not negligible.

[1] Mott, Proc. Roy. Soc. **135**, 429 (1932).

44. Multiple Scattering of Fast Electrons. N. L. OLESON, K. T. CHAO AND H. R. CRANE, *University of Michigan.*—A more extensive series of measurements of multiple scattering in the energy interval 3–10 Mev has been made in carbon, copper, iron, cadmium and lead, using a cloud chamber.[1] The scattering distribution is found to be nearly gaussian as expected. In the table below, the results are given in terms of the average $H\rho\theta$, the angle θ being measured in the plane projection.

SCATTERING MATERIAL	WEIGHT PER CM^2 G	NUMBER OF TRACKS	$\overline{H\rho\theta}$
C	0.82	842	2.20
Cu	0.174	543	1.93
Fe	0.173	435	1.84
Cd	0.111	633	2.01
Pb	0.071	641	1.73
Pb	0.157	397	2.68
Pb	0.362	273	4.03

$\overline{H\rho\theta}$ is in gauss centimeter degrees $\times 10^{-5}$. The experimental results on carbon contain measurements over three different energies, 6, 8, and 10 Mev, but as the variation of $\overline{H\rho\theta}$ with energy was within the experimental uncertainty, all the tracks have been put together in the above table. An investigation of the scattering by amorphous substances is now in progress in order to determine whether the crystal size has any effect on the scattering as predicted by Wheeler.[2]

[1] N. L. Oleson, K. T. Chao, J. Halpern and H. R. Crane, Phys. Rev **56**, 482 and 1171 (1939).

[2] J. A. Wheeler, Phys. Rev. **57**, 352 (1940).

45. Close Electron-Electron Collisions at Energies of One or Two Mev. J. S. BROCK, *University of North Carolina. (Introduced by A. E. Ruark.)*—Relativistic mechanics predicts that when a fast electron collides with another initially at rest, the angle between the two paths after collision is not 90° but decreases as the velocity of the incident particle approaches that of light. This has been confirmed by Champion[1] who studied, in the cloud chamber, the conservation of energy and momentum in collisions of beta-particles with energy up to 0.9 Mev. I have examined 4000 nitrogen photographs obtained by Dr. C. C. Jones, extending the range up to 2.5 Mev. This study yielded 13 measurable events occurring in the gas. In some cases the conservation laws based on the Lorentz formulas are closely obeyed; in others they are apparently violated, which may be due either to radiation loss (very infrequent at these energies according to Möller), or to multiple scattering. An equal number of air photographs remains to be examined. Analyses of the data will be presented using both the Lorentz and Abraham expressions for energy and momentum. This type of study differs from studies of the interaction of electrons with large-scale external fields (Zahn-Spees; Rogers-McReynolds-Rogers), for it deals essentially with the interaction of just two electrons.

[1] Champion, Proc. Roy. Soc. **A136**, 630 (1932).

46. Small Fluctuations in the Space Charged Limited Electron Current from a Fine Tungsten Wire. H. W. BERRY AND R. N. VARNEY, *Washington University.*—In using the balanced space charge method of detecting very feeble positive ion currents, a limiting sensitivity of the detector is reached when the size of the currents sought equals the random fluctuations of the space charge currents as shown by a galvanometer in the bridge circuit (about 10^{-9} amp.). Hence the cause and elimination of these fluctuations were the next step required to increase the sensitivity. Experiments to date indicate the following results: (1) The various batteries in the circuits are not responsible for the fluctuations. The fluctuations are the same whether a second space charge cylinder or an ordinary resistance is used in the balancing arm of the bridge. (2) The presence of small traces of gas, presumably oxygen, causes a large amount of the fluctuation. Extreme degassing of the tube and the addition of a getter markedly decreased the fluctuations. (3) The role of gas in the tube seems to be one of increasing the work function of the tungsten wire. This conclusion is based on the observation that removal of the fluctuations is accompanied by an increased total emission.

If space charge neutralization by random positive ions caused the fluctuations, removal of the ions by improved vacua should cause a decrease in the total electron current.

47. The Mechanism of Electron Space Charge Neutralization by Positive Ions. H. KARR AND R. N. VARNEY, *Washington University.*—One of the early theories proposed by Kingdon to explain the powerful neutralizing effect of positive ions on an electron space charge was that the positive ions spiraled for a long time around the fine filament before being drawn in to it. Subsequent investigations also by Kingdon showed that positive ions might also be trapped in a potential trough which was formed by the thermal emission of electrons from the filament, and that this mechanism could account for the effective space charge neutralization. We have established this second explanation rather directly by using an oxide-coated cathode of large diameter in place of the customary filament so that positive ions could no longer spiral around the cathode without hitting it. This device has proved to be quite as sensitive to positive ions as the filament type of apparatus. Qualitative measurements at present indicate that at least 50,000 electrons are liberated per positive ion formed. Hence the trapping rather than the spiraling of the positive ions seems necessarily to be the explanation of the effects observed.

48. Effect of Thermal Environment on Electrical Properties of Arcs. C. G. SUITS, *General Electric Company.*—The steady-state voltage gradient E for an arc confined between flat insulating plates increases sharply for decreasing plate separation, when the separation is less than the arc diameter determined from photographic data. A similar effect is observed when an arc is struck in a granular insulating medium, as, for example, quartz sand, where E rises to very high values compared to an arc in free convection. To observe the effect of the cooling medium on the transient arc properties the current is suddenly reduced to zero for an adjustable interval, following which voltage (1500 volts d.c.) is reapplied to the electrodes. The minimum time interval (recovery time) which allows the gap to establish insulating strength is observed. For an arc between flat plates the recovery time decreases to a minimum, then increases as plate separation is decreased. The recovery time measured for an arc in free convection where the heat loss is only to the electrodes and the ambient air depends upon the electrode size and separation. As the electrode separation is increased, the recovery time goes through a sharp minimum, then a maximum, followed by a decrease to zero at the maximum electrode separation for maintaining the arc. Applying this result to the simplest d.c. interrupting device, i.e., separating contacts, a current zero can be imposed by shunting a charged condenser across the arc at the moment of most favorable separation. Compared to the conventional means of suppressing a d.c. arc with a condenser permanently shunted across the contacts, the new method permits a ten times improvement in interrupting ability with the same value of capacitance.

49. Influence of a Longitudinal Magnetic Field on a Low Pressure Arc. C. S. CUMMINGS AND L. TONKS, *General Electric Company.*—This problem has, apparently, never been investigated experimentally, although a theoretical treatment[1] has been published. A cylindrical mercury arc tube, of 4.6 cm internal diameter and 62 cm long between the open end of the Hull type segmented cathode and the graphite anode, and equipped with probes, was placed in a uniform longitudinal magnetic field. All quantitative tests were carried out at 4 amp. arc current and 7 bars Hg pressure. The presence of a magnetic field of 50 oersteds broke the discharge into two distinct portions at a point about 30 cm from the cathode. Lowering the vapor pressure increased this distance, but changing arc current or field strength did not affect it. On the anode side of the transition point the arc filled the whole tube, but was more concentrated toward the axis than in zero field. Toward the cathode the arc did not fill the tube, but retained the diameter of the cathode and showed its cell structure. Redistribution of current density at the cathode persisted into the anode portion of the arc. No evidence of a constrictive effect such as has often been presumed to exist was found, but strong transmission effects occur. Probe methods failed in the higher fields, so that the measurements could only give semi-quantitative confirmation of the theoretical changes expected in the magnetic field.

[1] L. Tonks, Phys. Rev. 56, 360 (1939).

50. Acceleration and Average Cross Drift of Electrons in a Magnetic Field. C. G. SMITH, *Raytheon Manufacturing Company.*—Considerations of momentum lead to expressions for the average drift of an electron across a magnetic field when there is an acceleration normal to the field. The well-known drift in the case of uniform electric and magnetic fields is calculated. The method is applied to calculate the circular component of current in a cylindrical plasma in which a radial electrical field exists, the plasma being in a uniform longitudinal magnetic field. Application of the method is made to evaluate an axial drift of electrons in a magnetic field whose lines are circles about a given axis, the electron meantime being acted upon by a driving e.m.f. giving it an acceleration parallel to the magnetic lines.

51. The Electromotive Force of Saturated Weston Standard Cells Containing D_2O. LANGHORNE H. BRICKWEDDE AND GEORGE W. VINAL, *National Bureau of Standards.* (*Introduced by E. C. Crittenden.*)—Weston saturated standard cells (Hg, Hg_2SO_4, $CdSO_4$, 8/3 water, satd. $CdSO_4$ soln., satd. Cd amalgam) have been made with water containing up to 98 mole percent D_2O. The e.m.f. was found to decrease with increasing D_2O content. The temperature coefficient between 17° and 28°C is independent of the D_2O content. The cells are of the H type and of about the same size as the N.B.S. standards of e.m.f. The hydrated $CdSO_4$ crystals for each group were prepared in contact with the solution used in the cells of that group. The electrolytes were $0.03N$ in H_2SO_4.

Mole % D_2O	Number of Cells	E.M.F. at 28°C international volts	$\Delta E/\%\ D_2O$ micro-volts/%
0	5	1.017890	—
6	3	867	3.8
50	3	717	3.5
79	3	588	3.8
98	3	502	4.0

The solubility of cadmium sulphate (moles $CdSO_4$ per mole water) in H_2O-D_2O mixtures containing from 0 to 98 mole percent D_2O decreases linearly with increase of the D_2O content. Extrapolating to 100 percent D_2O, the solubility of $CdSO_4$ is 8.4 percent less in D_2O than in H_2O at 24°C. Within experimental error the D_2O-solubility relation was found to be independent of temperature from 0° to 52°C.

52. A Lock-in Amplifier for Alternating-Current Measurements. Walter C. Michels and Norma L. Curtis, *Bryn Mawr College.*—A new modification of the bridge detector developed by Cosens[1] has been built with two important changes from the original design. The triodes are replaced by pentodes with a steady potential on the plates and with the locking-in voltage applied to the screen, and the rectification is accomplished by the use of vacuum thermocouples in the plate circuits. The circuit retains the sharp frequency selectivity of the Cosens detector but possesses two advantages, since a relatively low powered oscillator may be used to supply the screen voltage and the operation on the linear portion of the transfer characteristic enables an analysis of the circuit to be carried out.

[1] Cosens, Proc. Phys. Soc. London **46**, 818 (1934).

53. An Electrical Memory System for Rapid Null Measurements. Edward P. Bentley, *Massachusetts Institute of Technology.*—Rapid electrical comparisons in time can be made accurately and automatically with a simple and inexpensive null method "memory" circuit that combines the stability of an a.c. amplifier with the rapid time response of a d.c. amplifier. A high-gain resistance-coupled amplifier is used, with tubes one-two, three-four, and five-six directly coupled. Tubes two-three and four-five are condenser-resistance coupled, with the grid resistors replaced by commutators. These close once each cycle while an unknown voltage is supplied to the amplifier. Since the grids of tubes three and five are grounded, the outputs of the previous tubes are impressed across the coupling condensers. When the commutators are opened, the condensers hold their charges while a series of comparison voltages is observed. When the comparison voltage equals the unknown voltage, the grids of tubes three and five are once more at ground potential. A trigger circuit fed by the output from tube six trips when the grid of tube five reaches ground potential, thus indicating the match point.

54. An Extended Wave-Length Spectrum of Oscillations in a Triode with Positive Grid. Ronold King, *Harvard University.*—Barkhausen-Kurz oscillations have been investigated[1, 2] using a coupled-circuit model in which a cloud of electrons moving periodically through the grid at a frequency determined by the potential gradient serves as a primary, while the electrodes and the attached circuit constitute a secondary. Experimental curves of generated wave-length as a secondary (parallel line) is lengthened comprise *B* ranges in which the wave-length is characteristic of the secondary, and *A* ranges in which it is practically constant. Using a 100-watt triode (RK-38) a more complete wave-length spectrum has been obtained. At low grid voltages (25–75 volts) and zero plate voltage conventional curves are obtained as the secondary is lengthened. For higher grid potentials (75–125 volts) the *A* ranges disappear leaving overlapping *B* ranges. At still higher voltages (125–175 volts) overlapping *A* and *B* ranges following two and three branches of the theoretical curves appear. Three nonharmonic frequencies are generated simultaneously in a way hardly to be described as an anomaly due to asymmetries as suggested by Hollmann for a slight overlapping of conventional curves.[3] While justifying the use of a characteristic primary frequency in a manner surpassing earlier results, the new curves suggest that a model involving three separate clouds of electrons is physically unreasonable. This is further indicated by the simultaneous observation under certain conditions of two primary frequencies of which each responds to the secondary as described above.

[1] Max Dick, *Die Grundschwingung der Raumladeschwingungen im elektrischen Bremsfeld* (Springer, 1936).

[2] R. Wundt, Zeits. f. Hochfrequenztechn., Vol. 36, p. 133.

[3] H. E. Hollmann, *Physik u. Technik der ultrakurzen Wellen* (Springer, 1936), Vol. 1, p. 127.

55. Investigation of Dynatron Hysteresis at Low Frequencies. Paul L. Copeland and J. M. Kubert, *Armour Institute of Technology.*—In cathode-ray oscillographic studies of plate current *vs.* plate potential curves of electron tubes operated from potential sources varying cyclically at frequencies lying within the range of 26 to 600 cycles per second, J. M. Hollywood[1] observed hysteresis loops in the portions of these curves which were dominated by secondary emission. The phenomenon was explained by Copeland and Hollywood on the basis of field inhibited and field assisted secondary emission of electrons from charged layers on the plate surface. The present report concerns work with a mechanical contactor (somewhat like that of Joubert[2] by means of which the observations were extended to lower frequencies than those covered by Hollywood.

[1] J. M. Hollywood, Master's Thesis in the Department of Electrical Engineering, M. I. T. (1932).

[2] J. Joubert, J. de phys. **9**, 297 (1880).

56. Thermistors, Their Characteristics and Uses. G. L. Pearson, *Bell Telephone Laboratories.*—Thermistor is a contraction of the words "thermal resistor" and designates an electrical resistance whose value is markedly dependent on its temperature. Thermistors having a large negative temperature coefficient of resistance can be made from any of a large class of substances known as semi-conductors. Those materials which have been found most useful for this purpose are metallic oxides. Both directly and indirectly heated thermistors have been constructed. The former type consists of a semi-conducting body and two metal leads while the latter has in addition a heating coil which is electrically insulated from the semi-conductor but in good thermal contact with it. The electrical and thermal characteristics of the Western Electric 1A directly heated thermistor as well as those of an indirectly heated unit are presented. An analysis of these characteristics suggests several uses for thermistors, some of which are: a sensitive temperature or power measuring device, a temperature compensating device for electrical circuits, a thermally operated rheostat with no moving parts, a voltage regulator, a low frequency oscillator, a time delay device, and any of a large number of measuring devices dependent on the flow of thermal energy from a hot body.

57. On Some Points of the Bose-Einstein Condensation. LOUIS GOLDSTEIN, *New York University, Washington Square College.* (*Introduced by Eugene Feenberg.*)—The condensation of ideal Bose-Einstein, B-E, gases is restricted to systems whose phase space has cells of dimensions h^3, h being Planck's constant. A linear chain of atoms or a two-dimensional B-E fluid does not show any quantum condensation effect. External conservative fields of force influence in different ways the condensation temperature T_0. If the field destroys the uniform distribution of the gas in coordinate space then T_0 changes, following the characteristic properties of the field's potential brought into connection with the linear dimensions of the vessel containing the gas. If the field is uniform and changes the potential or internal energy of each atom by the same amount, T_0 remains independent of the field; e.g., an ideal diamagnetic (dielectric) B-E gas placed in uniform magnetic (electric) fields. When the uniform field changes the internal energy of the atoms by different amounts (splitting of the fundamental energy level, the excited states of the atom being left out of account) T_0 cannot but increase and tend asymptotically, for saturating fields, toward $s^{2/3}T_0$, s being the number of levels into which the ground state is split by the field; e.g., an ideal paramagnetic B-E gas in uniform magnetic fields.

58. On the Charge Distribution of Elementary Particles. V. F. WEISSKOPF, *University of Rochester.*—As shown by the author[1] the following function can be calculated by means of the quantum theory of elementary particles:

$$G(x)=\int\rho(r-x/2)\rho(r+x/2)dr.$$

Here $\rho(x)$ is the charge density at the point r. $G(x)$, for a single particle, represents the charge distribution in the particle itself. For particles with half-integral spin $G(x)$ is $\sim 1/x^2$ for $x\ll h/mc$, whereas for a particle with spin zero or one (meson) $G(x)\sim 1/x^4$ for $x\ll h/mc$. The latter $G(x)$ does not lead to a finite value for the integral $\int G(x)dx$. This seems to be a serious objection to the use of the present formalism of the quantum theory of particles for integral spin. It is essential that the theory of a free particle alone is used in this calculation, so that the result is independent of the form of the interaction energy with the electromagnetic or with other fields. This strong singularity of $G(x)$ is produced by correlations between the charge density fluctuations of the particle and of the vacuum, and is connected with the fact that the particles obey Bose statistics.

[1] V. F. Weisskopf, Phys. Rev. **56**, 72 (1939).

59. Effect of Nuclear Motion on the Energy of the Ground State of H_2^+. VIVIAN JOHNSON, *Purdue University.*—In calculations of the energy levels of H_2^+ (the two-center problem), the internuclear distance R is generally considered to be constant. This introduces some error because the nuclei are in motion about the center of gravity of the system, and thus the value of R fluctuates about a mean value. Van Vleck[1] has developed a method for calculating the energy correction due to this cause. In order to apply this method, it is necessary to find the wave functions expressed explicitly in terms of R. The Schrödinger equation for the two-center problem is separable in elliptical coordinates, ξ, η, and φ, and the ground state wave function is given by $(1/\sqrt{2\pi})X(\xi)Y(\eta)$. $Y(\eta)$ is found explicitly by following the methods of Hylleraas[2] and Sandeman;[3] and $X(\xi)$ is evaluated by use of the methods of Jaffe[4] and Chakravarty.[5] This explicit ground state wave function is then used in obtaining an estimate of the energy correction described above.

[1] J. H. Van Vleck, J. Chem. Phys. **4**, 327 (1936).
[2] E. A. Hylleraas, Zeits. f. Physik **71**, 739 (1931).
[3] I. Sandeman, Proc. Roy. Soc. Edinburgh **55**, 72 (1935).
[4] Geo. Jaffe, Zeits. f. Physik **87**, 535 (1934).
[5] S. K. Chakravarty, Phil. Mag. **28**, 423 (1939).

60. Van der Waals Energies. J. BARDEEN, *University of Minnesota.*—An approximate value for the van der Waals energy between two systems A and B is obtained by calculating the energy of system B in the field of system A, supposing that the electrons of system A are in fixed positions. The result is then averaged over the coordinates of the electrons of A. Let the van der Waals energy so derived be called W_A. Systems A and B may be reversed in the above calculation and an energy W_B found. The true van der Waals energy is given roughly by $W_AW_B/(W_A+W_B)$. The method is applied to the calculation of the van der Waals energy between a harmonic oscillator and a metallic surface.[1] If system A is the oscillator, the energy W_A is that found by the image method.[2] The calculation of the energy W_B is more difficult and leads to an integral involving the probability density for pairs of electrons in the metal. When evaluated for a free electron model which should be approximately valid for the monovalent metals, it is found that W_B differs from W_A by a factor $\sim 1.3e^2/r_sh\nu$, where r_s is the radius of a sphere whose volume is equal to the volume occupied per electron and ν is the frequency of the oscillator. If this factor is large, the van der Waals energy will be given approximately by the image value, W_A, while if it is small, the energy will be closer to W_B.

[1] Pollard and Margenau, Bull. Am. Phys. Soc. **15**, No. 1, p. 9 (1940).
[2] Lennard-Jones, Trans. Faraday Soc. **28**, 334 (1932). Due to an error, the value given here is too large by a factor of two.

61. Van der Waals Interaction of Metals and Molecules. E. J. R. PROSEN, R. G. SACHS AND E. TELLER, *The George Washington University.*—Lennard-Jones[1] has assumed that the van der Waals interaction of a molecule with a metal surface can be obtained by averaging the potential of the image force over the unperturbed proper function of the molecule. This gives an r^{-3} dependence of the interaction on the distance of the molecule from the surface. Straightforward application of second order perturbation theory leads, on the other hand, to an r^{-1} dependence if a free electron gas is assumed in the metal, and to r^{-2} for a degenerate Fermi gas. Lennard-Jones' treatment assumes a parametric dependence of the metal proper function on the position of the electrons in the molecule and neglects differentiation with regard to the parameter. The second-order perturbation method disregards the interaction of metal electrons. With the help of the variation principle, it can be shown that Lennard-Jones' procedure is justified for great distances r and high electron densities in the metal, while second-order perturbation theory gives correct results only for small distances and low electron densities. Lennard-Jones' formula also gives an upper limit for the long distance interaction of a molecule with any solid surface.

[1] Lennard-Jones, Trans. Faraday Soc. **28**, 334 (1932).

62. Self-Diffusion in Polycrystalline Zinc. P. H. MILLER, JR., *University of Pennsylvania*, AND HARRY DAY, *General Electric Company*.—Six polycrystalline samples of zinc were prepared so that there was no reorientation or growth of the individual crystals when they were heat treated at 383.5°C for 5 hours to permit appreciable diffusion to take place. A thin layer of radioactive Zn^{65} (half-life 8 months) was electroplated on one accurately plane end of the crystal sample which was a cylinder. After heat treating the crystal was cut into two-mil sections and the activity of each section measured. The activity of the sections lay on the curve corresponding to Fick's law with the exception of the first, and the deviation of this first point permits the calculation of the percent of surface atoms not diffusing. The diffusion coefficients, D, are:

CRYSTAL	D	% ATOMS NOT DIFFUSING
I	$4.18 \pm .13 \times 10^{-4}$ cm² deg⁻¹	47.7%
II	$4.79 \pm .21$	5.3
III	$5.49 \pm .13$	4.5
IV	$6.14 \pm .18$	2.7
V	$5.65 \pm .05$]	6.2
VI	$5.73 \pm .11$	3.9

The probable error is the least square error in the slope $(1/4Dt)$ of the straight line in the $\log_e c$ *vs.* x^2 plot. The difference in the values of D arises from the random orientation of the small crystals, and on the assumption that there are 15 crystals on the end of each cylindrical sample the difference in diffusion constant along the a and c axes is calculated to be about 30 percent. This means only a very small difference in the activation energy.

63. The Measurement of Self-Diffusion in Metallic Zinc. FLOYD R. BANKS,* *Morgan State College*, AND HARRY DAY, *General Electric Company*.—The coefficient of self-diffusion in single crystals of metallic zinc has been measured at four temperatures near the melting point. A thin deposit of radioactive Zn^{65} (half-life eight months), obtained from Cu^{65} by proton bombardment, is electrolytically deposited on a flat, polished, and etched surface of a single crystal of ordinary inactive Zn. The sample is then held at an elevated temperature for a fixed time to allow the Zn^{65} to diffuse into the crystal. After diffusion the impregnated crystal is cut into sections on a lathe. The sections are cut parallel to the original face of the crystal and are approximately two-thousandths of an inch thick. The thickness of each section is accurately determined by weighing the section and computing the thickness from the known density of Zn, and the measured diameter of the face from which the sections are cut. The activity of each section taken from the sample is measured by means of a Geiger counter. From the measured activity and thickness the concentration of each section is calculated and the diffusion coefficient D obtained. The following values for the diffusion coefficient parallel to the hexagonal axis have been obtained:

$D = 9.84 \times 10^{-4}$ cm²/day at $T = 410.4$°C
$D = 7.44 \times 10^{-4}$ cm²/day at $T = 400$°C
$D = 4.39 \times 10^{-4}$ cm²/day at $T = 374.4$°C
$D = 3.84 \times 10^{-4}$ cm²/day at $T = 364.7$°C

The value for the activation energy Q for the diffusion process (obtained from the plot of D against $1/T$°A) is 17,600 cal./mol.

* The work reported here was carried out at the University of Pennsylvania.

64. Changes of State of Monolayers on Water. EDWARD BOYD AND WILLIAM D. HARKINS, *University of Chicago*.—If a gaseous film of pentadecylic acid on water is compressed at a temperature between 18° and 40° (or somewhat higher) it passes through the following phases: I, gas, G, which condenses by a change of the first order to II, liquid expanded, L_1, whose π, σ relation is almost an equilateral hyperbola. This changes by what appears to be an anomalous or diffuse first order change to III, intermediate phase, I, in the (a) transition region, T, which has an extremely large compressibility. This changes, without any perceptible kink into IIIb, liquid condensed film, L_2, with a linear π, σ relation and low compressibility. On further increase of pressure this liquid film freezes by a change of the second order to IV, solid, with very low compressibility. In the L_2 region the viscosity (η) of the film follows the relation: $\text{Log}\,\eta = \log \eta_0 + k\pi$. An extensive study in this laboratory of the areas at which changes of state occur is not in accord with the ideas of Dervichian[1] and of Rideal. For example the maximum area covered by L_2 does *not* correspond to spherical molecules in contact and the areas at which changes occur in condensed states do *not* correspond exactly to areas in the three dimensional solid as determined by molecular tilt. π = film pressure, σ = area, and σ_m = molar area.

[1] Dervichian, J. Chem. Phys. **7**, 931 (1939).

65. Energy and Entropy of Extension and Spreading of Monolayers. WILLIAM D. HARKINS, T. FRASER YOUNG, AND EDWARD BOYD, *University of Chicago*.—The thermodynamic relations concerning the expansion or contraction of monolayers have been unknown, but may be obtained from:

$$h = (\partial H/\partial\sigma)_T = -\left[\frac{\partial(\pi/T)}{(1/T)}\right]_\sigma \tag{1}$$

$$s = (\partial S/\partial\sigma)_T = (\partial\pi/\partial T)_\sigma, \tag{2}$$

$$\Delta H_m = \int_{\sigma m_1}^{\sigma m_2} (\partial H/\partial\sigma)_T d\sigma_m, \tag{3}$$

$$q = Ts = h + \pi, \tag{4}$$

$$Q_m = T\int_{m_1}^{\sigma m_2} (\partial S/\partial\sigma)_T d\sigma_m = \Delta H_m + \int_{\sigma m_1}^{\sigma m_2} \pi d\sigma. \tag{5}$$

H = enthalpy: S = entropy: q = heat absorbed: small letters indicate values for unit area, and subscript m, values per mole. The following processes are considered, with numerical illustrations in erg cm^{-2}: A, extension of surface of pure water, $h = 116$; B, extension of film, h (pentadecylic acid) is 367 for the transition film and 161 for the expanded liquid film; and $C = B - A$, spreading, $h = 250$ for the transition film and 45 for the expanded film, at 22 and 18°C, respectively, and $\sigma = 38\text{A}^2$ per molecule. In spreading the film spreads over a clean water surface, in extension the area of the water does not change. Allow a film to spread from solid to gas. The numerical values give ΔH_m for pentadecylic acid at 18° from lowest to highest area for the phase: solid, ΔH_m = small; phase change solid-liquid, $\Delta H_m = 0$, therefore fusion is a second order change; liquid condensed, ΔH_m small; transition film, $\Delta H_m = 8000$ ($Q_m = \Delta H_m + 73$) cal. mole^{-1}, and expanded liquid, ΔH small, ΔH_m, vaporization, several thousand calories. At higher temperatures ΔH_m decreases for the transition film, but increases for the expanded liquid.

66. Specific Heats of Nickel-Copper and Nickel-Iron Alloys from 1.1 to 20.4°K. W. H. KEESOM, *Kamerlingh Onnes Laboratorium, Leiden,* AND B. KURRELMEYER, *Brooklyn College.*—The specific heats of four nickel-copper and three nickel-iron alloys have been measured in the temperature ranges obtainable with liquid helium and with liquid and solid hydrogen. Over most of this range the results for each alloy can be expressed in the form $C_v = \gamma T + bT^3$. The constants γ and b and the Debye temperatures Θ derived from b are tabulated in Table I for the alloys, and the values given in the literature for Cu, Ni, Co, and Fe are also included. The results are discussed in connection with the electronic energy band calculations of Slater for nickel.

TABLE I.

METAL	ATOMIC PERCENTAGE NICKEL	γ cal./mole deg.^{2}	b cal./mole deg.^{4}	Θ °K
Cu – Ni	81.61	1.58×10^{-3}	8.11×10^{-6}	386
Cu – Ni	61.97	1.52	9.74	363
Cu – Ni	42.07	1.66	8.23	384
Cu – Ni	21.58	0.457	12.28	335
Fe – Ni	84.47	1.16	6.80	409
Fe – Ni	79.65	1.08	6.88	407
Fe – Ni	47.50	1.21	10.16	358
Nickel	—	1.74	6.60	413
Copper	—	0.178	12.90	330
Iron	—	1.20	4.70	462
Cobalt	—	1.20	5.36	443

67. Thermal Conductivity of Metals. C. C. BIDWELL, *Lehigh University.*—As indicated in a previous paper elementary classical considerations suggested a relation between thermal conductivity k, atomic heat C, density ρ, and absolute temperature T of the form $k/C\rho = K/T + K_0$. The first term on the right appeared to contain the velocity of the elastic waves in the crystal lattice and therefore involved the temperature. K_0 applied to atomic collisions and did not involve temperature. The considerations suggested that the intercept was the value of $k/C\rho$ for the molten condition. Whether the theoretical considerations stand or not, data on lead, tin and zinc show that the equation holds for these metals and that the intercept predicts the value of $k/C\rho$ for the molten state. New data on lead are presented and a modification of the experimental method described.

68. *p*H Determinations on Sludge of Particulate Carbonaceous Materials and Ash Discharged in the Atmosphere by Fuel Burning Sources. S. BLOOMENTHAL, *University of Chicago,* AND I. DEUTCH, *Chicago Department of Smoke Inspection and Abatement.*—General recognition of the injurious effects of atmospheric pollution led to the present large scale study of its source. Slides of dust precipitated from flue gases of many types of industrial fuel burning plants in Chicago during a quantitative determination of dust loading will be projected and discussed. It is suggested for the first time that *p*H measurements on sludge of dust and ash may aid in "fingerprinting" the source. The following determinations were made with a vacuum tube potentiometer amplifier using a glass electrode and correlations obtained:

1. *p*H of the sludge of precipitated dust and its ash.
2. *p*H of the sludge of dust and ash from dust collectors.
3. *p*H of the sludge of ash of the coal used in the test.
4. *p*H of the sludge of settled dust and its ash, collected by a complainant.

Ash sludge from Pocahontas coal gives a *p*H of 9.4 in contrast with a value of *p*H equal to 11.6 obtained for ash sludge from Franklin County, Illinois coal.

69. Square Wave Analysis of Linear Pulse Amplifiers. R. D. HUNTOON, *New York University.*—The frequency analysis of a linear amplifier made by E. A. Johnson and A. G. Johnson[1] shows that it is of advantage to use a relatively narrow band amplifier in counting pulses. The argument is based, however, upon an ideal amplifier with zero phase distortion and a sharp frequency cut-off at each end of the band, conditions not realized in the usual amplifier. The very simple nature of the pulse impressed upon the grid of the input tube lends itself nicely to analysis by the square wave method.[2,3] This method uses the response of the *actual amplifier* to a square wave as the basis for calculation. The results of such an analysis agree qualitatively with the results of the frequency method using an ideal amplifier. The square wave method has an additional advantage. Curves which are easily obtained from a cathode-ray oscilloscope can be quickly analyzed by a simple graphical treatment to indicate the proper selection of circuit parameters and ion collection time to operate the amplifier at maximum efficiency with a given chamber. A simple square wave generator will be described and the method of interpretation of the curves outlined.

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[1] E. A. Johnson and A. G. Johnson, Phys. Rev. **50**, 170 (1936).
[2] Gilbert Swift, Communications, 19 (1939).
[3] A. V. Bedford and G. L. Fredendahle, Proc. I.R.E. 25 (1939).

70. Use of Interval Selection in Measuring Short Decay Constants. ARTHUR ROBERTS, *Massachusetts Institute of Technology.*—The use of interval selection methods for the measurement of short ($10^{-7}-1$ sec.) daughter half-periods has been analyzed. Two types of interval selection have been compared. The single distribution interval selector[1,2] is best suited for cases in which parent and daughter radiations are indistinguishable (α–α, β–β, γ–γ sequences), the coincidence interval selector[3–5] when parent and daughter radiations are distinguishable (α–β, α–γ, β–α, β–γ, γ–α, γ–β sequences). The latter possesses the advantages of (1) extension to shorter half-periods than the single distribution interval selector, (2) ability to determine the sequence of emission of radiations. It cannot be used for the analysis of single pulse distributions. Equations, containing only observable quantities, for the determination of half-periods by the use of both types of interval selector have been developed which replace previous approximate,[3] incorrect,[6] or more cumbersome[7] equations. The relative sensitivity[8] of the two methods has been determined.

[1] Roberts, Bull. Am. Phys. Soc. **15**, No. 1, 16 (1940).
[2] Driscoll, Hodge and Ruark, Rev. Sci. Inst. in publication.
[3] Dunworth, Nature **144**, 152 (1939).
[4] Rotblat, Nature **144**, 248 (1939).
[5] Montgomery, Ramsey, Cowie, and Montgomery, Phys. Rev. **56**, 640 (1939).
[6] Ruark, Phys. Rev. **56**, 1165 (1939).
[7] Devol and Ruark, Phys. Rev. **51**, 710 (1937).
[8] Evans and Mugele, Rev. Sci. Inst. **7**, 441 (1936).

71. A Hard Vacuum Tube Pulse Equalizing, Sharpening Circuit. L. J. STROHMEYER AND R. D. HUNTOON, *New York University.*—A single stage hard vacuum tube scale-of-two circuit[1,2] has been modified so as to produce sharp pulses whose amplitude and width are independent of the wave form of the input signal. Input pulses having a width of 100 sec. to 10^{-4} sec. work equally well and a change in bias permits operation with either positive or negative input pulses. Since the input pulses are essentially the same as the interstage pulses in a conventional scaling circuit, this circuit may be used as an input sharpener-equalizer for Lifschutz-Lawson or Reich counting circuits. The tripping level may be chosen at will and when once set it will remain constant over an extended period of operation, making the sharpener useful as a pulse discriminator.

[1] H. Lifschutz and J. L. Lawson, Rev. Sci. Inst. **9**, 83 (1938).
[2] H. J. Reich, Rev. Sci. Inst. **9**, 222 (1938).

72. Starting Potentials of Geiger-Müller Counters in Oxygen-Nitrogen Mixtures. ROBERT D. HEIDENREICH, *Case School of Applied Science.* (*Introduced by R. S. Shankland.*)—The starting potentials of two Geiger-Müller counters with cathodes of copper and chromium, respectively, have been observed using a Johnson[1] control circuit with a scale-of-16 dividing circuit and a Cenco recorder. The starting potentials are shown to increase linearly with the gas pressure in the mixtures employed over the pressure range of 160 to 40 mm of Hg. C. L. Haines[2] has found that there is in general a deviation from linearity at lower pressures for the gases he studied. The data indicate that the starting characteristics are practically independent of the cathode materials employed and that there are apparently two main effects of oxygen upon the behavior. First, a surface effect at the central wire anode and, second, a volume effect. At small concentrations of oxygen the two effects are quite distinct, but at higher concentrations the volume effect predominates. There is evidence that the surface conditions at the central wire are important in determining the characteristics of air filled counters.

[1] T. L. Johnson, Rev. Sci. Inst. **9**, 218 (1938).
[2] C. L. Haines, Rev. Sci. Inst. **7**, 411 (1936).

73. Threshold Potentials for Discharge Counters. ARTHUR F. KIP AND SANBORN C. BROWN, *Massachusetts Institute of Technology.*—The Werner equation for threshold voltage of GM counters was found to fail for the coaxial cylinder counters studied by Brown and Evans.[1] Although Werner's general statement of the threshold criteria, which is in essence that of Townsend, is correct, the approximations as used in his equation are shown to amount to empirical fitting of the data for GM counters, and since they lack generality are not to be expected to apply to other geometries. Calculations based on the minimum size of the initial electron avalanche necessary for onset of the corona process indicate that the initiatory avalanches of both GM and coaxial cylinder counters are of the same order of magnitude. The calculations agree with previously published results of point-to-plane discharge studies.[2] The point of view established shows the essential similarity of the initiatory process in all counters having non-uniform fields.

[1] S. C. Brown and R. D. Evans, Phys. Rev. **53**, 914(A) (1938).
[2] L. B. Loeb and A. F. Kip, J. App. Phys. **10**, 142 (1939).

74. The Starting Mechanism of Discharge Counters. SANBORN C. BROWN AND ARTHUR F. KIP, *Massachusetts Institute of Technology.*—The operation of GM counters is empirically predicted by the Werner equation, but it fails to predict the observed behavior of coaxial cylinder counters at low pressure.[1] A hypothesis is advanced, based on the pressure dependence of the photoelectron yield at the cathode, which predicts the behavior of both kinds of counters. The conditions under which GM and coaxial cylinder counters operate lead to similar values for n and γ at threshold, where n is the number of secondary photoelectrons produced at the cathode surface per electron in the avalanche. It can be shown from the work of Posin[2] that γ increases as the pressure decreases, for constant n. The restriction to pressures below 1 cm on coaxial cylinder counters is thus a necessary condition for a sufficient production of photoelectrons at the cathode by the initiating avalanche. Such low pressures are not necessary in a GM counter because of the larger number of photons produced in the first avalanche, due to the exceedingly high fields near the center wire. Experimental studies on the consequences of varying the photoelectric efficiency of the cathode surface are in agreement with predictions based on this point of view.

[1] See preceding abstract.
[2] D. Q. Posin, Phys. Rev. **50**, 650 (1936).

75. A Technique for Counting High Energy Protons in the Presence of Fast Neutrons. J. A. VAN ALLEN* AND N. F. RAMSEY, JR.,* *Department of Terrestrial Magnetism,* *Carnegie Institution of Washington.*—For the purpose of observing the angular distribution of protons ejected from a thin paraffin film by 13 Mev neutrons from the Li (d,n) reaction, we have developed a set of three proportional counters in triple coincidence. Following a suggestion of Bonner and Breit the counters are separated by a foil of approximately one cm stopping power sufficient to prevent neutron recoils which originate in the walls or gas of one counter from reaching another. The technique has been successfully used in obtaining the energy distribution of protons recoiling in the forward direction from lithium neutrons. The necessary geometric and intensity improvements are now being made in order to resolve the two high energy groups of recoil protons at angles of 30° to 45° and hence to make possible the angular distribution measurements. Preliminary indications are that this will be feasible.

* Carnegie Institution Fellow.

76. A Large Cloud Chamber. C. C. Jones, D. A. McGraw, T. E. Pardue, Arthur Ruark and Katherine Way, *University of North Carolina.*—A transmission type cloud chamber is described with a field of view approximately 6 feet by 1 foot and a depth of 10 inches parallel to the viewing direction.

77. A Cyclotron Ion Source with Retractable Filament. B. R. Curtis, *Harvard University.*—One of the chief objections to the use of ion sources in the cyclotron has been the short lifetime of the filaments. This difficulty has been surmounted by making it possible to change filaments without losing the vacuum, thus saving the loss of time entailed in obtaining a vacuum and in outgassing the vacuum system. This has been accomplished by an improved ion source design. During change of filaments the vacuum is maintained by means of a commercial gate valve. The stem of the valve is made vacuum-tight by a pressure grease joint, the faces of the gate not being altered. The filament is mounted at the end of a copper tube which can be inserted through the valve into a larger tube that supports the capillary. The faces of the valve do not leak sufficiently to be recorded on an ionization gauge. Preliminary adjustments of the ion source, with all other conditions the same and without feelers on the dees, have increased the beam current from a maximum of 22 microamperes of deuterons with 11 Mev energy, using the ordinary filament, to 35 microamperes using the ion source.

78. Automatic Tuning for the Cyclotron. E. M. Purcell, *Harvard University.*—The Harvard cyclotron has been equipped with a device which automatically maintains maximum beam current. A six-toothed aluminum vane spins at 3450 r.p.m. above the dee line, slightly modulating the frequency of this resonant line at 345 c.p.s. On the same shaft, outside the line enclosure, notched iron vanes rotating in slots milled in the core of a small transformer generate 40 volts at 345 cycles synchronous with the frequency modulation. When operating slightly off resonance a small 345-cycle component appears in the beam current, of amplitude proportional to the slope of the resonance peak at the instantaneous operating point. By using the synchronous voltage from the small "alternator," a simple two-tube circuit detects the phase and amplitude of the beam current modulation, and feeds into the vacuum-tube magnet voltage stabilizer a voltage of the proper sign to cause the necessary field correction. The tuner "takes hold" when the beam appears, quickly finds the maximum, and keeps the current very close to the maximum without further attention. With 15 microamperes beam current the beam is maintained despite an arbitrary adjustment which would ordinarily change the field/frequency ratio by one percent. The method makes current stabilization unnecessary.

79. The Production of Proton Beams. E. S. Lamar and W. W. Buechner, *Massachusetts Institute of Technology.*—Additional work has been done on proton sources of the general types previously described.[1,2] It is found that with the metal capillaries the total output current and the proton percentage are very erratic in their behavior, due presumably to changes in surface conditions on the walls surrounding the discharge. The average proton yield from these sources is about ten percent. Coating the surfaces with phosphorous pentoxide to reduce the recombination of atomic hydrogen on the walls increases the yield to about fifty percent. Pyrex sources on the other hand are extremely consistent in their behavior, the total "focusable" currents obtainable for a given geometry and a given arc current exceeding the averages for the metal capillaries by a factor of about three, and the proton percentages without water vapor being about fifty percent. With a 1.00 ampere arc operating in a 3.0-mm diameter Pyrex capillary, the "focusable" current obtainable from a 1.0-mm diameter outlet is 2.34 ma. The distinction between total and focusable current and the fraction of the total gas that is ionized will be discussed. A simple arrangement will be described by which the neutral gas entering the experimental tube may be reduced to ten percent of the gas represented by the ion beam itself.

[1] Lamar, Samson and Compton, Phys. Rev. **48**, 886 (1935).

[2] Lamar, Buechner and Compton, Phys. Rev. **51**, 936 (1937).

80. The Focusing of Proton Beams. W. W. Buechner and E. S. Lamar, *Massachusetts Institute of Technology.*—Considerable work has been done with the lens system formed by a simple cone and cylinders previously described.[1] Making use of the fact that traces of gas in the high vacuum region render the beam luminous, these beams have been studied photographically as a function of the various electrode potentials and of the arc variables. These same beams have been studied by electrical scanning, by using a collector with an inlet orifice 1.0 mm in diameter. The electrical method gives, in addition to the beam diameter, the distribution of current within the beam. The results of these two types of investigations will be presented as functions of electrode potentials and arc variables. The lens system investigated is free from spherical aberration so long as the total beam current is equal to or less than the "focusable" currents mentioned in the preceding abstract. With a total voltage of 21,000 volts, a parallel beam of hydrogen ions having a current of 1.0 ma has been focused into the high vacuum region through a tube $\frac{1}{8}''$ in diameter and 1 inch long located $3\frac{1}{4}$ inches from the source outlet. This simple lens system is particularly adaptable to proton sources of the low voltage capillary type.

[1] Lamar, Samson and Compton, Phys. Rev. **48**, 886 (1935).

81. Recombination of Ions from Gas Flames. G. R. Wait and O. W. Torreson, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The recombination coefficient of ions from a flame of illuminating gas was determined by Kennedy[1] who found a value of 6.4×10^{-10}. Hogg[2] estimated a value about 27 times this for large (Langevin) ions of the atmosphere. Owing to the considerable difference in these values, the coefficient of ions from a gas flame was redetermined. Ions from a flame were allowed to accumulate to high concentrations in a closed room after which the rate of diminution was measured. The diminution was found to follow the law: $-dN/dt=\alpha_N N^2$ where N represents the number of ions per unit volume. The value of α_N, the recombination coefficient, was found to diminish with time of burning of the gas. Extrapolated back to zero time and forward to 90 minutes after lighting the gas, the values were 1.5×10^{-8} and 6.4×10^{-10}, respectively. The average number of unit charges per ion reported by Kennedy was 4.5 while in the present investigation it was found to be unity. For equilibrium conditions, the ratio of uncharged to charged particles of one sign, originating in the burning gas, was about five. The number of negative ions exceeded the number of positive by about 15 percent.

[1] Proc. R. Irish Acad. **A33**, 58–74 (1916).
[2] Beit. Geophysik **41**, 32–55 (1934).

82. Negative Ion Formation in Iodine Vapor by Electron Impacts. Rolf Buchdahl, *Johns Hopkins University.*—With an apparatus similar to the one used by Lozier,[1] the negative ion formation in I_2 vapor was investigated as a function of the electron velocity (0–7 ev). The following reaction is responsible for negative ion formation at these velocities:[2] $I_2+e\rightarrow I^-+I$. Measurements of the kinetic energy of the ions for different electron energies show that all the ions are formed by the same reaction. The variation of the yield as a function of the velocity of the electrons can be understood with the help of a potential-curve diagram, by considering transitions from the ground state of the I_2 molecule to the ground state of the I_2^- molecule. The probability that an electron colliding with an I_2 molecule forms a negative ion varies between 10^{-4} and 10^{-3}. With the aid of an energy cycle one can calculate the electron affinity of the iodine atom, if one knows the dissociation energy of the neutral molecule, the kinetic energy of the incoming electron and the kinetic energy of the ions. The value of the electron affinity obtained by this method is $3.2\pm.2$ ev which is in agreement with other determinations.[3,4]

[1] Lozier, Phys. Rev. **46**, 268 (1934).
[2] Hogness and Harkness, Phys. Rev. **32**, 784 (1928).
[3] Sutton and Mayer, J. Chem. Phys. **3**, 20 (1935).
[4] Glockler and Calvin, J. Chem. Phys. **3**, 771 (1935).

83. Recombination and Electron Attachment in the F_2 Layer of the Ionosphere. Fred L. Mohler, *National Bureau of Standards.*—The conventional theory of the ionosphere is that electrons are produced by photo-ionization and disappear by pure recombination. Observations indicate, however, that electrons in the F_2 layer disappear also by negative ion formation so that the apparent recombination coefficient, α', decreases with the pressure. This would raise the F_2 level above the level where production of electrons is a maximum. Apparently F_2 is roughly 100 Km above this level in midsummer but much lower in the winter. If the ratio of negative ions to electrons, λ, is small F_2 will be at a pressure p such that $p/p_0=\alpha/\alpha'$ where p_0 is the pressure at which production of electrons is a maximum and α is the electronic recombination coefficient. In midsummer $p/p_0=1/20$ and $\alpha=2\times 10^{-12}$. A value of this magnitude has been predicted by theory. A seasonal variation of p/p_0 can be ascribed to a variation in λ for it is very sensitive to temperature. It is probable that p_0 is at the F_1 level and that both F levels arise from atomic oxygen ionization as has been suggested by Bradbury.[1]

[1] Bradbury, Terr. Mag. and Atmos. Elec. **43**, 55 (1938).

84. Electron Impact Study of O_2 with a Mass Spectrometer. John T. Tate and Homer D. Hagstrum, *University of Minnesota.*—An investigation of the O^+ ion products from the dissociation process $O_2\rightarrow O+O^+$ indicates strongly that the potential energy curve of the molecular ion to which transition takes place on electron impact possesses a maximum which lies 0.6 volt above the potential energy of the dissociation products. This conclusion is suggested by a study of the ion peak shape which indicates that the probability of formation of the ions of minimum kinetic energy (0.3 volt) is relatively large. Such could not be the case if the nature of the distribution in kinetic energy of the products were determined solely by the position of the potential energy curve relative to the Franck-Condon region. The existence of a potential energy curve which has a relatively high maximum (1.3 volts above the asymptote) has recently been suggested by Herzberg and Mundie to explain certain predissociation data on NO.[1] A study of the process $O\rightarrow O^++O^-$ again leads to the conclusion, drawn for similar processes in NO and CO,[2,3] that the O^- ion formed in electron impact processes may exist in an excited state which, in contradistinction to the normal state, is characterized by very weak binding of the additional electron. It will also be shown how the realization of the meaning of the ion peak shape has made it possible definitely to ascribe the second break in the ionization efficiency curve for ions of m/e value 16 to the onset of the ionization process yielding O_2^{++}.

[1] G. Herzberg and L. Mundie, J. Chem. Phys. **8**, 263 (1940).
[2] H. D. Hagstrum and J. T. Tate, Phys. Rev. **55**, 1136(A) (1939).
[3] H. D. Hagstrum and J. T. Tate, Phys. Rev. **57**, 561A (1940).

85. On the Thermal Activation of the Oxygen Molecule. Homer D. Hagstrum and John T. Tate, *University of Minnesota.*—In the course of the study of the oxygen molecule reported in the previous abstract it was found that the relative abundance of impurities containing oxygen depended upon the temperature of the filament. The effect was studied more carefully by investigating the dependence of the relative partial pressures of O_2 and the impurities CO, CO_2, and H_2O, determined with the spectrometer, upon the temperature of an auxiliary platinum filament placed in a bulb connected directly to the vacuum system of the mass spectrometer. The bulb and the entire vacuum system including filaments were baked out thoroughly (partial pressure of any impurity less than 3×10^{-7} mm of mercury). The pressure of O_2 was adjusted to about 10^{-4} mm. At a filament temperature of 1280°K the partial pressure of O_2 began to fall and at 1740°K it had dropped to 46 percent of its original value. The fall in the O_2 abundance was accompanied by rises in those of CO^+, CO_2^+, and H_2O^+. Evidence will be presented which makes it plausible that the process involved is one in which oxygen molecules condense on the hot platinum filament and evaporate in activated form, perhaps in the $^1\Delta$ or $^1\Sigma$ metastable states or both. These molecules possess sufficient activation energy to react with substances of low vapor pressure adhering to the glass walls of the bulb upon striking them. On allowing the process to continue the walls of the bulb "cleaned up" and the effect vanished. The dissociation of H_2 by a heated tungsten filament was also studied by this method and the temperature at which dissociation begins agrees with that found by Langmuir and Mackay.[1]

86. A Simple and Rugged Mass Spectrograph for Routine Analysis. WALKER BLEAKNEY AND CHARLES S. CUMMINGS, *Princeton University.*—In recent years a demand has been rising for a mass spectrograph of simple and rugged construction which could be used for routine analysis of chemical compounds or isotopic mixtures. An instrument has been built embodying these features. It can be baked at elevated temperatures while on the pumps, insuring a very good vacuum. In addition it is readily demountable. The whole instrument can be taken completely apart in ten minutes. All wax, rubber or grease joints have been eliminated by the use of copper or aluminum gaskets. The analyzer is of the 180° type with a slit separation of 15 cm. The ion source is recessed into a spherical cavity in the pole in such a way that the electrons are confined to a narrow beam by the magnetic field. The design gives high efficiency for collection of the ions. Differential pumping between ion source and analyzer may be applied. At present the instrument is being used with slit widths of 0.5 mm and 1.0 mm giving a theoretical resolving power of $m/\Delta m = 50$. In practice this limit is nearly reached. The performance indicates that with narrower slits the instrument will be useful up to mass 100 or higher.

87. Ionization of Methyl and Ethyl Alcohol by Electron Impact. CHARLES S. CUMMINGS AND WALKER BLEAKNEY, *Princeton University.*—The products of ionization by electron impact in methyl and ethyl alcohol have been studied with the new mass spectrograph described in another paper. The reactions involved in their formalton have been deduced for most of the ions found. In metihy alcohol ions corresponding to masses 12, 13, 14, 15, 16, 17, 28, 29, 30, 31 and 32 were detected. Their appearance potentials were respectively 22.6±0.2, 24.5±0.5, 15.4±0.5, 14.0±0.5, 14.1±0.3, 19.2±1.0, 13.8±0.2, 14.2±0.2, 12.4±0.1, 11.8±0.1, 10.8±0.2 volts. In ethyl alcohol ions corresponding to masses 12 through 17, 19, 24 through 32 and 40 through 46 were observed. More complete tables of relative abundances and appearance potentials will be shown. The evidence indicates that in the formation of mass 31 in methyl alcohol and masses 45 and 31 in ethyl alcohol the oxygen atom, due to the positive charge on the ion, becomes trivalent and forms a double bond with the carbon and a single bond with one of the hydrogens. This raises the dissociation energy of the ion and is in accord with the observed low appearance potentials. The appearance potentials indicate further that in almost all cases the reaction that produces an ion is the one that requires the least energy. All the observed ions were primary ions resulting from a single collision.

88. A New Mass Spectrograph Having Extremely High Dispersion and Resolving Power. E. B. JORDAN, *University of Illinois.*—During the past two and one-half years a new mass spectrograph having extremely high dispersion and resolving power and employing both velocity and direction focusing has been designed and constructed. The ions diverging from a second slit S_2 pass through a crossed electric and magnetic field analyzer having an effective length of 115 cm. The effect of this arrangement is to produce a velocity spectrum in front of a third slit S_3 which allows 0.2 percent of this spectrum to pass on and be focused upon a recording plate by means of a magnetic field. The mean angle of deflection of the ions in the magnetic field is $\pi/3$ radians. The mass spectrum thus produced has a mean dispersion of 14.6 mm for one percent mass difference. The performance of the instrument to date indicates that approximately all of the theoretical resolving power of 29,200 is attainable. The mass differences as obtained by taking the mean of the ratios of the doublet separation to the forward and backward dispersion line separations are accurate to 5 parts in 10^7 when expressed in mass spectra units. Furthermore, theory and experiment show that this relation holds true regardless of plate position within rather wide limits. Satisfactory spectra of the methane series have been obtained with exposure times of one minute. Sample spectra and the corresponding mass differences will be shown.

89. A Mass Spectrograph for Separation of Heavy Isotopes. K. H. KINGDON AND H. C. POLLOCK, *General Electric Company.*—An all-metal mass spectrograph of the Dempster type has been constructed. The analyzer is a copper tube of 3 cm internal diameter and 12.5 cm radius of curvature. It is fitted with removable metal headers at each end, the joints being made with lead gaskets, so that furnace, slits, and collectors can be removed and replaced in a few minutes. With 0.15 mm entrance slits and 0.2 mm

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[1] I. Langmuir and G. M. J. Mackay, J. Am. Chem. Soc. **36**, 1708 (1914).

exit slit the instrument resolves the Hg isotopes satisfactorily. We have also used it with 0.3 mm entrance slits to prepare samples of the separated U isotopes. 1.8 microgram of U^{238} was obtained in three hours' operation. For this purpose UCl_4 was evaporated from a nichrome $\overline{V}$ furnace which contained both the heater filament and a filament to ionize the vapor. The upper collimating slit was made part of the furnace to avoid condensation of UCl_4 on it. The magnet current is kept constant by using the cut-off of a magnetron in a series solenoid to regulate the generator field current through phase control of two FG-95 thyratrons.

90. A New Electron Microscope. L. Marton, *RCA Manufacturing Company, Inc.*—A magnetic electron microscope suitable for examination of biological and other specimens by transmission has been constructed at the RCA laboratories in Camden. The instrument incorporates many entirely new features, and utilizes some of the principles previously described by the author.[1] In order to take full advantage of the improvement in performance obtained by having the specimens very close to the objective lens, the "stage" carrying the specimens is introduced between the pole pieces of the objective coil. The "stage" can be moved both vertically and horizontally without reference to the alignment of the electron optical system. Furthermore, provision is made for cooling the specimen with liquid air or other refrigerant, when necessary. A coaxial arrangement of a light objective within the pole pieces of the objective coil permits simultaneous light and electron optical observation. Air locks are provided at the object and photographic chambers to facilitate changing plates and specimens. These are so designed that greased joints are unnecessary. Preliminary results show a resolving power considerably better than 100A.

[1] L. Marton, Bull. Acad. Belg., Bruxelles **20**, 439 (1934); **21**, 553 (1935); **21**, 606 (1935); **22**, 1336 (1936): Physica **3**, 959 (1936).

91. Design and Performance of an Electron Diffraction Camera. J. E. Ruedy, *RCA Manufacturing Company, Inc.*—An electron diffraction camera has been built for use in the study of photo- and secondary electron emissive surfaces. The electron beam is produced by a modified cathode-ray tube gun having an a.c. heated tungsten wire cathode, for which the focusing voltages are supplied by rectifiers. Beam velocities up to 40 kv are available. The maximum beam current, after reduction by a screening aperture, is about 0.1 μa, which is sufficient to make visible most patterns which can be photographed. When a picture is to be taken the beam is reduced until the exposure time is one or two seconds. The specimen adjustment mechanism and photographic shutter control are of new design and have proven themselves very satisfactory. A port directly above the specimen position is used to mount an electron gun for measuring the low voltage secondary emission ratio of the material being studied. The pumping system consists of a Megavac fore pump and a four-inch diameter, three-stage oil diffusion pump. The latter can be isolated and kept operating while the photographic plate or specimen is being changed in the diffraction chamber.

92. A Generalized Theory of the Concave Grating. H. Beutler, *University of Chicago.*—Continuing the investigations reported earlier,[1] a general formula is set up for reflection and diffraction by a concave grating for an arbitrary position of the luminous point or of the image. The formula involving the three space coordinates contains as special cases all the known mountings of the grating, for example, grazing incidence and stigmatic mounting. Expanding the formula in power series and using the Fermat condition for image formation, one obtains expressions for aberration, astigmatism, coma and higher order effects, which have been numerically calculated and are represented by a set of graphs for any incident and emergent angle. These factors determine the quality of the image, which in turn limits the attainable resolution. Some of the interesting results are: Heretofore the aberration determined an optimal grating width; now there is obtained an optimal circular area, the diameter of which is equal to the previously allowed width. The presence of coma limits the length of the rulings allowed for large angles. Its effect is small for Eagle mounting (incident angle equal to emergent angle). For stigmatic mounting (incident light parallel) aberration, astigmatism and coma disappear completely at the normal.

[1] H. Beutler, Phys. Rev. **57**, 354 (1940).

93. Analysis of Singly Ionized Cerium. W. E. Albertson and G. R. Harrison, *Massachusetts Institute of Technology.*—New Zeeman effect measurements and new visible and near infra-red wave-length data have made possible extension of the analysis, which now accounts for 3407 lines—an estimated 98 percent of the total intensity of radiation in the Ce II spectrum in the region 2500–9000A. These lines result from transitions within two groups of levels which have not as yet been connected; the first contains 234 levels and the second 67. The smaller group is based on the parent configuration $4f^2$, from which $(^3H)6s$, $(^3H)6p$, $(^3F)6s$, and $(^1G)6s$ have been found complete, as well as nearly all of $(^3H)5d$, $(^3F)6p$, and $(^1G)6p$. The coupling in $4f^2$ is nearly (LS), whereas the $6s$, $6p$ and $5d$ electrons add on with nearly (JJ) coupling. It is estimated that the larger group lies about 5000 cm^{-1} above this group and will combine with it to give intense infra-red lines. The larger group is believed to arise from the configurations $4f5d6s$, $4f5d^2$ and $4f6s^2$ for the low levels, and $4f5d6p$, $4f6s6p$, $5d^26s$ and $5d6s^2$ for the higher combining levels.

94. Line Spectra in the Vacuum Ultraviolet. J. C. Boyce and L. Misch, *Massachusetts Institute of Technology.*—A survey of existing observations of line spectra in the vacuum ultraviolet shows reasonably complete data, for the first five spectra of each element, for most of the lighter elements. Beyond calcium the increasing complexity of the spectra introduces two difficulties, the larger number of lines to be measured, and the greater wave number accuracy necessary to avoid false intervals in the analysis of the spectra. Support from the Carnegie Institution of Washington has made possible a program of systematic observation of such spectra to fill the wide gaps in the existing data. Comparative exposures from various light sources will be necessary to identify the various stages of ionization, but a start has been made with sparks in nitrogen for fifteen elements. Some of these plates have now been measured on the Harrison automatic comparator.[1] A parallel project of the Works Progress Administration provides clerical assistance in reading and tabulating the record films from the automatic comparator. On plates with dispersion 4.25A/mm the average of six measurements (three in each direction) gives a precision of 0.003A. Priority in observation and measurement will be given to spectra under investigation in this and other laboratories. Spectrum plates and comparator records will be made available to properly qualified investigators engaged in the term analysis of particular spectra.

[1] G. R. Harrison, J. Opt. Soc. Am. **25**, 169 (1935); Rev. Sci. Inst. **9**, 15 (1938).

95. Zeeman Effects in Ruthenium Spectra at High Fields (Ru I and Ru II). George R. Harrison and J. Rand McNally, Jr., *Massachusetts Institute of Technology.*—Using a 1700-kw Bitter electromagnet to produce fields up to 95,000 gauss[1] the Zeeman effects of the first and second spectra of ruthenium have been recorded with three 10-meter concave gratings, at 0.8A/mm in the range 2200 to 5500A, and at 1.6A/mm to 8000A. Although an electric arc was used as source, the magnetic field increased the excitation almost to that of a spark. Some 300 clearly resolved patterns have thus far been reduced to obtain both g and J values for terms, and 100 entirely unresolved patterns have been measured to determine g values. A number of very unsymmetrical lines have been found, and these are being especially investigated along the lines indicated by Mack and Laporte,[2] and by Roberson and Mack[3] for tungsten λ4659. The data obtained are being used to extend the classification of Ru I and Ru II.

[1] Harrison and Bitter, Phys. Rev. **57**, 15 (1940).
[2] Mack and Laporte, Phys. Rev. **51**, 291 (1937).
[3] Roberson and Mack, Phys. Rev. **55**, 116 (1939).

96. The Hyperfine Structure of CsII. R. A. Boyd and R. A. Sawyer, *University of Michigan.*—The first accurate measurements of h.f.s. in CsII were made by Kopferman[1] who published results on nine lines and established the nuclear spin as 7/2. These nine lines involved transitions among eight levels in the CsII spectrum, the analysis of which was first given by Laporte, Miller and Sawyer,[2] who classified and extended the level scheme of Sommer.[3] Further extensions of the classification in this laboratory and elsewhere[4] have revealed many more terms, resting however chiefly on constant frequency differences. Examination of the hollow cathode spectrum of CsII with a Fabry-Perot interferometer shows that many lines have h.f.s. The present work was undertaken with the purpose of using the h.f.s. to check the classification and to fix the j values and if possible the configurations of the terms. A study of the structure of fourteen lines has verified nine energy levels, and fixed their j values and h.f.s. internal factors. One of these terms, 122,365.5, has not previously been published. The research is being continued.

[1] H. Kopferman, Zeits. f. Physik **73**, 437 (1931).
[2] O. Laporte, G. R. Miller and R. A. Sawyer, Phys. Rev. **37**, 845 (1931) and **39**, 458 (1932).
[3] L. A. Sommer, Ann. d. Physik **75**, 163 (1924).
[4] J. Olthoff and R. A. Sawyer, Phys. Rev. **42**, 766 (1932); R. Ricard, Comptes rendus **206**, 905 (1938); M. A. Wheatley and R. A. Sawyer, unpublished.

97. Studies of Coupling in *WI* from Paschen-Back Effect. J. H. Roberson and J. E. Mack, *University of Wisconsin.*—The dependence upon the magnetic field of the energies of two close neighboring levels of the neutral tungsten atom, previously studied[1] in smaller fields, has been investigated up to a magnetic field of 10^5 c.g.s. (plates by Harrison). The interaction constant k is independent of M and the field except for fluctuations of the order of 0.05 cm^{-1}, which may be due to the wandering of the reference lines in the field. In addition, k values have been obtained for several weaker interactions in the same spectrum. General considerations show that asymmetries of this sort occur only on account of the LS interaction between the levels concerned; so the phenomenon can be described as the well known Paschen-Back effect, occurring to a pair of levels only to the extent to which, in LS language, they belong to one or more multiplets in common. Certain coupling properties among the WI levels $5d^46s(^6D)6p\ ^{7,5}FDP$ have been determined with the aid of these data.

[1] J. E. Mack and O. Laporte, Phys. Rev. **51**, 291 (1937); J. H. Roberson and J. E. Mack, Phys. Rev. **55**, 1126 (1939).

98. A Spectrographic Method for the Measurement of the Rate of Recombination of Atomic Hydrogen. W. M. Preston, *Harvard University.*—Previous methods for the determination of the rate constants of the various processes by which hydrogen atoms recombine to form molecules have been indirect, or have required troublesome corrections, and do not agree well. An attempt has been made to use the absorption spectrum of atomic hydrogen as a direct and sensitive measure of atomic concentration. The light source is an intermittent hydrogen discharge, emitting strongly the first line of the Lyman series at 1215.6A, Ly_α. Light from the source passes through an absorption cell, closed by lithium fluoride windows, and is analyzed by a one-meter vacuum spectrograph. Atomic hydrogen is produced by a brief electric discharge through hydrogen gas in the absorption cell. After a short variable interval Δt, the source tube is flashed, and the transmitted intensity of Ly_α, reduced by the absorption due to any hydrogen atoms in the absorption cell, is measured by a photoelectric cell. The method succeeded to the extent that hydrogen atoms could be detected and their rate of recombination determined. However, the recombination process was due largely to a wall effect, rather than to triple collisions in the gas volume. The usefulness of the method is at present limited because no way has been found to "poison" the walls, which does not involve the presence of water vapor in the absorption cell. Water vapor unfortunately has a narrow, strong absorption band at just the wave-length of Ly_α.

99. On Sommerfeld's Fine Structure Constant. Alfred Landé, *Ohio State University.*—The problem of the self-consistent wave field in the p, E space with the rest value $mc=b$ and in the r, t space of Dirac's signal intervals with the rest signal radius a leads to an integral equation with the ratio $ab/\hbar=\mu$ as its eigenvalue. A strict solution has now been found. The ground eigenfunction represents a constant density in the proper space, which is a Gaussian-like distribution in the ordinary space. The eigenvalue is as small as $\mu=0.030$. The fine structure constant $\alpha=\mu/\gamma$ depends on the factor γ in Dirac's signal radius $a=\gamma e^2/mc^2$.

100. The Illinois Linear Accelerator. J. H. Manley, L. J. Haworth, E. A. Luebke, and M. P. Vore, *University of Illinois.*—With an accelerating tube and Zinn-type ion-source, ion currents of 350 microamperes at the target at 225 kv have been obtained. The ion path is 350 cm and practically all of the ion current can be focused to a spot less than 2 mm in diameter. Novel features of focus control, target construction for a D–D neutron source and an arrangement for modulation of the deuteron beam will be discussed. The apparatus is being used for a survey of slow neutron excitation functions.

101. Neutron Velocity Measurements. L. J. Haworth, J. H. Manley, M. P. Vore and E. A. Luebke, *University of Illinois.*—Special circuits have been developed for neutron velocity measurements. A master oscillator triggers a special circuit which allows the deuteron beam to strike the target of the accelerating tube for an accurately known time. At the same time a novel oscilloscope sweep circuit is triggered and neutron pulses produced at the detector and fed to the oscilloscope are thus accurately timed with respect to the target pulse. Since the detector pulses are less than 10^{-6} sec. wide, the resolution is determined entirely by the target pulse width which is limited only by the available intensity.

102. Anomalous Scattering of Neutrons by Helium and the D–D Neutron Spectrum. Emmett Hudspeth and Henry Dunlap, *Rice Institute.*—An investigation of the variation of the ratio of the scattering cross section of neutrons by helium and hydrogen has been made. Neutrons were obtained from a *d–d* source partly surrounded by 3 cm of paraffin. The anomalously high cross section in helium[1] at 1.0 Mev was found, and the helium-hydrogen cross-section ratio diminishes to about half this maximum value at 1.4 Mev. No other maxima were observed. The *d–d* neutron spectrum was also investigated by helium recoils. The spectrum appears to be homogeneous; no evidence was found for a low energy group of neutrons with an intensity as great as 1 percent of the main group.

[1] H. Staub and W. E. Stephens, Phys. Rev. **55**, 131 (1939).

103. Resonances in the Disintegration of Carbon by Deuterons. T. W. Bonner and Emmett Hudspeth, *Rice Institute.*—The excitation curve for the production of neutrons from the bombardment of carbon by deuterons has been obtained. The yield curve shows resonances at 920, 1130, and 1300 kv. These resonances are at the same position as those found for the production of γ-rays.[1] It seems that these resonances correspond to levels in an excited intermediate N^{14} nucleus which subsequently may either break up into N^{13} and a neutron or may fall to the ground state by the emission of a γ-ray.

[1] W. E. Bennett and T. W. Bonner, abstract 160.

104. Fast Neutron Collision Cross Sections of C and H. E. O. Salant, *Washington Square College, New York University,* and N. F. Ramsey,* *Carnegie Institution of Washington.*—Measurements of the scattering of the high energy group of D Li neutrons have been repeated[1] under improved conditions. Uncertainties in the energy and in effects of geometry are now small. Diameter of target is 1 cm, of copper detector is 2.5 cm; target-to-detector distance is 35 cm. Tests show the presence of only the ten-minute period of copper in our experimental procedure and negligible scattering from the room. Further evidence is found for placing the copper *n–2n* threshold close to 12 Mev.[2] With three thicknesses of scatterers (50–85 percent transmissions), cross sections do not vary. Experiments were performed at 15° and at 90° to the 0.9-Mev deuteron beam, yielding 15- and 14-Mev neutrons, respectively. The collision cross sections σ are:

	$\sigma\times 10^{-24}$ cm^2		
Energy Mev	*n-C* obs.	*n-p* obs.	*n-p* theor.
14	1.27 ± 0.04	0.70 ± 0.06	0.66
15	1.36 ± 0.05	0.66 ± 0.07	0.61

The observed *n-p* cross sections were evaluated from the observed neutron cross sections of carbon and of paraffin whose carbon-hydrogen content was determined by chemical analysis. The theoretical values are from Kittel and Breit.[3]

* Carnegie Institution Fellow.

[1] E. O. Salant, R. B. Roberts and P. Wang, Phys. Rev. **55**, 984 (1939).

[2] R. Sagane, Phys. Rev. **53**, 492 (1938).

[3] C. Kittel and G. Breit, Phys. Rev. **56**, 744 (1939).

105. The Elastic Scattering of Fast Neutrons. G. Placzek and H. A. Bethe, *Cornell University.*—Bohr, Peierls and Placzek[1] have shown that, apart from the inelastic scattering, we have also to expect an important elastic scattering of fast neutrons by nuclei, which has a cross section of the order of nuclear dimensions, goes mostly into the forward direction and, for wave-length small compared to the nuclear radius, goes over into the geometric shadow of the nucleus. Recent experiments[2,3] seem to demonstrate this effect clearly. In the particular case of sticking probability equal to one, the angular distribution of the elastic scattering can be derived directly from general principles. The cross section per unit solid angle σ in this case is

$$\sigma=\left\{\frac{RJ_1(kR\vartheta)}{\vartheta}\right\}^2,$$

where R is the nuclear radius, k the wave vector, ϑ the scattering angle and J_1 the Bessel function of order 1. This seems to be in qualitative agreement with the experimental results of Wakatuki and Kikuchi.[3] If the sticking probability is smaller than one, the angular distribution is more complicated but can be computed on the basis of a nuclear model recently proposed by Bethe.[4]

[1] N. Bohr, R. Peierls and G. Placzek, Proc. Copenhagen Academy, to appear shortly.

[2] R. F. Bacher, Phys. Rev. **57**, 352 (1940).

[3] T. Wakatuki and S. Kikuchi, Proc. Phys. Math. Soc. Jap. **21**, 656 (1939).

[4] H. A. Bethe, Bulletin A. P. S., New York Meeting, 1940.

106. The Angular Distribution of Slow Neutrons Scattered from Various Materials. Martin D. Whitaker and William C. Bright, *New York University.*—The assumption of spherical symmetry in the distribution of scattered neutrons of low energy must be abandoned at least in cases involving magnetic,[1] crystalline[2] or *light* materials. An experimental study of this question of angular distribution of scattered slow neutrons is being made. The annular ring technique has been adapted for angles of less than 90°. Scattering samples 28 cm in diameter and having a transmission of 50 percent are placed midway between a boron detector and the 600-mg Ra-Be neutron source suitably placed in paraffin. The detector is shielded from direct radiation by paraffin, Cd, and B_4C, so that only neutrons scattered through selected angles reach the detector. Various angular regions can be selected by varying the distance from source to detector and by using different parts of the samples. Preliminary comparisons of the scattering of lead with that of several other materials are shown in the table. If the ratios of scattering to total cross section given in the third column are correct and if the distribution were the same for the materials, the numbers in columns one and two should be identical with those in three.

	10° to 45°	10° to 90°	$(\sigma_s/\sigma_t)\times 100$
Pb	100	100	100
Paraffin	160	150	100
C	136	120	100
$MnSO_4$	93	68	63
Fe	70	84	75

[1] O. Halpern and M. H. Johnson, Phys. Rev. **55**, 898 (1939).
[2] M. D. Whitaker and H. G. Beyer, Phys. Rev. **55**, 1101; **55**, 1024 (1939).

107. The Scattering of Slow Neutrons by Molecules. R. G. Sachs and E. Teller, *The George Washington University.*—It has been shown by Fermi[1] that the cross section for the scattering of slow neutrons by protons is four times greater for strongly bound protons than it is for free protons. A simple generalization of this factor of four can be given for the scattering of neutrons whose energy is great as compared to the energy differences of the rotational levels of the scattering molecule but small compared to the quanta of molecular vibration. In this case, the proton may be treated as free if its mass is replaced by a mass tensor depending on the mass and structure of the molecule. Thus for the scattering of neutrons in H_2 the effective mass of the proton is equal to its real mass if the relative velocity of the neutron and the molecule is perpendicular to the H–H axis, and it is twice the protonic mass if the direction of the relative velocity is parallel to the H–H axis. One obtains for H_2 a scattering cross section per proton which is 1.22 times greater than the cross section for the free proton.

[1] E. Fermi, Ricerca Scient. VII-II, 13 (1936).

108. Further Experiments with Mono Energetic Slow Neutrons. C. P. Baker and R. F. Bacher, *Cornell University.*—Using the intermittent ion source for the cyclotron and an amplifier with adjustable time of sensitivity previously reported,[1] the range of neutron energies has been extended. Evidence for the resonance absorption of rhodium and indium has been obtained. Results uncorrected for resolution of the apparatus but corrected for time delay in amplifier and ionization chamber show that minimum transmission occurs at 0.9 ev for both elements. A study of the transmission of thick cadmium (0.45 g/cm^2) indicates that the transmission is approximately 5 percent at 0.2 ev and 50 percent at 0.5 ev. Direct evidence of the finite life of thermal neutrons in paraffin has been found. The BF_3 ionization chamber was placed next to the paraffin block and the number of neutron pulses counted in 50-microsecond time intervals after the neutron burst. Neutrons were detected for 400 microseconds after the burst and these neutrons were found to be absorbed by thick cadmium. Preliminary results indicate that the decay curve is exponential except for the start and that the mean life is about 160 microseconds.

[1] Baker and Bacher, Phys. Rev. **57**, 351 (1940).

109. Bragg Reflection of Neutrons from MgO Crystals. George J. Thiessen, *Columbia University.*—Existing evidence[1–3] for coherent scattering of neutrons is mostly of a qualitative nature. The direct approach in experiments by Mitchell and Powers[3] did not yield a rocking curve due to small neutron intensities. The present experiments were undertaken when the much greater intensities from the Columbia cyclotron became available. To simulate a 3″×4″ crystal, seven single crystals of MgO were mounted on a brass plate and this was mounted on a spectrometer. In spite of heavy shielding with Cd, B_4C, paraffin and water, the background was approximately equal to the total intensity of the scattered neutrons. A divergence of the beam of at least 6° was permitted. Under these conditions rocking curves were obtained. Preliminary measurements of energy distribution of neutrons in the beam are in agreement with the Maxwellian distribution and the $1/v$ law of absorption in the boron detector. The coherent scattering is from 60 to 80 percent (depending on collimation) of the scattered beam.

[1] Von Halban and Preiswerk, Comptes rendus **203**, July, 1936.
[2] Beyer and Whitaker (in the process of publication).
[3] Mitchell and Powers, Phys. Rev. **50**, 486 (1936).

110. The Relative Distribution in Energy of the Neutrons from the (p,n) Reactions in Lithium and Beryllium. J. E. Hill, *University of Rochester.*—The yields of neutrons from thick targets of lithium and beryllium bombarded by 6.7-Mev protons are found to be the same within 15 percent when a silver detector encased in paraffin is used.[1] However, the activity induced in aluminum by the reaction $Al^{27}(n,p)Mg^{27}$ is four times stronger for the lithium than for the beryllium neutrons under the same conditions. In the reaction $Li^7(p,n)Be^7$, which has a definite threshold at a proton energy of 1.86 Mev[2,3], neutrons with a definite upper energy limit are produced for protons of any fixed energy above the threshold. By varying the energy of protons on lithium it is found that the $Al(n,p)$ reaction occurs only for neutrons with energies above about 3.0 Mev (this supersedes the previously reported value of 2.6 Mev).[1] The low yield of this reaction with beryllium neutrons suggests that these neutrons are largely of lower energies even though the threshold of the $Be^9(p,n)B^9$ reaction is about the same, 2.01 Mev.[4, 5] At the threshold it is probable that B^9 is formed in a metastable state but for higher proton energies the compound nucleus B^{10} probably disintegrates directly into three or more heavy particles of which one is a neutron. This would account for a preponderance of neutrons of much lower energy than that expected from the threshold.

[1] J. E. Hill, Phys. Rev. **55**, 1117(A) (1939).
[2] J. E. Hill and G. E. Valley, Phys. Rev. **55**, 678(A) (1939).
[3] R. O. Haxby, W. E. Shoupp, W. E. Stephens and W. H. Wells, Phys. Rev. **57**, 348(A) (1940).
[4] J. E. Hill, abstract 57, New York Meeting, February 24, 1940.
[5] R. O. Haxby, W. E. Shoupp, W. E. Stephens and W. H. Wells, abstract 58, New York Meeting, February 24, 1940.

111. Relativistic Corrections to Neutron-Proton and Proton-Proton Scattering. L. E. Hoisington, *University of Wisconsin.*—Relativistic corrections to the neutron-proton and proton-proton ^1S scattering cross sections have been calculated from one of Breit's equations[1] which is invariant to order v^2/c^2. The changes in the logarithmic derivative due to the correction terms were computed to the first order by a perturbation method based on the Riccati equation.[2] The scattering cross section was kept fixed and changes in depth required to compensate the effect of the corrections were computed for a "square well" interaction potential having a width e^2/mc^2. For the neutron-proton potential (nonrelativistic depth $=11.54$ Mev) these changes are $+0.005$ Mev for zero energy, -0.028 Mev for 4-Mev and -0.134 Mev for 16-Mev neutrons. For the proton-proton potential (nonrelativistic depth $=10.5$ Mev without interior Coulomb potential) the required changes are $+0.011$ Mev, -0.004 Mev for 0.8-Mev and 2.4-Mev protons, respectively. The Coulomb field inside the well was neglected. It is expected that the changes are also approximately correct for an interaction potential with interior Coulomb field (depth $=11.3$ Mev). The range of force (width of potential well) required by experiment is increased slightly by the corrections.

[1] G. Breit, Phys. Rev. **53**, 153 (1938), Eq. (17).
[2] G. Breit, H. M. Thaxton and L. Eisenbud, Phys. Rev. **55**, 1018 (1939), Eqs. (9), (9.1).

112. Scattering of One- to Three-Mev Protons by Helium. N. P. Heydenburg and N. F. Ramsey,* *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The scattering of protons of from one to three Mev energy by helium has been experimentally examined for the existence of resonance scattering analogous to the neutron-helium resonance observed for 1-Mev neutrons by Staub and Stephens.[1] As has been pointed out,[2] if n–n and p–p nuclear forces are equal, such a resonance should occur in p-He scattering for 2-Mev protons. The number of protons scattered 140° were first observed as a function of their energy. No evidence for a resonance scattering of comparable sharpness to the neutron-helium resonance was observed, even though a p resonance scattering should have been easily observable. There was, nevertheless, a very broad maximum centered at 2 Mev, whose half-width was over 1 Mev and height only a factor of 2 in contrast with Staub and Stephens' half-width of 200 kv and height a factor of 9. A greater breadth for the p-He resonance can, as suggested by U. Fano, be justified; hence, our results are not inconsistent with those of Staub and Stephens or with the equality of n–n and p–p forces. Measurements of the angular distribution of the p-He scattering are now being made at different energies. These show that only about half the 140° scattering can be attributed to an s wave.

* Carnegie Institution Fellow.
[1] H. Staub and W. E. Stephens, Phys. Rev. **55**, 131 (1939).
[2] H. Primakoff and H. H. Goldsmith, Phys. Rev. **55**, 1117 (1939).

113. Lifetime of Excited Diacetyl Molecule. G. M. Almy and Scott Anderson, *University of Illinois.*—Many substances containing the acetyl radical, CH_3CO, e.g., acetone, show identical green fluorescence when exposed to light they will absorb. In acetone this fluorescence is due to the growth of diacetyl formed under the action of light. Several properties of diacetyl fluorescence have been reported and we can now add to these the results of measurements bearing on the lifetime of the excited state of diacetyl in vapor at 25°C. (1) Direct visual phosphoroscope measurements of the decay of the fluorescent intensity show a mean lifetime (τ) of $1.7\pm0.2\times10^{-3}$ second. (2) By the use of photographic photometry of the fluorescence, a quantitative study of the diffusion of excited diacetyl molecules from an illuminated beam into a shadow containing unexcited molecules yields the product of the diffusion coefficient (D) by τ. Combined with τ from (1) a value of $D=3.0\times10^{-2}$ (at 25°C and adjusted to 1 atmosphere pressure) is obtained, which is about that to be expected from kinetic theory. (3) The integrated absorption coefficient over the absorption band associated with the fluorescence leads, however, to a much shorter τ of about 10^{-5} second.

Since the quantum yield of fluorescence in diacetyl has been found to be about 1/30, the mean lifetime against fluorescence may be 30 times the value measured in (1), or about 0.05 sec. The conclusion seems to be that after excitation the molecule goes into a metastable state of long life.

114. The Infra-Red Spectrum of Potassium Cyanate. Dudley Williams, *University of Florida.*—The transmission of potassium cyanate in solution has been studied in the region 2μ–14μ. The observed spectrum was found to change with the age of the solution. In freshly prepared solutions absorption frequencies near 2180 cm^{-1} and 840 cm^{-1} were observed. Soon after the preparation of a solution, additional bands made their appearance and the original bands decreased in intensity. The changes in spectrum of a saturated solution were followed for a period of ten days. The additional bands appear in regions where NH_4 and CO_3 groups would be expected to absorb. It is probable that potassium cyanate decomposes in aqueous solution in the following manner:

$$KOCN+3H_2O\rightarrow NH_4OH+KHCO_3$$

(with intermediate steps involved). If the frequencies 840 cm^{-1} and 2180 cm^{-1} be regarded as frequencies ν_1 and ν_3

of a linear cyanate group, the following force constants are obtained: $k_{OC} = 4.6 \times 10^5$ dynes/cm and $k_{CN} = 15.9 \times 10^5$ dynes/cm. These values are in fair agreement with the corresponding constants of other triatomic systems having similar electronic structure.

115. The Raman Spectrum of Formic Acid Vapor. L. G. Bonner and J. S. Kirby-Smith, *Duke University.*—The Raman spectrum of gaseous formic acid has been obtained at temperatures up to 200°C and pressures up to 4 atmos. We have been able to separate the spectrum of the single molecules from that of the double and wish to assign tentatively the frequencies 232, 919, 1346, 2945, and 3566 cm^{-1} to the monomer and 232, 981, 1049, 1346, and 2945 cm^{-1} to the dimer. By comparison with the known infra-red spectra of formic acid and its deuterium derivatives, it is possible to assign a number of these frequencies to vibration modes.

116. Raman Spectra of Aqueous Solutions of Sucrose. Forrest F. Cleveland, *Armour Institute of Technology.*—The Raman spectra of saturated and 30 percent solutions of sucrose have been obtained with a spectrograph having a linear dispersion of 33A/mm at 4500A. No differences were observed in the spectra of the dilute and concentrated solutions. Thirty-eight lines, in addition to the broad water band extending from 3140 to 3684 cm^{-1}, were observed. Eleven of the nineteen frequencies reported by Polara[1] for sucrose agree fairly well with frequencies observed in this study, but the remaining eight were not found. Depolarization measurements have been made for the more intense lines. The frequencies 105(6), 117(4) and 135(3) were observed also on a spectrogram made with pure water and are therefore not to be ascribed to sucrose. Chemical evidence indicates that the sucrose molecule consists of a pyranose ring (one oxygen and five carbon atoms) and a furanose ring (one oxygen and four carbon atoms), linked together by an oxygen atom. The spectroscopic results seem consistent with this view.

[1] V. Polara, Accad. Lincei, Atti 14, 293 (1931).

117. The Rotational Structure of the Fundamental ν (C−H) Vibration Band of Formic Acid. Lincoln G. Smith and V. Williams, *Princeton University.*—The rotational structure of the fundamental infra-red band, $\nu(\text{C}-\text{H})$, in the monomer spectrum of formic acid has been obtained with a 4800 line echelette grating in the first order. The appearance of this band is very similar to that of the $\nu(\text{O}-\text{H})$ harmonic bands described by Bauer and Badger[1] and Thompson.[2] This structure consists of sharply defined lines forming pQ and rQ branches whose separations show a divergence closely resembling that of the O−H bands. In the region of the band center (approximately 2910 cm^{-1}) there is definite structure which cannot be assigned to either the pQ or rQ series. However, there is no strong qQ branch indicating that the change in dipole moment must be very nearly perpendicular to the axis of least moment of inertia.

[1] Simon H. Bauer and Richard M. Badger, J. Chem. Phys. 5, 852 (1937).

[2] H. W. Thompson, J. Chem. Phys. 7, 453 (1939).

118. The Infra-Red Absorption Spectrum of Cystine and Deuterium Cystine. C. M. Herget and J. D. Hardy, *Russell Sage Institute of Pathology, New York Hospital.*—The J. D. Hardy infra-red recording spectrophotometer[1] was used, which instrument is well adapted to making rapid and accurate surveys of infra-red absorption spectra from 1 to 14μ. A spectrum can be obtained in about forty-five minutes. The various cystine samples were spread in the form of dry powders on a rocksalt plate from suspension in 95 percent ethyl alcohol. The troublesome scattering at the shorter wave-lengths, which such procedure usually incurs, was compensated for by introducing into the control beam of the spectrophotometer a roughened rocksalt plate which introduced an amount of scattering equal to that in the sample beam. Besides that of normal cystine, there has been obtained the spectrum of cystine with deuterium replacing the hydrogen of the carboxyl group, the hydrogen of the amino group, and the hydrogen on the α-carbon atom.

[1] J. D. Hardy and A. I. Ryer, Phys. Rev. 55, 1112(A) (1939).

119. Absorption Spectrum of Monochlorobenzene at 2750−2400A. H. Sponer and S. H. Wollman, *Duke University.*—The absorption spectrum of C_6H_5Cl at 2750−2400A was photographed in the first order of a 3-m grating spectrograph. The band system corresponds to an electronic transition $A_1 \rightarrow B_2$ (monochlorobenzene has the symmetry C_{2v}) with the transition moment lying in the molecular plane perpendicular to the C−Cl bond. In agreement with this assignment to an allowed transition the O,O band appears strongly both in the vapor at 37,052 and in the solid at 36,860 cm^{-1}. Since C_6H_5Cl possesses eleven totally symmetrical vibrations several progressions of these must be expected. Accordingly the observed structure becomes more complicated towards the violet because of the increasing number of possible combinations of totally symmetrical vibrations. Frequencies of 931, 965 and 1041 cm^{-1} are regarded as totally symmetrical carbon vibrations in the upper state. The C_6H_5Cl spectrum is only two times stronger than the corresponding benzene absorption, although the first represents an allowed and the second a forbidden transition. It is therefore not impossible that the mechanism which brought the benzene spectrum into appearance, namely the excitation of an E_g^+ vibration, remains relatively important in C_6H_5Cl. In this connection the strongest band of the second group of the spectrum, which lies 525 cm^{-1} apart from the O,O band, is tentatively associated with the corresponding vibration in C_6H_5Cl.

120. Absorption System of Sulphur Dioxide at 3800A. N. Metropolis and H. Beutler, *University of Chicago.*—Photographs of the absorption of SO_2 on the 30-foot grating spectrograph revealed an electronic transition at 3879A, the long wave-length end of the known absorption. Discrete bands can be observed with a one-meter absorbing layer, indicating that the electron jump is forbidden. The vibrationless transition lies at 25,774.6 cm^{-1}; the breathing vibration ν_1' in the new state is 908 cm^{-1}, the deformation vibration is $\nu_2' = 362$ cm^{-1}. Fourteen bands fit these constants ($v_1' = 0$ to 3, $v_2' = 0$ to 3), the transitions $\Delta v_1 = 1$ and $\Delta v_2 = 1$ being the strongest ones. A perturbation occurs in

$v_1'=1$. Besides these bands, some weaker ones appear. Attempts to explain them within the possible number of levels in the named two sequences failed. Tentatively they may be assigned as transitions involving the change of the asymmetric mode of vibration. For $\Delta v_3=2$, a fairly intense band at 27,843 cm^{-1} may be accounted for very weak bands suggest the transitions to (1′,0′,0′), (1′,0′,1′) and (1′,1′,1′). Pictures taken at approximately 500°C exhibit the absorption from thermally excited levels v_2'' and v_1'' and confirm the value of the electronic transition.

121. The Absorption Spectrum of HgIn and HgTl. J. G. Winans, Francis J. Davis, and Victor A. Leitzke, *University of Wisconsin.*—It has been possible to obtain absorption bands of HgIn and HgTl even though these molecules appear to have such small binding energy that they are nearly 100 percent dissociated at the temperatures required to give the vapor pressures of indium or thallium necessary for molecule formation. The absorption bands are obtained with a quartz tube containing indium or thallium, mercury, and neon at about 5 cm pressure. The tube is heated generally to give a mercury pressure of about 10 cm and a 2-cm diameter bulb containing a drop of In or Tl is heated locally to about 1100°C with a blow torch. The source of heat was removed and after from 5 to 40 seconds of cooling the absorption spectrum was photographed. A type H3 mercury arc served as light source. The absorption bands obtained have sharp edges on the short wave side and form series with nearly equal intervals extending to longer wave-lengths from the most intense band. The HgIn bands are near 2700A while the HgTl bands are near 3230A. The wave numbers at the sharp edges with estimated intensities are: for HgIn 37,563.5 (9), 37,412.6 (10), 37,246.5 (2), 37,098.3 (9), 36,933.7 (5), 36,782.0 (6), 36,621.5 (4), 36,465.1 (1); for HgTl 31,035.8 (10), 31,012.6 (9), 30,946.1 (2), 30,943.8 (9), 30,933.2 (1), 30,854.1 (3), 30,848.6 (6), and 30,693.3 (1).

122. Molecular Structure of Nitrogen Dioxide and Nitric Acid by Electron Diffraction. Louis R. Maxwell and V. M. Mosley, *Bureau of Agricultural Chemistry and Engineering.*—New electron diffraction photographs have been taken of NO_2 extending the region previously investigated[1] to include larger angles of scattering. An interference ring was found at $(1/\lambda)\sin\frac{1}{2}\theta=0.49$ followed by another ring appearing at 0.94 as determined by visual measurements. The outer portion of the pattern consists of two rather broad rings and two well-defined minima. Theoretical intensities of scattering were computed for various nitrogen valence angles assuming the positions of the two oxygens to be equivalent. The best fit and probably the correct structure gives the angle $O-N-O=130\pm2°$ with the $N-O$ distance, 1.21±0.01A. Photographs were also obtained from pure nitric acid vapor at 70°C. The interference maxima were measured visually as far out as the eighth maximum at $(1/\lambda)\sin\frac{1}{2}\theta=1.83$, a prominent minimum was seen at 1.54. Theoretical intensities were computed for various likely models omitting the scattering by the hydrogen atom. A good agreement was obtained for a planar model having an NO_2 group with the same structure as found for nitrogen dioxide. The third oxygen atom O′ is located at a distance of 1.41A from the nitrogen atom and equidistant from the other oxygens. A model having the nitrogen atom slightly out of the plane containing the oxygens also gave good agreement with the experimental results. This model however is considered less probable in view of Raman spectrum data which apparently require a planar structure[2] for $O'-NO_2$.

[1] L. R. Maxwell, V. M. Mosley and L. S. Deming, J. Chem. Phys. **2**, 331 (1934).

[2] J. Chedin, J. d. phys. et rad. **10**, 445 (1939).

123. Self-Consistent Field for Methane. L. A. Young, *Carnegie Institute of Technology.*—Calculations similar to Hartree's for atoms have been carried out for CH_4. The main difference between this work and the Hartree method for atoms lies in the fact that the potential of the four protons is averaged over a sphere in addition to the usual averaging, leading to a central field problem. The angle dependence of the resulting Hartree functions was taken as $\frac{1}{2}(s+\sqrt{3}p)$, corresponding to four equivalent tetrahedral bonds. The resulting radial Hartree equation contained $\frac{3}{2}\hbar^2$ as the average square of the angular momentum rather than the conventional $l(l+1)\hbar^2$. The calculations were extremely sensitive, but by using the proper combination of initial and final fields (70 percent, 30 percent) of the previous stage of calculation for the initial field of each stage, rapid convergence was obtained. The resultant self-consistent functions will be discussed in respect to their applicability not only to CH_4 but also to the $C-H$ bond in other molecules involving tetrahedral carbon.

124. Variational Treatment of the C−H Bond in Methane. C. L. Bartberger, *Carnegie Institute of Technology.*—By using the self-consistent function for three of the bonds in CH_4 an approximate two-electron equation was derived for the fourth bond. This was treated by the standard variational method. The trial function included the tetrahedral angle dependence for each electron, and factors depending on the sum and difference of the distance of each electron from the central carbon atom. The approximate wave function found by minimization leads to a charge density agreeing closely with that given by the self-consistent function. This strengthens the belief that these Hartree functions will prove useful in future molecular calculations. The problem here discussed arose in a more general study of the $C-H$ bond in halogen derivatives of methane.

125. Field Emission from Tungsten Single Crystals. John H. Daniel, *Massachusetts Institute of Technology.* (*Introduced by W. B. Nottingham.*)—Qualitative measurements of field emission from single crystal tungsten "points" have been made with the electron projection tube after the manner of Müller.[1] Electrolytic etching of tungsten wire provides a superior method of obtaining a microscopic point, which is mounted at the center of a spherical bulb coated inside with fluorescent material. Emission of electrons under the field concentrated around the point takes place radially to the screen, giving a highly magnified emission picture of the single crystal point. Müller's observations are confirmed, and the crystallographic directions of high emission are found to agree with those expected from Nichols' quantitative measurements of thermionic work function.[2] The emission varies more strongly with work function than thermionic emission, and improved quantitative measurements on constant, single-valued work function areas under uniform fields are under way to investigate the empirical dependence of field emission on the cubed power of work function.[1] Theory predicts a $\frac{3}{2}$-power law.

[1] E. W. Müller, Zeits. f. Physik **108**, 668 (1938).
[2] M. H. Nichols, Phys. Rev. **57**, 297 (1940).

126. Additional Experimental Evidence of a Periodic Deviation from the "Schottky Line." W. B. NOTTINGHAM, *The Massachusetts Institute of Technology.*—Seifert and Phipps,[1] and Turnbull and Phipps[2] have shown that the thermionic emission from a heated filament does not increase linearly with the square root of the electric intensity at the surface of the emitter as has been thought to be the case. For high fields deviations from the "Schottky Line" of the order of one percent may be observed with certainty, if the technique of measurement is so refined that the measurements are made to an accuracy of 0.1 percent. A polished wire, heat treated to grow very large tungsten crystals, has been studied for the temperature range 1327°K to 1790°K, with the result that the maxima and minima observed by Seifert *et al.*, between fields of 40 kv per cm and 250 kv per cm, have been verified. The deviations at low fields are perhaps more easily observed with fine grain filaments of the kind used by Seifert.

[1] R. L. E. Seifert and T. E. Phipps, Phys. Rev. **56**, 652 (1939).
[2] D. Turnbull and Phipps, Phys. Rev. **56**, 663 (1939).

127. Temperature Effects on the Secondary Emission from Pure Metals. D. E. WOOLDRIDGE, *Bell Telephone Laboratories.*—Measurements have been made with a relative precision of 0.1 percent on the temperature dependence of a secondary emission coefficient of several pure metal surfaces. In the cases of iron and cobalt, the crystal structure transformation is accompanied by an abrupt change of about 1 percent in the secondary emission. For nickel, the effect of the magnetic transformation does not alter the secondary emission by as much as 0.3 percent. In the absence of crystal structure or magnetic changes, the temperature coefficient of secondary emission is less than the coefficient of linear expansion of the metal.

128. Exchange Energy of Electrons in Metals. CONYERS HERRING, *Princeton University,* AND A. G. HILL, *Massachusetts Institute of Technology.*—The exchange energy of the valence electrons in a metal plays an important part in the theoretical calculation of many properties (binding energy, work function, paramagnetism, etc.). It has been customary to assume that this exchange energy has the same value as for a free electron gas of a density equal to that of the electrons in the metal. An investigation of the accuracy of this assumption yields the result that for low electron densities the exchange energy per electron can be expanded into a series in powers of the radius of the Fermi distribution in momentum space. The leading term is the free electron value; the next term can be easily calculated from the wave functions which occur in Bardeen's method[1] of calculating the Fermi energy. This correction term is small for the alkali metals, but is quite appreciable for beryllium. Unfortunately, beryllium is divalent, and since for a divalent metal the power series fails to converge, the correction so calculated cannot be trusted. The behavior of the exchange energy for high electron densities can be calculated, however, and from this certain qualitative conclusions can be drawn.

[1] J. Bardeen, J. Chem. Phys. **6**, 367 (1938).

129. Rectilinear Electron Flow in Beams. J. R. PIERCE, *Bell Telephone Laboratories.*—Electrodes have been devised by means of which rectilinear electron flow according to well-known space charge equations can be realized in beams surrounded by charge free space. These electrodes have been used in designing electron guns having desirable characteristics.

130. On the Resonant Frequency of a Type of Klystron Resonator. E. H. SMITH, *Massachusetts Institute of Technology. (Introduced by Philip M. Morse.)*—Calculations of the resonant frequency and corresponding field have been made for one of the common types of Klystron resonators for different values of the relative dimensions. Since the shape of the resonator is such that no exact solution is possible, an approximation method must be used. Thus, a polynomial passing through sixteen adjustable points is used to approximate the field, and the best fit is obtained from the Ritz variation principle by a successive approximation method. The calculated frequencies agree with those measured by Barrow and Mieher* to within 3 percent for usable gap widths, with somewhat poorer results for large gaps. Probably the most useful results are the calculated field values, as these are difficult to measure experimentally and useful in resonator design. We may expect the field to have accuracy of the same order as the frequency.

* W. L. Barrow and W. W. Mieher, paper to appear in Proc. I.R.E.

131. Calculation of Driving-Point Impedance in Electromagnetic Field Problems. J. A. STRATTON AND L. J. CHU, *Massachusetts Institute of Technology.*—The Rayleigh-Sommerfeld theory of propagation along an infinite straight wire is a solution of a homogeneous system of Maxwell equations, and expresses the allowed *free* modes of oscillation. It gives no clue to the relation between the amplitude of steady-state modes and the applied electromotive force. The present paper discusses certain solutions of inhomogeneous field equations corresponding to arbitrary distributions of impressed e.m.f. In the case of the infinite wire it is shown that the complementary waves as well as the principal wave are excited with amplitudes determined by the nature of the source. If the conductivity is high the complementary waves are rapidly attenuated and the propagation approaches that found by Sommerfeld. When the e.m.f. is applied in the neighborhood of a point, the driving-point impedance has a definite value. It becomes infinite as the conductivity approaches infinity. The same method is applied to an elongated, prolate spheroid with a concentrated e.m.f. of arbitrary frequency impressed at the center. This is the problem of the forced, steady state oscillations of a linear antenna. The results give radiation resistance and reactance as a function of frequency and eccentricity and the relative amplitudes of the modes excited by a specified e.m.f.

132. Electrolytic "Polishing" of Tungsten. L. E. PETERSON, P. A. GUARINO AND E. A. COOMES, *University of Notre Dame.*—The electrolytic polishing of tungsten as previously described[1] has been studied further, mainly to understand the physical processes involved. Experiments were carried out on 50-mil rod to study (1) steady state and (2) transient phenomena, which seem to govern, respectively, the final plateau and the initial rise of the current *versus* voltage curve. The previous experiments were again performed, except in the present case the solution (0.025 normal NaOH) was swept with nitrogen in the region near the anode. The characteristic current *versus* voltage curve in this case exhibited no sharp maximum and the plateau value was much higher than without nitrogen. Again polishing took place on the plateau, but no etching could be observed following the polishing action. A good polish was obtained on a 50-mil tungsten rod at a current density of 50 ma per square centimeter in 25 minutes. To study transient phenomena, plots of instantaneous current *versus* instantaneous voltage were taken over a range of frequencies from 1/240 to $\frac{1}{3}$ cycle per second, using a 0.5 normal solution. In every case, as the voltage increased, the current rose to a sharp peak and then fell to the plateau value; for descending voltages, no peak value was observed in the current, thus giving a "hysteresis" loop. The value of the peak reached by the current varied with frequency, the maximum of the ratio of peak to plateau current occurring at 1/40 c.p.s. with a value of approximately 2. For 1/240 c.p.s. the ratio was 1.5, while at $\frac{1}{3}$ c.p.s. the ratio was 1.2. All of the phenomena observed may be related to the fundamental effects already reported.[2]

[1] J. M. Hughes and E. A. Coomes, Phys. Rev. **55**, 1138 (1939).

[2] W. C. Elmore, J. App. Phys. **10**, 724 (1939).

133. A High Frequency Square Wave Generator. WM. E. PARKINS AND LLOYD P. SMITH, *Cornell University.*—In connection with a project on the separation of isotopes by electrical means a circuit for generating square waves at high frequencies has been developed. This circuit may have general application where square wave voltages of a few megacycles frequency are required across small capacitances. (To exemplify the possibilities, for the project mentioned a one-megacycle square voltage wave of 35 volts amplitude and 2 percent ripple was obtained across 35 mmf with 4 percent of the cycle necessary for one 70-volt change.) The method involves driving two or more successive stages through cut-off, a sine wave voltage of the desired frequency being impressed on the grid of the first stage. Up to a certain point additional stages improve the voltage transition time; the above example was obtained with four stages each using a 30-watt tube. Because of their moderately low interelectrode capacitances, high transconductance and high plate current capabilities, transmitting beam power tetrodes have been found very adaptable to this circuit. To insure maximum rate of change of voltage and minimum ripple, a small inductance of the correct value for critical damping must be inserted in the plate circuit of each stage.

134. Anomalous Scattering of 6.7-Mev Protons by Al. G. KUERTI AND T. R. WILKINS, *University of Rochester.*—The scattering camera reported earlier[1] has been used to study the scattering of 6.7-Mev protons by Al. The following improvements have been made. To control exposures a current integrator attached to an ionization chamber registers the beam after passing through the camera. To prevent the beam from entering the camera during field fluctuations, two 1-mm wide slits 16 cm apart were inserted between the cyclotron and the camera. These contribute also to the uniformity of the beam. Stopping foils inserted between the scattering foil and the plates reduce the ranges to lengths suitable for registration in the plates (4.7 Mev). The scattering foil (2.2 cm air equiv.) was placed at 45° to the beam allowing simultaneous exposure of 34 plates distributed over the upper forward and lower backward quadrants. Relative exposures varied from 1 to 57, being constant (57) over the backward quadrant. Deviations from Rutherford's formula begin to occur at 35°. σ_{anom} varies from roughly 15×10^{-26} cm^2 at 35° through a minimum (3.4) at 105° to 11 at 170°. $\sigma_{\text{anom}}/\sigma_{\text{class}}=0.24$ at 35°. The peak energy of the scattered protons is constant at all angles except for the shift due to recoil. The closest approach calculated from the angle at which Rutherford's law still holds for these 6.7-Mev protons is 6.8×10^{-13} cm, in agreement with the results known from scattering of α-particles by Al.

[1] T. R. Wilkins and G. Kuerti, Phys. Rev. **55**, 1134 (1939).

135. High-Energy Secondaries Produced by Million Volt Electrons in Nitrogen Gas. GEORGE A. HORNBECK AND E. IRL HOWELL, *University of North Carolina. (Introduced by A. E. Ruark.)*—Existing data on the production of energetic secondaries by fast electrons are scanty. Williams and Terroux[1] observed 69 secondaries in oxygen with energy greater than 7500 volts, in 18 meters of track; their primaries had energies in the range 0.13 to 1.6 Mev. We have studied 35 meters of track in nitrogen, using photographs kindly put at our disposal by Dr. C. C. Jones. The incident electrons are mostly recoils produced at the walls of the chamber by gamma-rays from a sealed mesothorium source. The tracks are measured stereoscopically, due account being taken of momentum parallel to the magnetic field. Secondary electrons with energies greater than 12,000

TABLE I.

E (MEV)	METERS OF TRACK	n
0.67–0.99	8.5	12
1.00–1.32	5.4	16
1.33–1.65	4.1	8
1.66–1.98	6.4	13
1.99–2.31	7.8	13
2.32–2.64	2.3	0

volts (range > 3 mm) can be recognized unambiguously. The data are in Table I, E being the primary energy and n the number of secondaries with energy of 12,000 volts or more.

The work is being continued; comparison of observed cross section with theory will be made at the time of the meeting when a larger body of data will be reported.

[1] Proc. Roy. Soc. **A126**, 289 (1929–30).

136. The Determination of a Nuclear Energy Level from the Energy Spectrum of Scattered Particles. T. R. WILKINS AND G. KUERTI, *University of Rochester*.—The scattering camera, developed by the authors, has been used to study the energy spectrum of a beam of protons (6.7 Mev) after being scattered by a foil of Al (2.2 cm air-equivalent). The range distribution of the tracks in the photographic plates shows a single peak at small angles but with increasing angle a second peak appears. The separation of these peaks corresponds to a reduction in the energy of the peak of the beam which for the protons used was about 0.9 Mev. This is in agreement with the energy of the gamma-ray of excited Al reported by Richardson[1] and also with the differences of the energies of the protons ejected in the $\alpha-p$ reaction on Mg reported by Duncanson and Miller[2] and by Haxel.[3]

[1] J. R. Richardson, Phys. Rev. **53**, 127 (1938).
[2] W. E. Duncanson and H. Miller, Proc. Roy. Soc. **146**, 396 (1934).
[3] O. Haxel, Physik. Zeits. **36**, 804 (1935).

137. Mass and Beta-Ray Energies of Ne^{23}. WILLIAM W. WATSON AND ERNEST POLLARD, *Yale University*.—Under bombardment by 2.7-Mev deuterons we find strong activity which decays with a half-life of 45 ± 5 seconds and so is due to Ne^{23}. We have observed the absorption curve for the beta-rays from this element and find the upper limit to be 4.1 ± 0.3 Mev. A Fermi plot of the data shows that they are fitted best by two straight lines which indicates a second group whose upper limit is 2.6 ± 0.4 Mev. This is presumably due to decay to an excited state of Ne^{23}, 1.5 Mev above the ground state. We have established the presence of gamma-rays. The maximum energy given leads to a mass of 23.0005 ± 0.0006 for Ne^{23}. This indicates that the maximum energy of the protons in the reaction $Ne^{22}(dp)Ne^{23}$ should be 6.5 Mev, giving a range of 51.9 cm at right angles to the deuteron beam. This group is masked by a group due to $Ne^{20}(dp)Ne^{21}$ but there is some evidence for its presence when neon enriched in Ne^{22} is bombarded. There is definite evidence for a group of protons from $Ne^{22}(dp)Ne^{23}$ of energy change 0.9 Mev corresponding to an excited state of Ne^{23} 5.6 Mev above ground.

138. Experimental Values of the Matrix Element in Fermi's Theory of β-Decay. ROBLEY D. EVANS, *Massachusetts Institute of Technology*.—Fermi's theory[1] of β-decay affords a means of computing the radioactive decay constant λ in terms of the maximum energy of the β-spectrum E_m, the atomic number Z (taken negative for positron emitters), the nuclear radius ρ, a universal constant or group of constants g, the theoretical shape of the β-ray spectrum for allowed transitions, and the squared matrix element $|G|^2$ which roughly describes the amount of overlap between the proton and neutron wave functions in the nucleus. By graphical integration for a series of values of Z and E_m, families of curves are obtained which describe the theoretical shape of the β-ray spectra, and the integrated transition probability λ, the latter being proportional to the unknown matrix element $|G|^2$. These join smoothly with Grönblom's[2] analytically derived values for $Z=0$, and with Fermi's[1] values for $Z=82.2$ and Møller's[3] values for $Z=-82.2$ (positrons). Comparison with 60 experimental values[4] of λ, E_m, and Z allows evaluation of the apparent matrix elements as a function of Z. These show a general and marked decrease with increasing Z, so that even the most probable transitions among the heavy elements have apparent matrix elements which are less than one percent of those found for the lightest elements. This probably indicates that the matrix elements are not of the order of unity for heavy elements, as is often assumed.

[1] Fermi, Zeits. f. Physik **88**, 161 (1934).
[2] Grönblom, Phys. Rev. **56**, 508 (1939).
[3] Møller, Phys. Rev. **51**, 84 (1937).
[4] Livingood and Seaborg, Rev. Mod. Phys. **12**, 30 (1940).

139. The Energy Distribution of the Beta-Rays in Forbidden Transitions. E. J. KONOPINSKI, *Indiana University*, AND G. E. UHLENBECK, *University of Michigan*.—The success of Fermi's theory, as originally given, in explaining the form of the beta-ray energy distribution for an "allowed" transition and the fact that the best measured distributions are practically all in the "forbidden" class suggests investigation of the consequences of the theory for the forbidden spectra. This has been done for the lightest nuclei ($Z\approx0$), after making certain assumptions relating transitions analogous to quadrupole and magnetic dipole, not only with Fermi's original interaction but also with the so-called K–U modification of his law. The latter leads to much larger deviations from the "allowed" distribution than are compatible with the experimental results. On the other hand, Fermi's original law leads to a small deviation in the correct direction. The deviation is too small to account for the well-measured spectrum of P^{32} but that may easily be due to the neglect of the Coulomb field. The correction arising from this factor still awaits numerical evaluation but it is already apparent that the Coulomb influence is considerable for much lighter nuclei than was the case for the allowed transitions. The consequences of using other laws of interaction than those mentioned above will also be discussed.

140. The Shape of "Allowed" Beta-Ray Spectra. J. L. LAWSON, *University of Mighican*.—The experimental determination of the shapes of beta-ray spectra has been accomplished with accuracy only for transitions of the "forbidden" type. This is because the half-life must be long in order to make accurate observations, and the energy must be high to eliminate instrumental errors. However the observed distributions have been compared with those predicted from theories which were developed for "allowed" transitions, and therefore such comparisons do not constitute a check for the validity of these theories. It is now shown that the artificially produced radioactive indium isotope of mass 114 decays, by an internally converted gamma-ray of energy 0.19 Mev and half-life 50 days, to a level in indium, which subsequently decays by an allowed beta-emission of maximum energy 1.99 Mev and half-life 72 sec. to stable tin. It is thus possible to determine the energy distribution of particles for this allowed beta-transition accurately with the magnetic spectrometer, since the beta-rays are quite energetic and of long duration, i.e., in equilibrium with the 50-day gamma-ray. The experimental results indicate essential agreement with the shape predicted from the Fermi theory.

141. The Preparation of Absolute β-Ray Standards. JOHN W. IRVINE, JR., AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—Electrolytic deposits of lead dioxide containing known quantities of RaD have been prepared. The sources are deposited on thin platinum foil and the weight of lead obtained directly. These deposits contain approximately 0.5 mg Pb/cm^2, and are stable and coherent. After equilibrium has been established, they serve as standard sources of RaE β-rays (E max. $=1.17$ Mev). The lead was obtained from analyzed uranium minerals.[1,2] From uranium content, lead-uranium ratio and the decay constant of UI, the specific activity of the lead at the time of separation from two different minerals has been calculated as 8.04×10^3 and 3.59×10^3 β/min./mg Pb. For sources with activities lower than several thousand counts per minute, it is necessary to dilute with inactive lead before the electrolysis.

[1] Baxter and Alter, J. Am. Chem. Soc. **55**, 2785 (1933).

[2] Nier, Phys. Rev. **55**, 153 (1939).

142. Distribution in Angle of Alpha-Particles from Li^7+H^1. V. J. YOUNG, G. J. PLAIN, W. B. MCLEAN, A. ELLETT, *State University of Iowa.*—We find the distribution of alpha-particles from Li^7+H^1 is not spherically symmetric, a result in disagreement with the conclusions of earlier investigators,[1] who, however, worked only at rather low energies. Thick target data at energies as low as 150 ekv show the presence of a small $\cos^2\theta$ term and may be represented by

$$I(\theta)=1+.16\cos^2\theta,$$

while at 440 ekv the asymmetry is very marked, the data being well represented by

$$I(\theta)=1+.7\cos^2\theta.$$

Because of the rapid increase of yield with energy, it is to be expected that thin target data will show a slightly but only slightly greater $\cos^2\theta$ term. Preliminary thin target data appear to bear this out.

[1] F. Kirchner, Physik. Zeits. **34**, 785 (1933). J. Giarratana and C. G. Brennecke, Phys. Rev. **49**, 35 (1936). H. Neuert, Ann. d. Physik **36**, 437 (1939).

143. Distribution in Angle of Alpha-Particles from $F^{19}+H^1$. A. ELLETT, W. B. MCLEAN, V. J. YOUNG, G. J. PLAIN, *State University of Iowa.*—The distribution in angle of long range alpha-particles from fluorine bombarded by protons has been studied in the range 270–440 ekv. The distribution shows a very strong concentration in the forward direction. Intensity as a function of angle in the center of mass system may be represented by the equation

$$I(\theta)=1+.77\cos\theta+.17\cos^2\theta$$

for a bombarding energy of 375 ekv. The distribution shows little if any energy dependence and in particular is not observably different at 330 ekv bombarding energy. Targets were prepared by electrolyzing hydrogen fluoride on tantalum and were fairly thin, the apparent half width of the 330 ekv gamma-ray line being 40 ekv or less.

144. The Resonance in the B-P-α Reaction. W. B. MCLEAN, V. J. YOUNG, W. L. WHITSON, G. J. PLAIN, AND A. ELLETT, *State University of Iowa.*—The yield of alpha-particles of range greater than 2 cm from boron bombarded by protons has been studied as a function of bombarding energy in the range from 100 to 200 ekv, using a thin target, either methyl borate or boron trifluoride at pressures of 1 mm of Hg. The yield *vs.* energy curve shows an approximately exponential rise on which is superposed a sharp (half breadth $\sim$6 ekv) intense line at 160 ± 5 ekv. There is some indication of a weaker and much broader line at 190 ekv. Number range curves are not yet available, but the appearance of pulses on the oscillograph screen leads us to suppose that the high yield (line) at 160 ekv is due to emission of a homogeneous long range group.

145. Experiments with Radioactive Recoil Atoms. HENRY W. NEWSON AND LYLE B. BORST, *University of Chicago.* (*Introduced by S. K. Allison.*)—The angular distribution of the recoil atoms was measured (with 8-Mev deuterons) for the reactions C^{12} *d-n* N^{13} and As^{75} *d-p* As^{76}. The N^{13} reaction showed a sharp maximum at 35° and an equally sharp cut-off at 45°. Calculating[1] Q for these angles we find that most of the neutrons have energies between 5 and 7 Mev, and that $Q\cong 0$ for the highest energy neutrons. As^{76} showed a maximum at 25° and an apparent cut off at 50°. Here we find the majority of the protons near 4 Mev and considerable numbers up to 9 Mev; the apparent $Q\cong 2$ Mev, but weak groups of higher energy protons may have been missed. The distributions of Cu^{64} and Au^{198} (prepared by the *d-p* reaction) were compared under very poor geometrical conditions. The activity of Au^{198} was relatively greater than that of Cu^{64} at the larger angles. Both distributions indicated appreciable numbers of protons with energies above 10 Mev, and relatively more of them from the gold than from the copper.

[1] Newson, Phys. Rev. **48**, 79 (1935); Livingston and Bethe, Rev. Mod. Phys. **9**, 281 (1937).

146. Ring Method for Measuring Torsion Elastic Modulus. ALLEN KING, *Rensselaer Polytechnic Institute.*—The ring method[1] used for measuring Young's modulus may be adapted for the measurement of torsion moduli. The magnetic field is applied at the same point as before but, in this case, in the plane of the loop. If m is the mass per unit length of wire, a is the radius of the loop, c is the radius of the wire, E is Young's modulus for the specimen, and f is the resonance frequency, then the torsion modulus μ is given by the relation

$$\mu = E\varphi(B),$$

in which $\varphi(B)$ is a function of B only where

$$1/B = (2\pi m f^2/E)(a/c)^4(1+h)$$

and h is a gap correction term.

[1] Phys. Rev. **56**, 216 (1939); Rev. Sci. Inst. **11**, 114 (1940).

147. Scattering of Potassium Ions from Argon. R. N. VARNEY AND G. E. M. JAUNCEY, *Washington University.*—Experimental data have been obtained by Rouse[1] on the angular distribution of scattered K^+ ions of 90-, 180-, 270-, and 360-volt energies in Ne, A, Kr, Xe, and Hg. We have attempted to analyze these results to see whether they could be predicted by assuming simple inverse nth power scattering acting according to classical Newtonian laws. In the case of K^+ in A, an assumed inverse 5th power attractive force with a small solid sphere at the center, i.e., inverse infinite power repulsion, gave satisfactory agreement with experiment. The experimental results for Kr, Xe, and Hg show an increased scattering at large angles which cannot be accounted for by any simple central force law. However, in the case of these larger atoms, the polarizing force of the incoming K^+ ion doubtless distorts the electron shell to such an extent that a highly unsymmetrical structure is responsible for the observed scattering. Experiments on simpler gases, e.g., Li^+ in Ne or He, should provide interesting checks.

[1] A. G. Rouse, Phys. Rev. **52**, 1238 (1937).

148. Effects of Very High Pressures. ROBERT BYRON JACOBS,* *Massachusetts Institute of Technology.*—Quite recently Bridgman[1] has reported an experiment involving a pressure well over 100,000 kg/cm². Sodium chloride was studied, *and no transition was observed*, although one might easily have expected a transition of the type which both rubidium and potassium chloride are known to possess (that is, face-centered to body-centered structure). In 1938, on the basis of free energy calculations, the author[2] pointed out that in the case of NaI, no transition from the face-centered to the body-centered structure could be expected *at any pressure.* By analogy with the behavior of the other halide groups, it could be argued that a transition in NaCl would be even less probable than one in NaI. In view of the new experimental evidence, and of the likelihood of a general extension of the pressure range in further experiments, some new calculations have been made. For NaCl it is shown that the face-centered lattice remains thermodynamically more stable than the body-centered lattice as the pressure is increased indefinitely. Values for the total compressions to be expected are also given.

* Lalor Fellow in Physical Chemistry.

[1] P. W. Bridgman, Phys. Rev. **57** (Mar. 15, 1940).

[2] R. B. Jacobs, Phys. Rev. **54**, 468 (1938).

149. Longitudinal Vibrations of Ionic Crystals. R. H. LYDDANE, *University of North Carolina*, R. G. SACHS AND E. TELLER, *The George Washington University.*—For optically active, long wave-length vibrations in crystals there exists a difference between the longitudinal and transverse frequencies.[1,2] In the case in which there is only one infra-red active frequency and the lattice has cubic symmetry this difference is due to the fact that the coulomb interaction of the ions is not the same for the two vibrations. The difference in coulomb interaction depends on the distortion of the electronic clouds of the ions caused by ionic polarizability and by the influence of near neighbors. The polarizability of the ions may be expressed in terms of the dielectric constant, k', extrapolated from high (visible) frequencies. The influence of the near neighbors may be taken into account by introducing an effective ionic charge, e^*, in the following way: The ion is surrounded by a sphere of radius small compared to the wave-length of the vibration in question, and large compared to the lattice distance. Then the change of dipole moment caused in this sphere by a displacement, d, of the ion is defined as equal to e^*d. If e^* is expressed in terms of k, the actual dielectric constant, ω_t, the transverse frequency, and k', one finds for the relation between the longitudinal frequency, ω_l, and ω_t

$$\omega_l/\omega_t = (k/k')^{\frac{1}{2}}.$$

[1] R. H. Lyddane and K. F. Herzfeld, Phys. Rev. **54**, 846 (1938).

[2] R. J. Seeger and E. Teller, Phys. Rev. **56**, 352 (1939).

150. Electric Breakdown of Alkali Halides. R. J. SEEGER AND E. TELLER, *The George Washington University.*—A formula[1] derived for the electric breakdown of alkali halides has to be modified in that the so-called "reststrahl" frequency, which is a transverse vibration of the lattice ions, has to be replaced by a similar frequency of a longitudinal vibration. These two frequencies differ on account of the long-range effect of the ionic charges accumulated at the nodes of the longitudinal vibration.[2] The effect of the modification is that the previous formula must be multiplied by the square root of the dielectric constant and divided by the index of refraction for visible light. A direct comparison of the final result with experiment is impossible since the unknown "effective mass" of the electron in the lattice appears in the formula. If this effective mass, however, is calculated from the measured values of the breakdown fields, magnitudes obtained from the new formula are more closely that of a free electron.

[1] R. J. Seeger and E. Teller, Phys. Rev. **54**, 519 (1938).

[2] R. J. Seeger and E. Teller, Phys. Rev. **56**, 353 (1939).

151. Temperature Dependence of Young's Modulus for Single Crystals of Beta-Brass. JOHN S. RINEHART, *State University of Iowa.* (*Introduced by E. P. T. Tyndall.*)—The Young's modulus of five single crystals of brass in the beta-phase have been measured as a function of temperature from 25°C to 505°C for the purpose of studying the order-disorder phenomenon. The method of the composite piezoelectric oscillator described in detail by Balamuth, Rose, and others was used.[1,2] From linear plots of $1/E$ against the orientation function, values of the reciprocal of Young's modulus were obtained for the [100] and [111] directions as a function of temperature. The elastic constant, s_{11}, was found to change very little up to about 225°C, then increase with constantly increasing rapidity from about 3.9×10^{-12} to 5.1×10^{-12} at the critical temperature ($T_c=468°C$). From 468°C to 505°C, s_{11} increases about 0.5 percent. The results indicate that Young's modulus is closely associated with the degree of disorder.

[1] Balamuth, Phys. Rev. **45**, 715 (1934).
[2] Rose, Phys. Rev. **49**, 50 (1936).

152. Relaxation Effects in the Statistical Theory of Rubber Elasticity. EUGENE GUTH, *University of Notre Dame.*—According to the statistical theory of rubber elasticity, two types of relaxation may occur: One is due to the possibility of the sliding of the rubber chain molecules over one another; i.e., to the intermolecular viscosity. This type of relaxation gives rise to plasticity. The second is due to hindrance to the free rotations *in* the molecules; i.e., to intramolecular viscosity, which is responsible for the speed of retraction of stretched rubber. This second effect may be treated quantitatively by means of a generalized diffusion equation. The results yield for the model of rubber used a statistical interpretation of Maxwell's relation for a body with a finite time of relaxation.

153. An X-Ray Study of Fatigue in Aluminum. RAYMOND G. SPENCER AND J. WALLACE MARSHALL, *Albion College.*—Carefully prepared specimens of 17S–T aluminum alloy have been fatigued. X-ray diffraction patterns were taken as fatiguing progressed. These patterns show that distortion of crystallites precedes failure of the specimens. When a specimen is fatigued at a very high stress, deformation of the crystallites starts immediately after fatiguing starts and increases until failure of the specimen occurs; when a specimen is fatigued at a relatively low stress, very slight or no deformation occurs until it nears failure, at which time distortion starts and progresses very rapidly. The mechanism and results of distortion must be quite different for high stresses from those for low stresses. The results indicate that when a specimen is fatigued at a few thousand p.s.i. above its endurance limit, the incidence of lattice distortion indicates that the specimen is rapidly approaching failure. One can conclude from this that no detectable lattice distortion should occur when a specimen is fatigued below its endurance limit. Every specimen that we have run which exhibited lattice distortion has failed. These results do not agree with Barrett's[1] conclusions.

[1] Charles S. Barrett, Metals and Alloys **8**, 13 (1937).

154. The Structure of the X-Ray $K\beta_{2,5}$ Lines of Cu and Zn in Brasses. H. FRIEDMAN AND J. A. BEARDEN, *Johns Hopkins University.*—The pure metals Cu and Zn, previously measured,[1] exhibited $K\beta_{2,5}$ structures consistent with theories of their electronic bands.[2] In the present work on brasses, the structure of the $K\beta_{2,5}$ doublets of Cu and Zn has been studied with a double crystal spectrometer, the measurements covering a series of four alpha-brasses, 5 percent, 10 percent, 20 percent, and 30 percent Zn, a beta-brass and a gamma-brass. The Zn $K\beta_2$ emission, with increasing copper content, decreases in intensity on the high frequency side, while the low energy portion becomes relatively more intense as in pure Cu. In each alloy, both the Cu $K\beta_{2,5}$ and Zn $K\beta_2$ have identical shapes and almost the same widths, indicating a very thorough mixing of the Zn 4*s* electrons with the copper 4*s* and 3*d*. The Zn $K\beta_5$ is present in every alloy, and sharpens up as it decreases in intensity with decreasing Zn. This indicates that in pure Zn and the brasses, the 3*d* band of Zn lies sufficiently lower than the 4*s* band, so that while, in the alloys, the conduction electrons in Zn 4*s* and Cu 4*s* plus 3*d* bands are shared almost completely, the Zn 3*d* electronic levels do not mix appreciably with Cu 3*d* and are broadened mainly by interaction between Zn atoms alone.

[1] J. A. Bearden and C. H. Shaw, Phys. Rev. **48**, 18 (1935).
[2] W. W. Beeman and H. Friedman, Phys. Rev. **56**, 392 (1939).

155. The *L* X-Ray Transitions Involving the Conduction Bands of W and Pt. T. M. SNYDER AND J. A. BEARDEN, *Johns Hopkins University.*—A double crystal spectrometer was used to study the structures of the *L* absorption edges of W, WO_3 and Pt; and the related *L* emission lines of W and W_2O_5. These emission and absorption transitions involve, respectively, the filled and unfilled portions of the conduction bands of these solids. The spectra of metallic tungsten were compared with the density of conduction electron states as a function of their energy as calculated by Manning and Chodorow.[1] Although good agreement between the shape of the density of states curve and the observed structure of absorption edges was obtained, the emission lines did not show the expected structure. The WO_3 edges are shifted toward short wave-lengths with respect to those of W metal, and the large absorption maximum corresponding to transitions into the 5*d* band is broadened. The L_{II} and L_{III} edges of platinum were similar. The structure features appearing on the high frequency side of these edges correspond in their displacement from the edge, but not in relative magnitudes. In all cases the L_I edges showed entirely different structures from the L_{II} and L_{III} edges due to the action of the *l*-selection rule.

[1] Manning and Chodorow, Phys. Rev. **56**, 787 (1939).

156. The *K* Absorption Edges and $K\beta_{2,5}$ Emission Lines of Two Zinc-Nickel Alloys. W. W. BEEMAN AND J. A. BEARDEN, *The Johns Hopkins University.*—Measurements were made with a double crystal spectrometer on two Zn-Ni alloys containing 30 percent and 17 percent Zn, respectively. These alloys have a face-centered cubic lattice as does pure Ni. The Ni line is broadened by the addition of the Zn 4*s* electrons to the 3*d* and conduction bands, but not as much as by the addition of an equal number of Cu electrons in a Cu-Ni alloy. The Zn electrons are probably not as completely shared as those of Cu because of the higher nuclear charge of the former. The main peak of the Zn line is split in the 30 percent Zn alloy, and in both alloys there is structure on the low frequency side of the Zn line due to emission from the but slightly mixed 3*d* electrons of Zn. This structure has also been found in the brasses. The absorption edges show only small changes from those of the pure metals.

157. Electron Scattering in Bromine. C. H. SHAW AND T. M. SNYDER, *Johns Hopkins University.*—Electron scattering phases previously calculated in conjunction with work on the fine structure of the K x-ray absorption edge of bromine[1] were used to calculate the angular dependence of electron scattering in bromine gas. The phase shifts obtained disagree considerably with those of Arnot and McLauchlan,[2] being in general much greater for the larger values of angular momentum of the scattered electron. The angular dependence of scattering was calculated for electron energies of 15 and 40 volts. The agreement of the calculated curves with the experimental results of Arnot is shown.

[1] Snyder and Shaw, Phys. Rev. in press.
[2] Arnot and McLauchlan, Proc. Roy. Soc. **146**, 662 (1934).

158. Energy of Protons from Phosphorus, Chlorine, and Potassium under Deuteron Bombardment. Ernest Pollard, *Yale University.*—Bombardment of thick layers of P_2O_5, AgCl, and KOH by 3.3-Mev deuterons gives considerable yields of protons due to (dp) reactions. In each case the protons are in groups which are badly resolved in the case of phosphorus but definite for the other two elements. The ranges of the various groups correspond to the energy change values given in the table. There is some uncertainty as to the assignment of the lower Q values in chlorine and potassium but it is certain, on energetic grounds, that the greatest Q values correspond to Cl^{35} dp Cl^{36} and K^{39} dp K^{40} from which the masses of Cl^{36} and K^{39} can be deduced. The values are P^{32} 31.9844±0.0005, Cl^{36} 35.9795±0.0006, and K^{39} 38.9745±0.0010. Since Grahame and Walke report the upper limit of the beta-ray from Cl^{36} to be 0.7 Mev, the value 35.9787±0.0007 for the mass of A^{36} can be derived.

ELEMENT	PROTON RANGE (CM)	Q VALUE (MEV)
P^{31}	90.3	5.9±.3
$Cl^{35,37}$	104.5	6.9 "
	60.0	4.0 "
	36.9	2.3 "
$K^{39,41}$	85.3	5.6 "
	67.4	4.5 "
	51.5	3.4 "

159. The Disintegration of C^{12}, C^{13} and O^{16} by Deuterons. M. G. Holloway and B. L. Moore, *Cornell University.* (*Introduced by R. F. Bacher.*)—Carbon dioxide containing a high concentration of C^{13} has been bombarded with 1.02-Mev deuterons. The range of the emitted particles was measured by means of a pressure cell which is integral with an ionization chamber connected to a linear pulse amplifier. The reaction $H^2(d,p)H^3$ was used to determine the energy of the deuteron beam. For this purpose the disintegration energy was taken to be 3.98 Mev and the range measurement assumed to be correct. Three groups of protons previously observed by Cockcroft and Lewis[1] were measured: $O^{16}(d,p)O^{17}$, 5.75 cm and 10.96 cm (15°C, and 760 mm Hg); $C^{12}(d,p)C^{13}$, 16.21 cm. In addition, a group of alphas of 2.86 cm range was found definitely to belong to a reaction involving C^{13}, presumably $C^{13}(d,\alpha)B^{11}$, by comparison with ordinary CO_2. The group of protons from the reaction $C^{13}(d,p)C^{14}$ was not detected, although a 64-cm group might be expected in view of Pollard's work.[2] Because of the thin gas target and low bombarding energy such a group might escape detection. An upper limit of 1.2×10^{-28} cm^2 can be set for the cross section of the $C^{13}(d,p)C^{14}$ reaction with 1.02-Mev deuterons.

[1] J. D. Cockcroft and W. B. Lewis, Proc. Roy. Soc. **154**, 261 (1936).
[2] E. Pollard, Phys. Rev. **56**, 1168 (1939).

160. Emission of γ-Rays from the Disintegration of Carbon by Deuterons. W. E. Bennett and T. W. Bonner, *Rice Institute.*—Intense γ-rays have been found to be emitted when carbon is bombarded with deuterons with energies over 900 kv. The excitation curve is not a smooth one, but shows resonances at 920, 1160, 1300 and 1430 kv. The first three of these resonances are broad with half-widths of from 50 to 100 kv, but the resonance at 1.43 Mev is sharp, having an experimental half-width of about 6 kv. The origin of the γ-rays is not clear but it seems possible that they may arise from a simple capture of a deuteron by a carbon nucleus of mass 12. Another possibility is that they are connected with a short range group of protons from the reaction (C^{12}, H^2; C^{13}, H^1).

161. Production of F^{18} by Deuterons. William L. Davidson, Jr., *Yale University.*—Yasaki and Watanabe[1] have found that deuteron bombardment of oxygen gives rise to a 120-min. activity which is attributed to F^{18}. They were undecided as to whether the responsible reaction was $O^{17}(d,n)$ or $O^{16}(d,y)$. To test this point thin layers of PbO (litharge) deposited on Al foils, of 1 cm air equivalent absorption, have been bombarded by 3.5-Mev deuterons by the stacked foil method. After bombardment and several hours aging the foils were found to possess a characteristic 114-min. half-life, and rough absorption measurements gave an energy of 0.7 Mev for the particles emitted. Both these facts are in agreement with the properties of F^{18}. Evidence of γ-radiation was also found but is possibly only annihilation radiation. An excitation curve was plotted for this activity. It showed only the smooth rise characteristic of other known deuteron-induced reactions. This is prime evidence for ascribing the activity to $O^{17}(d,n)$, because a straight deuteron capture reaction would almost certainly exhibit resonance properties. Data from two separate runs, assuming the above reaction to be responsible, yield a cross section $\sigma=7.7\times10^{-26}$ cm^2 for 3.45-Mev deuterons and $\sigma=6.0\times10^{-26}$ cm^2 for particles of 3.25-Mev energy. These values are further evidence favoring the above assignment since they are of the same order of magnitude as the cross section for the well-known $O^{16}(dn)$ reaction.

[1] Yasaki and Watanabe, Nature 141, 787 (1938).

162. Radioactive Hydrogen from the Transmutation of Beryllium by Deuterons. R. D. O'Neal and M. Goldhaber, *University of Illinois.*—In the course of an investigation of the β-rays emitted from an "aged" Be target, which had been previously bombarded with 1-Mev deuterons, the maximum energy was found to be in good agreement with the value of 13±5 kev reported by Libby and Lee.[1] These β-rays had been ascribed to Be^{10}. However, in an attempt to identify chemically the radioactive isotope, we were unable to detect any activity in the beryllium precipitate. It appeared therefore plausible to ascribe the activity to H^3, which emits β-rays of similar maximum energy,[2] and which might have been formed by the reaction

$$Be^9+D^2\rightarrow Be^8+H^3.$$

We tested this assumption by showing that a radioactive gas could be extracted from the Be target, either by heating the target or by dissolving it in sulphuric acid. Further tests excluded the possibility that an appreciable fraction of the H^3-particles obtained had been formed by the disintegration of D adsorbed on the surface of the Be target.

[1] Libby and Lee, Phys. Rev. 55, 245 (1939).
[2] Alvarez and Cornog, Phys. Rev. 57, 248A (1940).

163. Excited State of Li^7 from the Reaction $Be^9(d,\alpha)Li^7$. L. S. Skaggs and E. R. Graves, *University of Chicago.*—Evidence for an excited state in Li^7 in the neighborhood of 0.5 Mev has been obtained from the reactions $Li^6(d,p)Li^7$ and $B^{10}(n,\alpha)Li^7$. We have investigated the reaction $Be^9(d,\alpha)Li^7$ using a thin BeF_2 target and an intense beam of deuterons of small energy spread. Range measurements were made using a variable pressure air absorption chamber and a shallow ionization chamber and linear amplifier for counting the alpha-particles. It was possible to bias the counting circuit so that it counted only the large pulses produced by alpha-particles entering the ionization chamber near the end of their range. Using this arrangement, we found two groups of alpha-particles differing in range by 3.1 mm. This difference indicates an excited state in Li^7 at 494±16 kv (r.m.s. deviation of experimental points). The excited state was found to be formed more frequently than the ground state. The energy released in the reaction was found by comparing the range of the alpha-particles produced with the range of alpha-particles from Po. The result was 7.09 Mev for the production of the ground state, in good agreement with the result of 7.04±0.06 Mev predicted by the reactions $Be^9(p,\alpha)Li^6$, $Li^6(d,\alpha)He^4$ and $Li^7(p,\alpha)He^4$.

164. Processes Induced in the Nuclei of Iodine and Bromine by High Energy Protons. W. H. Barkas,* E. C. Creutz, L. A. Delsasso and R. A. Sutton, *Princeton University.*—When iodine was bombarded by 6-Mev protons a negative radioactivity with a half-life of 75±2 seconds was observed. In the cloud chamber the electrons appeared to have a continuous distribution of energy extending up to about 350 kev. Chemical tests indicate that the activity is associated with a xenon isotope, the possible reactions being $I^{127}(p,n)Xe^{127}$ and $I^{127}(p,\gamma)Xe^{128}$. The most probable process for the production of these electrons is that of internal conversion. Bromine, when bombarded by protons, yielded three radioactive periods, namely: a 13±1-second negatron activity, a 55±2-second negatron activity and a long (~34-hour) positron period. When examined in a cloud chamber the short periods, like that of iodine, appeared as continuous distributions up to 300 kev. Only a doubtful resolution of the electrons belonging to the 13-second period from those corresponding to the 55-second period was obtained in experiments in which the bombardment time was varied or the observations delayed. Chemical tests indicate that the longer negatron period originates from a krypton isotope produced from bromine by a (p,n) or (p,γ) reaction. As in the case of iodine the negative electrons may best be accounted for by supposing that gamma-rays are internally converted. The positron activity is found to be a continuous spectrum extending up to 0.5 Mev, probably associated with Kr^{79} or Kr^{81}.

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165. Artificially Radioactive Element 85. D. R. Corson, K. R. MacKenzie and E. Segrè, *University of California.*—Bismuth bombarded with 32-Mev α-particles becomes α-particle radioactive. Two ranges of α-particles are present, one of 6.5 cm and one of 4.5 cm (at 15°C and 760 mm mercury). Sixty percent of the total number of alphas are in the long range group and 40 percent in the short. These two α-particles are not genetically related. There are also x-rays which show the absorption characteristics of polonium K x-rays. All these radiations separate chemically together as element 85, and all show the same half-life of 7.5 hours. A probable explanation of these effects is the following: The radioactive isotope of element 85 which is produced in the primary process has a half-life of 7.5 hours and branches, going to a bismuth isotope by alpha-emission (4.5 cm) and going to a polonium isotope by K capture. This polonium isotope has a very short life and decays by alpha-emission (6.5 cm) to a stable lead isotope. The identity of this range (6.5 cm) with that of actinium C′ strongly suggests that the primary product is 85^{211} formed by a $(\alpha,2n)$ reaction and that the polonium isotope is actinium C′. According to this scheme, the first branch leads to Bi^{207} which in turn should decay to Pb^{207}. As yet we have been unable to find this activity.

166. Some Chemical Properties of Element 85. E. Segrè, K. R. MacKenzie and D. R. Corson, *University of California.*—The chemical identification of element 85 is made on the basis of the following evidence: The activity can be easily separated from mercury, lead, thallium, bismuth and polonium ($80<Z<84$) by various reactions. The possibility that the new substance be a fission product is ruled out by physical arguments as well as by chemical evidence. Among its chemical properties we mention: It is precipitated by hydrogen sulfide in six normal hydrochloric acid solution with various carriers, and the sulfide is insoluble in ammonium sulfide; it is precipitated by stannous chloride in acid solution but not by sodium stannite in alkaline solution; it is volatile at comparatively low temperatures: a piece of bombarded bismuth loses most of the activity before melting (275°). The general behavior of element 85 is that of a metal, and in the usual scheme of analysis would go in the hydrogen sulfide group. It shows little resemblance to the other halogens. For example, in dilute nitric solution it does not precipitate with silver nitrate using iodide as a carrier. It can be distilled from dilute nitric acid solution or extracted with carbon tetrachloride but with yields very small compared with iodine under similar conditions. Dr. J. G. Hamilton has shown that element 85 is concentrated in the thyroid.

167. Thorium Fission Threshold. R. O. HAXBY,* W. E. SHOUPP,* W. E. STEPHENS,* W. H. WELLS, *Westinghouse Research Laboratories,* AND M. GOLDHABER, *University of Illinois.*—Neutrons from the reaction $\mathrm{Li}^7(p,n)$ were used to investigate the excitation function of thorium fission. By varying the energy of the protons from the Westinghouse pressure electrostatic generator, the maximum energy of the neutrons from the thick lithium metal target was correspondingly varied. An ionization chamber with thorium metal on the electrode and a linear amplifier were used to detect the fissions. It was then found that fissions occurred for neutron energies greater than 1.1 ± 0.1 Mev. This is an upper limit for the threshold, since it is uncertain how to extrapolate the excitation curve.

* Westinghouse Research Fellow.

168. Radioactive Isotopes of Rubidium. J. O. HANCOCK AND J. C. BUTLER, *Purdue University.*—Bombardment of sodium bromide with α-particles produces two radioactive isotopes of rubidium with half-lives of 20 minutes and $6\frac{1}{2}$ hours. To check these periods, krypton gas was bombarded with deuterons in a chamber separated from the cyclotron by a thin window. After bombardment the gas was displaced from the bombarding chamber over water or ethyl alcohol from which the rubidium was separated chemically. The decay curve shows periods of $6\frac{1}{2}$ hours, 200 hours and 42 minutes. The $6\frac{1}{2}$-hour period is thus believed to be due to Rb^{84} formed from $\mathrm{Kr}(d,n)\mathrm{Rb}^{84}$ and $\mathrm{Br}(\alpha,n)\mathrm{Rb}^{84}$. The 20-minute α-period is consequently assigned to Rb^{82}. The other periods obtained from the krypton cannot be assigned without further data. It was expected that Rb^{84} could be formed by the bombardment of Rb with fast neutrons, but the exposure of 1 gram of RbCl to Li+D neutrons and subsequent chemical separation of Rb gave no appreciable activity.

169. Nuclear Excitation of Indium by Electrons. GEORGE B. COLLINS AND BERNARD WALDMAN, *University of Notre Dame.*—The disintegration of beryllium[1] by electrons leads to the conclusion that it should also be possible to excite with electrons the metastable states of nuclei. In^{115} which has a metastable state[2] with a convenient period was selected. Accordingly, foils of indium were bombarded with 1.3-Mev electrons and the activities on the front and back sides measured with a G–M counter. The thickness of the foils (0.04 cm) was sufficient to prevent the electrons from producing activity on the back side. Back side activity was thus due only to x-rays produced in the indium, and front side activity is attributed to the combined effects of x-rays and electrons. The ratio of front side activity to back side activity was observed to be 2.3, and the ratio of electron excitation to x-ray excitation is thus 1.3. Other possible explanations for the above ratio are: (1) Absorption of the x-rays by the indium. This absorption was found by experiment to be negligible. (2) A more favorable geometry of the front side for x-ray excitation. This latter possibility was eliminated by following a suggestion of Professor Goldhaber which was to irradiate alloys of In-Pb and In-Al. The ratio of front side to back side activity for the lead alloy was less than that of pure indium, while this ratio for the aluminum alloy was greater, as would be expected only if electron excitation existed. A reasonable assumption concerning the efficiency of detection leads to a cross section for the process of between 10^{-32} and 10^{-33} cm^2.

[1] Collins, Waldman and Guth, Phys. Rev. 56, 876 (1939).

[2] Goldhaber, Hill and Szilard, Phys. Rev. 55, 47 (1939); Waldman, Collins, Stubblefield and Goldhaber, Phys. Rev. 55, 1129 (1939).

170. Effect of Exchange on Free Electron Diamagnetism. FREDERICK SEITZ AND J. B. SAMPSON, *University of Pennsylvania.*—In the Peierls-Wilson theory of free electron diamagnetism, which is based on a one-electron approximation, the diamagnetic contribution to the susceptibility is related to the Gaussian curvature of the energy *versus* wave number function at the top of the filled region of levels. Bardeen first pointed out that the exchange energy causes a temperature-dependent anomaly in the distribution of levels in this region and that the slope of the energy *versus* wave number curve becomes infinite as $-\log T$ at low temperatures. The effect of exchange on the Gaussian curvature has been investigated in the present work. The evaluation of the curvature necessitates solving the integral equation determining the energy to a higher approximation than Bardeen required in determining the electronic heat. It is found that the Gaussian curvature is almost exactly zero at room temperature for electron densities corresponding to the alkali metals, so that the free-electron diamagnetism is practically zero in the one-electron approximation. The effective mass turns out to be negative and equal to about $-0.4m$, in disagreement with the negative Hall coefficient of the alkali metals. This discrepancy presumably reflects the compensating influence of correlations.

171. Physical Representation of the Geomagnetic Field. A. G. MCNISH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.* (*Introduced by John A Fleming.*)—The general magnetic field of the earth may be represented to within the reliability of the observations by a dipole near the center (moment 8×10^{25} c.g.s. units), giving rise to about 80 percent of the field, and 14 secondary radially directed dipoles (average moment 0.1×10^{25} c.g.s. units) located at specified positions midway between the surface of the earth and its center, giving rise to the remainder or residual field. Secular change can be represented by the yearly addition of 13 dipoles of equal strength (moment 1.4×10^{22} c.g.s. units) at the same depth as the dipoles of the residual field. Continuance of secular change at the present rate for one hundred years would thus build up a new residual field. Interpretation of this model leads to the beliefs that (1) at least a considerable portion of the earth's magnetism (the residual field) originates at a lesser depth than the central core revealed by seismological evidence, and (2) secular change involves this residual field and therefore is due to changes taking place between the surface of the earth and the surface of the central core.

172. A Dilemma in the Magnetic Properties of $\mathrm{Gd_2(SO_4)_3\cdot 8H_2O}$. W. D. LEWIS, *Harvard University.* (*Introduced by J. H. Van Vleck.*)—Krishnan, Mookherji and Bose[1] have measured the magnetic anisotropy of $Gd_2(SO_4)_3\cdot 8H_2O$. They find a value unexpectedly large (~1 percent at room temperature) for an ion in an *S* state, and suggest that much of the observed anisotropy must be due to the dipole-dipole interaction of the paramagnetic Gd^{+++} ions. The anisotropy due to this source is computed by standard methods[2] and use of Zachariasen's x-ray measurements of the lattice parameters of the crystal.[3] An upper limit to this contribution is set and deducted from the observed anisotropy. Under the natural assumption that the remaining anisotropy is due to the crystalline field a lower bound is set to the part of the specific heat due to the crystalline Stark effect. Unfortunately Clark and Keesom[4] and de Haas and du Pré[5] have independently measured this quantity and find a much smaller value. Thus a dilemma exists. The most reasonable escape seems to be to attribute part of the observed anisotropy to contributions from paramagnetic impurities not in *S* states.

[1] Phil. Trans. Roy. Soc. **238**, 125 (1939).
[2] J. H. Van Vleck, J. Chem. Phys. **5**, 320 (1937), Sec. 4.
[3] J. Chem. Phys. **3**, 197(L) (1935).
[4] Physica **2**, 1075 (1935).
[5] Physica **6**, 705 (1939).

173. The Approach to Magnetic Saturation of Nickel under Torsional Strain. Albert R. Kaufmann, *Massachusetts Institute of Technology.* (*Introduced by Francis Bitter.*)—The magnetization of nickel may be accurately represented by the equation

$$I=I_s-(a/H)-(b/H^2)+CH$$

in the range of field from 600 to 6000 oersted. According to theory the constant *b* should depend on the crystal orientation of the specimen and on the internal strain while *C* is an ordinary susceptibility term. The significance of the constant *a* is not understood as yet. In the present experiments the values of the above constants have been determined as a function of torsional strain. Preliminary results indicate that *b* varies as the square of the elastic strain as predicted by theory, while *a* is largely dependent upon the amount of plastic deformation the specimen has received. The value of *C* is not greatly influenced by elastic or plastic distortion.

174. Effect of Heat Treatment on Ferromagnetic Impurities. F. W. Constant, H. E. Lenander and R. E. Faires, *Duke University.*—The effect of heat treatment on the ferromagnetic impurities found in commercial samples of copper, brass and silver has been studied. Hysteresis loops were determined by the sensitive torsion pendulum method before and after the specimens had been annealed. The annealing consisted of heating the specimen in a hydrogen atmosphere for several hours. The results found for copper and brass are in complete accordance with those found by Bitter and by C. T. Smith and confirm the belief that annealing leaves an iron impurity in a metastable, nonmagnetic, face-centered cubic state. The minimum annealing temperature necessary to produce this nonmagnetic state has also been investigated, as well as the effect of aging.

175. The Magnetic Properties of the Anhydrous Chlorides of the Iron Group at Low Temperatures. C. Starr, F. Bitter and A. Kaufmann, *Massachusetts Institute of Technology.*—Further measurements of the magnetization curves of the anhydrous chlorides of the iron group have been made at the temperatures of boiling and melting hydrogen. The *s*-type magnetization curves previously reported for ferrous chloride have been found to be characteristic of cobaltous chloride and nickel chloride, although the effect is not as large as for the ferrous salt. This magnetization curve is characterized by a very small initial susceptibility which decreases with decreasing temperature, followed by a very large susceptibility and eventual approach to magnetic saturation, both increasing with decreasing temperature. Manganous chloride does not exhibit these properties although its crystal structure is very similar to that of the other anhydrous dichlorides. Chromic chloride has a very large initial susceptibility, increasing with decreasing temperature. Ferric chloride does not have a similar behavior although the trichlorides have similar crystal structures. No true hysteresis has been found within the experimental error (less than 1 percent), although a small effect due to a packing phenomenon of the salt crystals does exist.

176. Absolute Measurement of Magnetic Susceptibility of Water in Weak Fields. Noel C. Jamison, *Northwestern University.*—G. Temple[1] suggested a modification of the Rankine magnetic balance which would permit the computation of absolute values of susceptibilities. Preliminary work which consisted of measuring the relative susceptibilities of benzene, carbon tetrachloride and toluene showed that, considering the magnitudes of the forces involved, considerable precision might be attained.[2] The force exerted by the specimen on the magnet was balanced by af orce resulting from the action of the magnetic field produced by a current in a coil. The susceptibility of the specimen may be computed if the distribution of magnetization in the magnet is known. This distribution was approximated by assuming a number of fictitious poles to exist along the axis of the magnet. The relative strength of the poles was computed from observations of the normal component of the magnetic field due to the magnet; the absolute values of pole strength were then found by magnetometer measurements. Preliminary computations yield a value of susceptibility of water a few percent below that which has been obtained at high fields. Refinements in experimental technique and computations may well bring the two values into agreement.

[1] G. Temple, Proc. Phys. Soc. **48**, 393 (1936).
[2] W. W. Meeks and N. C. Jamison, Phys. Rev. **57**, 71(A) (1940).

177. The Photoconductivity of NaCl in the Far Ultraviolet. J. N. Ferguson, *Cornell University.* (*Introduced by Lloyd P. Smith.*)—The photoconductivity of clear sodium chloride crystals has been measured over the wave-length region 2400A to 1500A. The measurements were made with the crystals in a vacuum monochromator. Absorption measurements could be made at the same time by means of a special photo-cell located behind the crystal. For the crystals investigated thus far photoconductivity was present over most of the above wave-length region.

178. Photoconductivity in Zinc Silicates. A. G. HILL AND L. R. ARONIN, *Massachusetts Institute of Technology.*—The following silicates have been tested for photoconductivity: Zn_2SiO_4 (both pure and with Mn activator), pure $ZnSiO_3$ and $ZnBeSiO_4$ with Mn activator. These samples were prepared from finely powdered chemicals by fusion on platinum strips. The Zn_2SiO_4:Mn phosphors show a spectral response in the range 2400A to 4350A similar to that observed by Hofstadter and Herman,[1] with a maximum around 2700A. For applied fields up to about 2000 volts/cm the response for the unpolarized sample at a given wave-length is strictly proportional to the field. The phosphor $ZnBeSiO_4$:Mn showed no photoconductivity to within one or two percent of that for Zn_2SiO_4:Mn in the range 2537A to 4350A, while the very weakly phosphorescent Zn_2SiO_4 and $ZnSiO_3$ show photoconductivity of the same order as Zn_2SiO_4:Mn, which raises the question as to whether the conductivity is impurity dependent. It may be that the method of preparation introduces impurities in the samples, which point is being further investigated. These last three silicates show a strong tendency to polarize in the presence of the applied field.

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[1] Phys. Rev. **54**, 864 (1938) and Phys. Rev. **56**, 212 (1939).

179. External Photoelectric Effect in Semi-Conductors. R. J. CASHMAN, *Northwestern University.*—Photoelectric yields for wave-lengths near the threshold have been obtained for Cu_2O in vacuum. The data are not in agreement with Fowler's theory which holds for metals. Similar tests on the data of Fleischmann[1] for several semi-conductors including Cu_2O show the same discrepancy. A simple analysis shows that the photoelectrons probably do not come from the first incompletely filled band of allowed energy states but from the first filled one where the Fermi distribution holds. These electrons should behave like those in a metal at absolute zero. The theoretical photocurrent takes the form $I=B(\nu-\nu_0)^2$. Plots of $I^{\frac{1}{2}}$ *vs.* ν proved to be linear for all the data tested except for a very small "tail" near the threshold (Fleischmann's data range from 2500 to 1850A). The "tail" is believed to be due to electrons coming from impurity levels very near the filled band. Extrapolation of the lines to zero current gives $h\nu_0$, the position of the top of the filled band. For Cu_2O, $h\nu_0=5.34$ ev; for Ag_2S, $h\nu_0=5.22$ ev. The thermodynamic potential for Cu_2O is then about 4.34 ev.[2]

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[1] Fleischmann, Ann. d. Physik **5**, 73 (1930).
[2] Condon, Phys. Rev. **54**, 1089 (1938).

AUTHOR INDEX TO ABSTRACTS OF THE WASHINGTON MEETING