Proceedings
of the
American Physical Society

MINUTES OF THE WASHINGTON, D. C. MEETING, APRIL 27–29, 1939

THE 227th regular meeting of the American Physical Society was held in Washington, D. C., at the National Bureau of Standards on Thursday and Friday, April 27 and 28, 1939, and at The Catholic University of America on Saturday, April 29, 1939. There were three parallel sessions for the reading of contributed papers on Thursday morning and afternoon, Friday morning and afternoon and on Saturday afternoon. On Saturday morning there were two parallel sessions. The presiding officers were Dean John T. Tate, President of the Society; Professor John Zeleny, Vice President; Dr. H. L. Curtis and Dr. Karl K. Darrow. The attendance at the meeting was over seven hundred.

On Friday evening the Society held its dinner at the Wardman Park Hotel. President Tate presided and called upon Professor R. T. Birge, Professor Nils Bohr, Dr. Lyman J. Briggs, Dr. Léon Brillouin, Dr. E. U. Condon, Professor H. D. Smyth and Professor John Zeleny to speak. There were two hundred and forty-seven members and their guests at the dinner.

Meeting of the Council

At its meeting held on Thursday, April 27, 1939 the death of one member (Kurt Ritzau) was reported. Two candidates were elected to fellowship and fifty-six candidates were elected to membership. *Elected to fellowship:* Paul M. Gross and Gleason W. Kenrick. *Elected to membership:* G. D. Adams, Jr., Charles L. Bartberger, France B. Berger, George A. Brueske, Georg Busch, Felix Cernuschi, Robert F. Christy, Howard S. Coleman, John G. Daunt, Leverett Davis, Lloyd T. DeVore, Werner R. Dubs, Walter P. Dyke, William N. English, Kenneth E. Fitzsimmons, Glyn W. A. Foster, John J. Gibbons, Piara S. Gill, Earle C. Gregg, Jr., Robert Q. Gregg, Berndt O. Grönblom, Howard C. Hardy, August C. Helmholz, Freeman K. Hill, Gilbert G. Hudson, Ivan Humphreys, Josef M. Jauch, Geoffrey Keller, Chihiro Kikuchi, Charles Kittel, R. S. Krishnan, Shuichi Kusaka, L. Jackson Laslett, Tom Lauritsen, Carl A. Ludeke, William B. McLean, C. W. McLenathan, John W. McNall, John M. Meek, Zen'emon Miduno, Lore C. Misch, James W. Moyer, Toshinosuke Mubo, Nathaniel B. Nichols, George Placzek, Foster F. Rieke, Robert W. Roop, Lynn H. Rumbaugh, Samuel J. Simmons, Massey Sitney, H. Hunter Smith, Harold A. Vagtborg, Samuel D. White, Zigmond W. Wilchinsky, Edwin F. Winkel and Walter Wrigley.

The regular scientific program of the Society consisted of one hundred and eighty-three contributed papers. The abstracts of these papers are given in the following pages. An author index will be found at the end.

W. L. SEVERINGHAUS
Secretary

Abstracts

1. University of Chicago Cyclotron. W. D. Harkins, H. W. Newson, R. J. Moon, A. H. Snell, L. A. Slotin, L. P. Borst, S. L. Simon, B. Carpenter and P. R. Bell.—A cyclotron built under the direction of the Chemistry Department of the University of Chicago has now been put into operation. The magnet frame is made of Armco steel and has a weight of about 60 tons; in addition there are 10.5 tons of copper in the exciting coils. The core diameter is 50 inches, having been designed to accommodate a projected accelerating chamber about 45 inches in diameter. The present accelerating chamber is 32.5 inches in diameter, and has a vacuum gap of 4.5 inches. The radiofrequency supply consists of two power triodes of the Sloan type, driven by a four-stage exciter with crystal control, and connected to the dee circuit through a short transmission line. With an operating frequency of 10.8 megacycles, deuterons are accelerated to a final energy of about 6.5 Mev.

2. The Massachusetts Institute of Technology Cyclotron. M. Stanley Livingston, John H. Buck and Robley D. Evans, *Massachusetts Institute of Technology.*—A 42-inch cyclotron is now under construction at Massachusetts Institute of Technology. This installation is to be the source of induced radioactive materials, to be used primarily in a cooperative medical research program supported by the John and Mary R. Markle Foundation. The cyclotron is housed in a new and specially designed laboratory building into which are built two baffle type water tank walls each two feet thick for protection of the operators. The magnet is constructed of Armco iron castings with General Electric exciting coils. Calibration data show the field to be exceptionally uniform and symmetrical. The "D's" are supported on the ends of coaxial quarter-wave resonant lines, eliminating insulators at points of high field. The oscillator unit uses shielded pair resonant lines for plate and grid circuits and Westinghouse 899 oscillator tubes. The cyclotron will be adjusted and operated by remote control from behind the protective walls. In the design of the cyclotron and the accompanying apparatus, an attempt has been made to combine the most satisfactory features of the various other installations. Slides will be shown illustrating the design features of the cyclotron and the laboratory.

3. The Purdue Cyclotron. W. J. Henderson, L. D. P. King and J. R. Risser, *Purdue University.*—The construction of the Purdue Cyclotron has been completed and it is now adjusted to produce deuterons of 8×10^6 electron volts energy or doubly charged helium ions of 16×10^6 electron volts energy. The magnetic field has been corrected by a ring shim of the type described by Rose.[1] In shimming the magnetic field to obtain maximum ion current it has been found that the slight bending of the $1\frac{1}{4}''$ steel lid and floor of the vacuum chamber is an important factor in giving the correct magnetic field. Following a suggestion by Livingston[2] a low voltage arc source of ions has been adapted to the cyclotron. Using this type of source the ion beam passing through the deflector system is five to six times greater than with a filament source of the hot tungsten type. The ion currents that are obtained with the arc source are about three microamperes of deuterons and 1/30 microampere of helium ions. The helium ions are being used to investigate the production of artificial radioactivity in various elements. Several new nuclear reactions have been observed.

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[1] M. E. Rose, Phys. Rev. **53**, 715 (1938).

[2] M. S. Livingston, M. G. Holloway and C. P. Baker, Rev. Sci. Inst. **10**, 63 (1939).

4. The Paths of Ions in the Cyclotron. L. H. Thomas, *Ohio State University.*—The author recently showed that in a cyclotron, the magnetic field of which varies suitably with position, the beam of ions may remain in resonance without being defocused, in spite of the relativity increase of mass with velocity, at least up to velocities at which terms in v^3/c^3 become important. The reasoning there used can be extended to give the required result to terms of all orders in v/c; the magnetic field required has then to be determined by numerical integration. The limitation to first-order variation of a central path, however, remains.

5. A New Type of Low Voltage, High Current Ion Tube for the Production of Neutrons. H. R. Crane and N. L. Oleson, *University of Michigan.*—An accelerating tube has been constructed which requires no difference of gas pressure to be maintained between the inside of the ion source and the high voltage accelerating gaps. The separation of the electrodes in the accelerating gaps is one mm. The ion source is a low voltage arc, employing a filament. It is easy to adjust the gas pressure to a value which is high enough so that a copious supply of ions is made in the source, but low enough so that no discharge takes place in the one-mm accelerating gaps. A large number of parallel holes pass through the accelerating electrodes and into the source, so that as many parallel ion beams are obtained. There is no limit to the number of parallel beams that can be used because there is no problem of the flow of gas from the source into the high voltage part of the tube. An experimental three-gap tube of over-all dimensions two inches diameter by 11 inches long produces a steady current of 1500 microamperes of deuterium ions at 35 kilovolts energy. Only a mechanical pump is used and a small leak of deuterium admitted. The only function of the pump and leak is to flush out other gases that form in the tube. If metal to glass seals were used, and the tube baked out, it could probably be sealed off. The purpose of the tube is to produce neutrons, by means of the D–D reaction.

6. Further Study of Cosmic Rays on the Pacific Ocean. Piara S. Gill, *University of Chicago.* (*Introduced by A. H. Compton.*)—Records of cosmic-ray intensity obtained on the R. M. S. Aorangi during 15 new voyages between

Vancouver and Sydney are discussed and compared with records taken during 11 voyages on the same route reported by Compton and Turner. The observed minimum of cosmic-ray intensity near the equator averages 10.3 percent less than the intensity at Vancouver, in good agreement with the value given by Compton and Turner. A correlation is found between the cosmic-ray intensity and the atmospheric temperature. An external temperature coefficient is found to be a function of latitude, with its highest numerical value of −0.25 percent per °C for latitudes higher than 40° (N and S). Using this variable temperature coefficient a latitude effect (about 8.5 percent) of magnetic origin alone is found. The mean latitude effect curve for 25 trips, corrected for external temperature, is flat beyond the critical latitudes (about 40°N and 38°S). The difference in cosmic-ray intensity between the Northern and Southern hemispheres beyond the critical latitudes after this temperature correction is found to be about 0 to 0.1 percent (probable error). This value is inconsistent with the galactic rotation effect predicted by Compton and Getting, but does not definitely rule out a more recent modification of their calculation.

7. Cosmic-Ray Bursts in Great Thicknesses of Lead. MARCEL SCHEIN AND PIARA S. GILL, *University of Chicago*.—Size-frequency distributions of bursts were obtained from analyses of records made by Carnegie model C cosmic-ray meters, shielded by 12 cm of lead, stationed at different locations. Energy distribution curves for the burst-producing radiation were made and compared with the depth-ionization curve obtained by Wilson. Because both curves, plotted on the same energy scale, have closely the same shape it was concluded that at least the greater part of the burst-producing radiation at sea level consists of penetrating ionizing rays, presumably mesotrons. The value of 10^{-4} was found for the creation probability of a burst by mesotrons of 2×10^{10} ev energy in a thickness of 12 cm of lead. This value leads to a cross section per nuclear particle (proton, neutron) of 2×10^{-30} cm^2, comparable to that estimated for nuclear explosions by Euler and Heisenberg. The ratio of the burst rates at Huancayo (3350 m above sea level) and Cheltenham (72 m) for different burst magnitudes was found to be constant, within the statistical errors, up to energies of about 1×10^{11} ev, and likewise for Teoloyucan (2285 m) and Cheltenham. For energies higher than 10^{11} ev the corresponding ratios of the burst rates increase rapidly with increasing energy of the incident particle. In order to account for this effect it is suggested that a part of the largest bursts is created by photons (electrons), a part which becomes predominant at higher elevations.

8. On the Production of the Hard Component of the Cosmic Radiation within the Atmosphere. L. W. NORDHEIM AND M. H. HEBB, *Duke University*.—The number of quanta or electrons of energy k times their range in unit lengths of radiation theory produced in matter by a primary electron of energy E is represented in excellent approximation by $N(k)dk=\alpha(E/k^2)dk$, where $\alpha=0.57$ for quanta and 0.44 for electrons. With this result and the available data on the energy distribution of the electrons coming from outside and on the distribution and absorption of the hard component (mesons) near sea level and underground, the hypothesis that the mesons are generated by the soft component within the atmosphere leads to the following consequences. The production efficiency by quanta or electrons of low energy (i.e. below 18 bev.) must be much smaller than by those of higher energy. The processes induced by the latter must be in the average of moderate multiplicity, the cross section being of the order 1/10 of that for the pair production by quanta. While in this way a reasonable account of the behavior of the hard component in the atmosphere can be given, considerable difficulties arise from the small absorption and the hardening of the cosmic radiation underground, as the required high cross sections for production of very energetic mesons would seem to necessitate similarly strong absorption by the inversion of the production processes.

9. New Evidence on the Nature of the Primary Cosmic Radiation. THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute*.—Our recent directional measurements of the cosmic radiation at very high elevations near the equator have shown but a slight asymmetry of the order of 22 percent at the zenith angle 60°, the greater intensity being from the west. In comparing this with the relatively large latitude effect at the same elevation it is clear that only a small fraction, of the order of one-fifth, of the total field sensitive radiation can be produced by unbalanced positive primary rays. Since analysis of the latitude and directional effects at sea level shows that practically one hundred percent of the field sensitive mesotron component is produced by positive primary rays, we may conclude that the mesotrons are not secondary to the primary electrons of the soft component as often supposed. Arguments based upon fundamental properties of space (zero space charge at great distances from cosmic-ray sources, and a potential equilibrium at all points) show that any unbalanced component of the radiation must consist of rays of both signs but unequal masses. These neutralize each other in space since they travel with equal velocities but unequal energies. The more massive positive rays primary to the mesotrons are probably protons or some other more massive ion. The soft component primaries can be accounted for in the same picture if the initial rays emitted from the source are electrons which multiply by pair formation in the atmosphere of the source before they are decelerated in the retarding field surrounding the source.

10. The Contribution to the Soft Component of Cosmic Radiation by the Disintegration of Mesotrons. MARTIN A. POMERANTZ AND THOMAS H. JOHNSON, *The Bartol Research Foundation of the Franklin Institute*.—The contribution to the soft component of cosmic radiation arising from the disintegration of mesotrons has been investigated at an atmospheric depth of 20 meters water equivalent. A quadruple coincidence counter train was mounted under a tower of lead in the basement of the Bartol Laboratory in such a manner that, when the apparatus was vertical, the net effective absorbing path traversed by coincidence-producing radiation was approximately two atmospheres. The absorption of the penetrating component which attained this depth was determined by interposing 20 cm of Pb in the system, and was checked against underground measurements by Auger and others.[1] When the apparatus was inclined toward a window at a zenith angle $\zeta = \sec.^{-1}(2)$ the amount of matter traversed by the coincidence-producing radiation remained the same, although the longer time required for the traversal of an equivalent mass of absorber resulted in a decrease in the intensity of the penetrating radiation, as has been previously reported.[2] Moreover, the absorption produced by 20 cm of Pb was much greater in this case, inasmuch as the disintegration of mesotrons had appreciably increased the soft component. From the absorption of the hard component determined by the vertical measurements, it was thus possible to arrive at a value of the ratio of the relative intensities of soft to hard component, $\kappa = 0.22$. The mean life of the mesotron has been calculated by applying this datum to Euler's relationship:[3]

$$\kappa = \frac{9}{4}\frac{x_0}{c\tau_0}\frac{\mu c^2}{2E_i} + \frac{1}{2}\frac{\mu c^2}{aT}.$$

With μ = one-tenth of the protonic mass, $\tau_0 = 2.8 \times 10^{-6}$ second, which is in good agreement with previous calculations.

[1] P. Auger, A. Rosenberg and F. Bertein, Comptes rendus **200**, 1022 (1935).
[2] T. H. Johnson and M. A. Pomerantz, Phys. Rev. **55**, 104 (1939).
[3] H. Euler and W. Heisenberg, Ergeb. d. Exakt. Naturwiss. (1938).

11. A Homogeneous Source of Protons for Use in Biological Investigations. G. W. Scott, Jr.* and C. P. Haskins, *Massachusetts Institute of Technology and Haskins Laboratory.*—A homogeneous source of high voltage protons for use in bombarding biological specimens is now under construction. The voltage supply is an electrostatic generator capable of producing voltages of the order of 600 kv, and with a current capacity of 750μA. The proton source is a modification of the focused electron beam type described by Scott.[1] Such a source is especially suited to this application because it permits easy control of beam intensity over a wide range as is demanded by the projected biological experiments. The significant features of this source will be discussed. The proton beam is to be accelerated in a multiple-section tube, mounted at 45 degrees to the horizontal as will be described. The tube will consist of a porcelain column six feet long and ten inches in diameter, held together with six textolite rods. A high resistance voltage divider rather than corona points will be used to distribute the potential among the accelerator sections, to ensure uniform distribution over a wide range of voltages. The beam will be analyzed and deflected through 45 degrees into the target chamber by a uniform magnetic field. There will be a brief discussion of the type of biological experiments to be performed with this apparatus.

* Haskins Laboratory Fellow.
[1] Phys. Rev. (in press).

12. Properties of the Hyperfine Structure of a Multiplet. Russell A. Fisher, *Northwestern University.*—Simple relations useful in the determination of nuclear magnetic moments from hyperfine structure data are available in many-electron atoms having well-defined multiplets. These relations, derived from the theory of hyperfine structure, are valid only if the relativistic corrections for the contributions of non-s electrons to the hyperfine splitting are negligible. With this assumption the following rules are derived: (1) In a multiplet having $S > L$ the sum of the several hyperfine interval factors within the multiplet depends only upon the contributions of the unbalanced s electrons of the configuration; (2) In a multiplet having $S < L$ the sum of the hyperfine interval factors within the multiplet depends only upon the contributions of non-s electrons. Several special cases of interest arise. If there is a single s electron in the configuration and $S > L$ the sum of the interval factors is $(L+\frac{1}{2})/Sa(s)$ where $a(s)$ is the coupling constant of the s electron. If there is no s electron in the configuration the sum of the interval factors is zero and in S states of such configurations there is no hyperfine splitting.

13. Intensities in the Hydrogen Secondary Spectrum. N. Ginsburg,* *Johns Hopkins University.*—In order to check on the analysis of the hydrogen molecular spectrum and to aid in the further analysis, a study of the relative intensities of about 600 lines in the region from 5600A to 8200A was made at various pressures and current densities. The region previously investigated by Kapuściński and Eymers[1] does not go further than 6442A and a number of very important bands lie in the near infra-red. The spectrograph used was of the Eagle type with a 15-foot, 15,000 lines/inch concave grating made stigmatic by means of a cylindrical lens. The photographic plates were calibrated by means of a step slit and a continuous source. This was a standardized tungsten band lamp; it gave the variation of the plate sensitivity with wave-length. The intensities in the molecular spectrum of hydrogen are very sensitive to the conditions in the discharge tube and the present investigation was made primarily to study these variations and to correlate them with the structure of the spectrum. Often this serves to fix the classification of lines in doubtful cases and it gives clues to the identity of unclassified lines.

* Johnston Scholar in Physics.
[1] W. Kapuściński and J. G. Eymers, Proc. Roy. Soc. **122**, 58 (1929).

14. A Recording Infra-Red Spectrophotometer. J. D. Hardy and A. I. Ryer, *Russell Sage Institute of Pathology, New York City.*—In an attempt to obtain quickly, quantitative data on the infra-red absorption spectra of biological materials an instrument of a semi-automatic recording type has been developed. Two light beams from the same Nernst filament are sent through a Wadsworth-Litrow rocksalt prism spectrometer and brought to focus on two junctions of a thermopile. The junctions are connected in opposition and the intensity of one beam can be adjusted to follow any changes in intensity of the other. No loss in sensitivity is sustained by such an arrangement and the practical resolving power of the instrument is comparable with any but the best grating spectrometers. The precision of the instrument at present is ±3 percent in transmission. The spectral range from 0.4 μ to 15 μ can be plotted on a recording drum in 30 minutes. The curves so obtained are in terms of percent absorption and wave-length. The advantages of such an arrangement are: (1) curves can be obtained in less than 1/10 the time required to plot them by hand. (2) Many bands which are missed by hand plotting are discovered. (3) The data are plotted in percent absorption so that the band intensities can be studied.

15. Additional Band Systems of Silver Halide Vapors and a New Thermodynamical Calculation of Their Dissociation Energies. N. METROPOLIS AND H. BEUTLER, *University of Chicago.*—In connection with a study of the electronic states of the silver halides, some doubt was raised concerning the accepted value of the dissociation energy of AgI. Consequently a new thermodynamical calculation has been made, and a value of 2.93±0.10 ev has been obtained (previously accepted value 2.01 ev). However, in the case of AgBr it was not yet possible to get consistent values of the dissociation energy from the thermochemical data and the optical observations. By the investigation of the absorption spectrum of AgI at shorter wave-lengths, two new band systems have been found; their analyses have been reported.[1] A further investigation at longer wave-lengths has revealed another new band system extending from 4600–4170A where a continuum begins. This continuum and the unique arrangement of these bands can be understood by the consideration of the above new value of the dissociation energy. The band-heads are represented by the following formula

$$\nu_h = 23906 + 151.2(v' + \tfrac{1}{2}) - 206.1(v'' + \tfrac{1}{2}) + 0.41(v'' + \tfrac{1}{2})^2$$

based upon 45 band-heads, originating from $v'' = 0$–12 and $v' = 0$–4. The bands degrade to the red and are nearly equally spaced. In AgBr two new analogous band systems have been observed; one system lies in the region 2400A and the other at 4200A. Their formulae will be given.

[1] N. Metropolis, Phys. Rev. **55**, 636 (1939).

16. The Use of Polaroid in Depolarization Measurements on Raman Lines. FORREST F. CLEVELAND AND M. J. MURRAY, *Lynchburg College.*—Continuation of preliminary experiments[1] has resulted in the development of a method by which the depolarization factors of Raman lines can be accurately determined with comparatively short exposure times and with elimination of errors due to the polarization characteristics of the spectrograph. A Polaroid disk, so oriented that it passes light whose electric vector is horizontal, is placed between the Raman tube and the lens which condenses the scattered light on the slit of the spectrograph. Two exposures of equal duration are made, one with the arc below, the other with it at the side of, the Raman tube. The ratio of the intensities in the two exposures (depolarization factor) is determined by comparison with the lines of seven argon spectra produced by argon light of known intensity ratios. Results for the depolarization factors of Raman lines obtained from a mixture of benzene and carbon tetrachloride are given and comparison with previous data for these compounds is made. This paper covers part of a research program which has been aided by grants from the Virginia Academy of Science, Sigma Xi, and the American Association for the Advancement of Science.

[1] F. F. Cleveland and M. J. Murray, Phys. Rev. **53**, 330(A) (1938).

17. The Infra-Red Absorption Spectrum of Methylamine Vapor. A. P. CLEAVES, *Duke University*, AND E. K. PLYLER, *University of North Carolina.*—The infra-red absorption of methylamine vapor has been measured in the region from 2–10μ with cells of 18 and 38 cm length, using pressures from 3 cm to 50 cm. The most intense band at 9.57μ corresponds to the parallel vibration between the methyl and amino groups. Its overtone at 4.83μ has also been observed. The bending vibrations of the two groups give rise to several bands in the region from 6–7μ. This causes considerable overlapping which makes it difficult to locate band centers and band types. Three bands which originate from CH vibrations occur at 3.39, 3.46 and 3.54μ. The last two are of the parallel type. The bands due to the NH valence vibrations have also been found in the region of 2.7–3.0μ. A number of weaker bands due to combinations and overtones has been observed.

18. The Absorption of Methylamine Vapor in the Photographic Infra-Red.* L. G. BONNER, A. P. CLEAVES AND H. SPONER, *Duke University.*—The absorption spectrum of gaseous methylamine in the photographic infra-red has been studied in a stainless steel tube 105 feet in length with inside mirror polish. A three-m grating spectrograph was employed in the first order, and spectra have been taken covering the region from 6000–12,000A. Bands have been found at 10,330, 9940 and 7940A at five cm, 20 cm and 60 cm pressures, respectively. The band at 9940A is resolved. There is indication of two more weak continuous bands at 10,120 and beyond 11,800A. The first two bands have been recently reported by Thompson and Skinner.[1] In agreement with their conclusions we believe that there is no free rotation in the methylamine molecule and that the moments of inertia are about 8×10^{-40} and 40×10^{-40} g cm^2. It seems probable, however, that all strong bands must be associated with NH frequencies. The positions of the strong bands agree fairly well with measurements in liquid methylamine.[2]

* Supported in part by a grant-in-aid from the Penrose Fund of the American Philosophical Society.

[1] H. W. Thompson and H. A. Skinner, J. Chem. Phys. **6**, 775 (1938).

[2] M. Freymann and R. Freymann, Comptes rendus **202**, 1674 (1936); J. de phys. et rad. **7**, 476 (1936).

19. Raman Spectra of Gaseous Amines. J. S. KIRBY-SMITH AND L. G. BONNER, *Duke University.* (*Introduced by H. Sponer.*)—An investigation has been made of the Raman spectra of a series of gaseous amines at pressures from two to three atmospheres. Results were obtained, using a high intensity apparatus built especially for the observation of the Raman effect in gases. Our measurements indicate Raman shifts as follows: Methylamine: 781 (2 *s*); 1042 (7 *s*); 1460 (3 *vb*); 2808 (6 *s*); 2889 (7 *b*); 2967 (10 *s*); 3368 (10 *s*); 3470 (2 *s*). Dimethylamine: 794 (2 *s*); 934 (7 *s*); 1448 (3 *vb*); 2792 (10 *s*); 2847 (7 *s*); 2965 (12 *vb*); 3384 (7 *s*). Trimethylamine: 271 (1); 363 (1); 422 (1); 830 (7 *s*); 1033 (2 *vb*); 1286 (5 *b*); 1457 (7 *vb*); 2741 (3 *s*); 2780 (10 *s*); 2829 (5 *s*); 2961 (10 *b*); 2990 (3 *vb*). A broad diffuse line without apparent structure lying at about 1450 cm^{-1}, and particularly intense in the case of trimethylamine, seems to be characteristic of these substances. This line is undoubtedly to be associated with the $C-H$ bending frequency. The $N-H$ valence frequencies which fall in the neighborhood of 3400 cm^{-1} appear as expected for the various compounds.

20. Excitation of O^{++} by Electron Impact. M. H. HEBB, *Duke University*.—The excitation of low states of certain atomic ions by impact of slow electrons is of considerable interest in the study of physical conditions in the nebulae. For this reason, at the suggestion of D. H. Menzel, a calculation was undertaken of the cross sections for transitions by electron impact between the lowest states of O^{++} which is a typical ion. The states considered were the ^3P, ^1D and ^1S states which arise from the ground configuration of the ion and lie within an interval of six volts. The method utilized was a modified Born approximation, using instead of plane waves the exact wave functions for an electron in a Coulomb field. Tables of the radial function in the Coulomb field were constructed and the radial integration of the integrals involved in the cross sections was carried out numerically. The $2p$ electrons of the ion were represented by an analytic approximation to the wave functions of Hartree for O^{++}. As a direct consequence of the Coulomb field, the cross sections in first approximation for electrons of low velocity vary inversely as the energy of the impinging electron and in order of magnitude range from 8×10^{-18} to 2×10^{-15} cm^2 for different transitions at ten volts.

21. Crystal Field Energy Levels in Pr Salts. CECIL B. ELLIS,* *Columbia University*.—In order that the rare earth crystal spectra may serve as a tool for determining the internal electric fields within crystals it is necessary that many of the patterns into which the crystal field splits the free-atom levels be experimentally determined. Hitherto in spite of the exhaustive low temperature wave-length lists of Spedding[1] and of Merz,[2] the crystal field lines could not be distinguished from the many vibrational lines usually present; so that no crystal field pattern has been completely identified except the ground state of Sm. By comparing the *raies ultime* in polarized light of thin crystals at room temperature (diluted with Ce) with the existing low temperature data, it is now possible to locate a few crystal field levels in two Pr salts: *Ethylsulfate:* $^3H_4=0$, 12, $\cdots$; $^1D_2=16708$, 16858, 16955; $^3P_0=20685$; $^3P_1=21275$, 21289; $^3P_2=22410$–22480 cm^{-1}. *Sulfate (Octahydrate):* $^3H_4=0$, 50, 110, 180, 230, 280, 320, 500; $^3P_0=20720$; $^3P_1=21158$, 21238, 21359 cm^{-1}. From comparison of Pr, Nd, Sm and Gd spectra it seems that sulfates and chlorides usually give the maximum possible number of almost equally spaced components, corresponding to crystal fields of low symmetry. In the ethylsulfates the number of components corresponds to a field of predominantly axial symmetry, which leaves M often a good quantum number—a point of great aid in analysis.

* Instructor at The College of the City of New York.

[1] F. H. Spedding *et al.*, J. Chem. Phys. **5**, 416 (1937).

[2] A. Merz, Ann. d. Physik **28**, 569 (1937).

22. Observations with a New Radiation Pyrometer. JOHN STRONG, *California Institute of Technology*.—Observations in the infra-red region of the spectrum were made with a new radiation pyrometer.[1] The monochromatic bands of radiation employed are isolated by means of the residual rays of apophyllite at 9.7μ, of quartz at 8.7μ, and of carborundum at 12μ. Solar observations on the strength of the Hartley ozone band and the Φ-band of water were made concurrently with the infra-red observations. Correlations between these observations have a bearing on the height and temperature of the ozone layer. The infrared measurements at 8.7 and 12μ give the absorption of the atmosphere in this spectral region and they allow of a comparison between the heat radiation emitted by the sun and the Rayleigh-Jeans heat radiation from a laboratory blackbody.

[1] J. Strong, Phys. Rev. **54**, 242(A) (1938).

23. $L\alpha$ Satellites for Elements $41<Z<57$. L. G. PARRATT AND C. A. RANDALL, *Cornell University*.—The x-ray satellite lines accompanying the $L\alpha$-emission for elements $41<Z<57$ have been systematically studied with a two-crystal vacuum spectrometer. The qualitative relation between atomic number and the integrated intensities of the satellites relative to the $L\alpha_{1,\,2}$ lines agrees with the photographic measurements of Hirsh[1] and further confirms the Coster-Kronig interpretation of Auger production of the initial satellite state. Quantitatively, however, the present relative intensity measurements with the ionization method are lower than the photographic measurements[1] by a factor of about one-sixth. The observed satellite contour for each element has been resolved arbitrarily into the apparent constituent component lines. The wave-lengths and relative intensities of these components have been measured. A few satellite components, hitherto unreported, are found. Theory predicts[2] fifteen $L\alpha$ satellite components for Au(79), about twice as many as are included in the present analysis for the middle range of atomic numbers.

[1] F. R. Hirsh, Phys. Rev. **48**, 722 (1935).

[2] F. K. Richtmyer and E. G. Ramberg, Phys. Rev. **51**, 925 (1937).

24. Intensity Anomalies in Electron Scattering from ZnO. R. M. WHITMER AND H. J. YEARIAN, *Purdue University*.—Experimental electron scattering curves for ZnO have been obtained at temperatures of $-183°C$ and at $+350°C$. There appears to be no appreciable variation of the anomalies observed at room temperature.[1, 2] Within this range, the temperature does not appear to affect the rate of decrease of intensity with increasing $(\sin\theta)/\lambda$, which indicates that the characteristic temperature is considerably above the 355° estimated by Yearian.[2] Lark-Horovitz and Ehrhardt[3] have computed electron scattering curves from experimental x-ray data on ZnO, applying a temperature correction which was monotonic in $(\sin\theta)/\lambda$. This type of correction is given further support by the present work.

[1] H. J. Yearian and K. Lark-Horovitz, Phys. Rev. **42**, 405 (1932).
[2] H. J. Yearian, Phys. Rev. **48**, 631 (1935).
[3] K. Lark-Horovitz and C. H. Ehrhardt, Phys. Rev. **55**, 605(A) (1939).

25. X-Ray Diffraction by Liquid Ethyl Alcohol. G. G. Harvey, *Massachusetts Institute of Technology.*—X-ray diffraction curves for liquid ethyl alcohol at a temperature of −75°C have been taken with monochromatic Mo $K\alpha$ radiation out to values of $(\sin\theta)/\lambda = 1.2$ and a Fourier analysis of these curves has been carried out. The weighted radial electron distribution function shows a number of well-defined peaks. The first of these, at about 1.5A, corresponds to the C−C (1.54A) and C−O (1.43A) distances in the molecule, the two being superposed. This composite peak is completely resolved from the remainder. A peak at about 2.4A may be interpreted as due to the other C−O distance within the molecule. These are the only definite distances, corresponding to permanent neighbors, that would be expected. A most interesting feature is the existence of a peak at about 2.9A corresponding to O−O intermolecular linkages, similar to the situation found in methyl alcohol.[1, 2] The area under this peak shows that each hydroxyl is linked to, roughly, two others, as was also found to be the case for methyl alcohol. Beyond this there are no very definite distances, the density curve rapidly approaching the average density.

[1] W. H. Zachariasen, J. Chem. Phys. **3**, 158 (1935).
[2] G. G. Harvey, J. Chem. Phys. **6**, 111 (1938).

26. Particle Size Determination with Side-Reflection X-Ray Cassette. C. Nusbaum, *Case School of Applied Science.*—In 1926 von Laue published an article in which he developed an expression relating the particle size of a diffraction sample to the width of its diffraction line. This relationship was more general than that of Scherrer, previously published, as it holds not only for the cubic system, but also for particles whose three dimensions are different. It applies only to a divergent beam and necessitates the use of a Debye-Scherrer cassette. In many cases it is more convenient to use a Seemann-Bohlin (side reflection) cassette as in the case of thin metallic deposits. In this cassette the slit, sample and film are located on its circumference. By making the vertical divergence of the beam incident on the sample very small, sharp line definition is obtained. von Laue's expression then becomes

$$n = K\left[B\cos\theta - \frac{1}{B}\frac{\pi}{4}\left(\frac{h}{R}\right)^2\cos^2\theta\right],$$

where K is a constant, h half the vertical height of the beam, θ the Bragg angle, and B is defined by $B = B_0/R\sec\phi$ where B_0 is the width of the line at one-half maximum intensity, R the radius of the cassette, and ϕ the angle of incidence of the refracted beam at the film.

27. Crystal Structure of $LiOH \cdot H_2O$. Raymond Pepinsky, *University of Chicago.*—$LiOH \cdot H_2O$ is monoclinic prismatic, with $a = 7.36$A, $b = 8.36$A, $c = 3.13$A, $\beta = 110.5°$. Space-group is $C_{2h}^3 - C2/m$, and density of 1.51 gives $Z = 4$ molecules per cell. Four oxygens are in reflection-planes, in hydroxyl groups, remaining four are in H_2O groups on twofold axes $(0,y,0)$. Lithiums are on twofold axes $(0,y,\frac{1}{2})$. Parameters are

$$\begin{aligned}&O_{\mathrm{OH}}\colon (104°, 0°, 160°);\\&O_{\mathrm{H_2O}}\colon (0°, 75°, 0°);\\&\mathrm{Li}\colon (0°, 125°, 180°),\end{aligned}$$

with the remaining positions following from symmetry. Each lithium is at the center of an almost perfect oxygen tetrahedron, of edge 3.1A and with a Li–O distance of 1.99A. Two such tetrahedra share an edge parallel to the a axis in a reflection plane, and the paired tetrahedra then form unending chains in the z direction. The chains of paired tetrahedra are linked by hydroxyl bonding, the distance between bonded O's in adjacent chains being 2.7A. A more complete discussion of the structure will be published elsewhere.

28. The X-Ray K Absorption Limits of Iron, Nickel, Copper and Zinc. H. Friedman and W. W. Beeman, *Johns Hopkins University.* (*Introduced by J. A. Bearden.*)—A double crystal spectrometer has been used to measure the mass absorption coefficients of Fe, Ni, Cu and Zn as a function of wave-length. Measurements have been made over a range of 50 volts at each K absorption limit. Intensities were measured with Geiger counters absorbing between 10 percent and 40 percent of the incident radiation. The I/I_0 ratios were repeatable to less than two percent at each point and wave-lengths were recorded to less than 0.02 x.u. employing the most recent data on emission lines to calibrate the instrument. Electroplated and rolled foils and metallic powders showed the same structure. For each metal definite structure has been found in the region lying within 20 volts of the high frequency side of the main edge, previously untested with the double-crystal spectrometer. The measurements also showed structure in the edges themselves in disagreement with some of the work of Barnes.[1] It is believed that this discrepancy is due partially to the higher resolving power of the crystals used and partially to the fact that the present work plots mass absorption coefficient. The shape of an I/I_0 curve is determined largely by the thickness of the absorber.

[1] A. H. Barnes, Phys. Rev. **44**, 141 (1933).

29. X-Ray Evidence on the Band Structure of Copper and Nickel. W. W. Beeman and H. Friedman, *Johns Hopkins University.* (*Introduced by J. A. Bearden.*)—Calculations have recently been made of the band structure of Cu[1] and the results extrapolated to Ni.[2] Experimental evidence about the variation of density of states in these bands is furnished by the fine structure of the K absorption edges and the shapes of the $K_{\beta_{2,\,5}}$ emission lines.[3] By a comparison of the wave-lengths of the K absorption limits and the $K_{\beta_{2,\,5}}$ lines, it can be shown that the latter must be due to transitions from the conduction levels and $3d$ bands to the empty K shell. Qualitative agreement is obtained in the case of Cu between the observed structure and the density of states in the conduction and d bands as calculated by Krutter. The structure for Ni is consistent with Slater's extrapolation of Krutter's work for Cu.

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[1] H. M. Krutter, Phys. Rev. **48**, 664 (1935).
[2] J. C. Slater, Phys. Rev. **49**, 537 (1936).
[3] J. A. Bearden and C. H. Shaw, Phys. Rev. **48**, 18 (1935).

30. A High Vacuum X-Ray Spectrometer. J. H. MUNIER, *Johns Hopkins University.* (*Introduced by J. A. Bearden.*)—A double-crystal spectrometer has been developed for the study of long wave-length x-rays. The x-ray tube has been placed in the highly evacuated spectrometer chamber, permitting the use of an open window which greatly reduces the absorption in the path of the radiation. The detector is a Geiger-Mueller counter which has an aluminum window of 0.0001-inch thickness. This window will stand sufficient air pressure for satisfactory operation of the counter. The crystals used are the aquamarine form of beryl $Be_3Al_2(SiO_3)_6$ in which the 1010 planes have a grating constant of 8.08A. The physical resolving power of the pair used is 2000. The instrument has operated in a highly satisfactory manner in a study of the satellite structure and shape of the M series emission lines of tungsten. A study of the structure of the K absorption limit of aluminum and the L absorption limit of copper at 8A and 13A, respectively, is in progress.

31. The Diffraction of X-Rays by Liquid Tin and Liquid Chlorine. CARL GAMERTSFELDER, *University of Missouri.*—X-ray diffraction patterns of liquid tin at 250°C and 390°C and of liquid chlorine at 22°C under its own vapor pressure have been obtained. A diffraction camera with a 9.20-cm radius was used with Mo K_α radiation monochromatized by crystal reflection. In the case of tin, a flat sample 0.006 cm thick was used, it was heated electrically and its temperature was measured by means of a thermocouple placed near the sample. Liquid chlorine was contained in a thin-walled glass capillary 1.5 mm in diameter. The diffraction patterns of tin showed three peaks with a slight shelf on the main peak, while those for chlorine show three maxima. These intensity curves were corrected, fitted and analyzed in the usual manner, to obtain the atomic distribution curves. The distribution curve for liquid tin at 250°C has its first maximum at 3.38A, and the area under this peak indicates the presence of ten nearest neighbors. This agrees well with the distribution of atoms about a given atom in white tin. The distribution curve for tin at 390°C is similar to that for the 250°C except that the peaks appear less distinct. The distribution curve for chlorine at 22°C under its own vapor pressure shows that each atom has one discrete neighbor at 1.84A. This indicates that liquid chlorine is molecular with two atoms per molecule.

32. The Structure of Liquid Potassium. N. S. GINGRICH, *University of Missouri,* AND C. N. WALL, *North Central College.*—Analysis of x-ray diffraction patterns of liquid potassium has led to the determination of the atomic distribution in potassium at 70°C and at 395°C.[1] Information concerning the liquid state can be obtained from these atomic distribution curves by a method which has been used for liquid sodium.[2] It is assumed that the potential energy of a simple liquid has a pronounced minimum for a certain set of atomic configurations, and it is effectively infinite for all others. This set of configurations is characterized by assigning to each atom a small volume v within which it is free to move independently of other atoms without appreciably altering the condition of minimum potential energy for the entire assembly. The "free volume" v is obtained from the atomic distribution curve, the free energy is obtained from the free volume, and the entropy of the liquid is obtained from the free energy. With atomic distribution curves at different temperatures, a relation between the free volume and the temperature may be found, and hence, by extrapolation, the entropy of the liquid at the melting temperature and at the boiling temperature can be determined. Using the entropy of solid potassium[3] at the melting temperature, we calculate the latent heat of fusion as 2.06 kj/mol (experimental value 2.38 kj/mol).[4] Using the entropy of potassium vapor at the boiling temperature,[2] we calculate the latent heat of vaporization as 87.5 kj/mol (experimental value 84.9 kj/mol).[4]

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[1] C. D. Thomas and N. S. Gingrich, J. Chem. Phys. **6**, 411 (1938).
[2] C. N. Wall, Phys. Rev. **54**, 1062 (1938).
[3] Simon and Zeidler, Zeits. f. physik. Chemie **123**, 383 (1926).
[4] *Int. Crit. Tables.*

33. The Mutual Absorption of the Rh and In Levels. J. H. MANLEY, *University of Illinois*; J. HORNBOSTEL, *New York University, Washington Square College,* AND H. H. GOLDSMITH, *Columbia University.*—We have employed the mutual absorption method,[1] applicable to case of overlapping levels, in order to obtain Γ_{In}, the width of the In level, and $|E_{\mathrm{In}}-E_{\mathrm{Rh}}|$, the spacing between the In and Rh levels. The four absorption curves (In abs − In det; In − Rh; Rh − Rh; Rh − In) obtained by using Rh detectors of 0.1 g/cm² and In detectors of 0.08 g/cm² and measuring the activity with a high pressure ionization chamber showed $\Gamma_{\mathrm{In}} \leqq \Gamma_{\mathrm{Rh}}$ and that $|E_{\mathrm{In}}-E_{\mathrm{Rh}}| \sim \Gamma_{\mathrm{Rh}}$. To check this and to obtain quantitative results without excessive calculations, measurements were made with thinner detectors ($\delta_{\mathrm{Rh}}=0.016$ g/cm² and $\delta_{\mathrm{In}}=0.0076$ g/cm²), a G-M counter and a scale of eight arrangement. The values of the absorption coefficients are: (a) $K(\mathrm{In}-\mathrm{In})=53\pm 4$, (b) $K(\mathrm{Rh}-\mathrm{Rh})=12\pm 0.8$, (c) $K(\mathrm{In}-\mathrm{Rh})=13\pm 3$, and (d) $K(\mathrm{Rh}-\mathrm{In})=5\pm 0.5$. These yield $\Gamma_{\mathrm{In}}=0.5\Gamma_{\mathrm{Rh}}$ and $|E_{\mathrm{In}}-E_{\mathrm{Rh}}|=1.1\Gamma_{\mathrm{Rh}}$ in agreement with the results obtained with the thicker detectors. The value of $|E_{\mathrm{In}}-E_{\mathrm{Rh}}|$ is close to that obtained from the boron absorption method, and from an application of the Cd $1/v^5$ law. The value of $K(\mathrm{In}-\mathrm{In})$ is also in agreement with the In resonance cross section previously determined[2] from an analysis of the In − In curve obtained with thick detectors.

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[1] H. A. Bethe, Rev. Mod. Phys. **9**,71 (1937), ¶61, E.
[2] Manley, Goldsmith and Schwinger, Phys. Rev. **55**, 107 (1939).

34. On the Relation Between Neutron-Alpha and Alpha-Proton Scattering. H. Primakoff, *Polytechnic Institute of Brooklyn*, and H. H. Goldsmith, *Columbia University*.—The assumption that the nuclear force between heavy particles is independent of charge leads to a simple relation between the proton and neutron elastic scattering cross sections for a given element.[1] A derivation of this relation has been found, independent of the details of the nuclear model and forces, and it has been employed in an attempted correlation of the experimental results of the scattering of neutrons from He,[2] and α-particles from hydrogen.[3] The resonance found in neutron-He collisions for a neutron energy $E_n \cong 1$ Mev should appear in the proton-He case, for $E_p \cong 2$ Mev or $E_\alpha \cong 8$ Mev. Some evidence for the occurrence of such a resonance appears in the scattering of Th C′ α-particles from hydrogen. Apart from the resonance, the magnitude and energy dependence of the neutron-α cross section is sufficient to account approximately for the observed deviations from the Rutherford-Coulomb scattering found for 2–6 Mev α-particles in hydrogen.

[1] H. Primakoff, Phys. Rev. **52**, 1000 (1937).
[2] H. Staub and W. E. Stephens, Phys. Rev. **55**, 131 (1939).
[3] Chadwick and Bieler, Phil. Mag. **42**, 923 (1921); Mohr and Pringle, Proc. Roy. Soc. **160**, 190 (1937).

35. Transmutation of Boron by Slow Neutrons with the Emission of α-Particles and Protons. J. B. Fisk, *University of North Carolina*.—The transmutation of B^{10} by slow neutrons has been observed some 40,000 times by use of BCl_3 vapor in an ionization chamber coupled to a linear amplifier and recording oscillograph.[1] Evidence is obtained for the reaction $B^{10}(n, p)Be^{10}$ as well as for the well-known reaction $B^{10}(n, \alpha)Li^7$, the two being about equally probable. The (n, α) reaction is studied in detail. There are four or five energy groups, the most energetic corresponding to 2.90 Mev in good agreement with the 2.98 Mev available as calculated from nuclear masses. The groups may be interpreted in terms of excited states of Li^7 at 200, 410, 640 and 840 kev above the ground level. Alternatively, one may interpret the results of the experiment in terms of a level in Li^7 at 410 kev, together with a "multiplet" in B^{11} at 2.90, 2.70 and 2.06 Mev above the Li^7 ground state (i.e. the B^{11} excited level into which the slow neutron is captured is about 11.5 Mev above the ground level of B^{11}). This scheme is internally consistent and is unique. There are, however, severe theoretical difficulties with this scheme, as well as with the alternative interpretation.

[1] W. Maurer and J. B. Fisk, Zeits. f. Physik (in press).

36. The Disintegration of Boron by Slow Neutrons. M. Goldhaber, R. D. Hill,* P. G. Kruger and F. W. Stallmann, *University of Illinois*.—It has been shown recently by Lawrance, Burcham and Goldhaber[1] that the angular distribution of the disintegration tracks obtained in the disintegration of boron by a well-defined beam of slow neutrons ($B^{10}+n^1 \rightarrow Li^7+He^4$) is asymmetrical, the direction parallel to the neutron beam being favored. In their experiments a boron impregnated photographic emulsion was used. In order to distinguish between the direction of the He^4 and Li^7 recoils, which is not possible in a photographic emulsion, we have studied the boron disintegration in a Wilson chamber, containing targets of thin boron glass (about 1.5 mm stopping power). A beam of slow neutrons entered the chamber through an aluminum window. The rest of the chamber was shielded by Cd and B_4C. The angular distribution of 60 tracks has been measured by stereoscopic reprojection. The results are in qualitative agreement with those obtained with the photographic emulsion. More α-particles are found to be emitted forward than backward relative to the beam direction. Experiments in which the Al window of the chamber was covered by Cd show that about 90 percent of the observed disintegrations were due to C neutrons. The range of the α-particles from the boron disintegration has been measured for 80 tracks. In agreement with Bower, Bretscher and Gilbert[2] only one group of α-particles has been found. If a second group exists, it must be less than ten percent in intensity.

* 1851 Exhibition Scholar.
[1] A. M. Lawrance, W. E. Burcham and M. Goldhaber, Proc. Roy. Soc. Ser. A (in press).
[2] J. C. Bower, E. Bretscher and C. W. Gilbert, Proc. Camb. Phil. Soc. **34**, 290 (1938).

37. The Occurrence of Slow Mesotrons. C. G. Montgomery, W. E. Ramsey, D. B. Cowie and D. D. Montgomery, *Bartol Research Foundation*.—The explanation of the difference in the absorption of cosmic rays by equal masses of water and air postulates that mesotrons disintegrate spontaneously into electrons and neutrinos. To investigate this effect the following experiment was performed. A tray of counters, placed over a lead plate two centimeters thick, detected mesotrons entering the lead. Below the plate was another tray of counters for detecting the disintegration electrons. The recording circuit registered those counter discharges in the lower tray which followed, by a certain time interval, counter discharges in the upper tray. Observations were taken with the lead plate alternately present and absent. The difference in the counting rates represents the number of mesotrons which have stopped in the lead plate and subsequently disintegrated. Although a considerable number of disintegrations were expected, no appreciable number were observed. For example, in one series of observations, the time lag was 1.6 microseconds, and we expected about 40 disintegrations to be recorded per hour. The observed rate was 2.5 ± 3.4 per hour. Observations with other time lags gave similar results. This discrepancy suggests that some type of absorption process other than spontaneous disintegration is very effective in removing slow mesotrons from the cosmic radiation.

38. Studies with the Neutrons from p-n Reactions in Lithium and Beryllium. J. E. Hill, *University of Rochester*. (*Introduced by L. A. DuBridge.*)—The relative neutron yields, from lithium and beryllium, bombarded with 4.4-Mev deuterons and with 6.7-Mev protons, were obtained by measuring the induced radioactivity in silver produced by the neutrons after filtering them through 10 cm of paraffin. The results show the neutron yields at these energies for the four reactions Li-d, Be-d, Li-p, Be-p, to be in the ratio 1 : 1 : 1.8 : 1.9, with a probable error of 15 percent. The neutrons from the reaction[1, 2] $Li^7(p\text{-}n)Be^7$

have a sharp and controllable upper limit of energy equal to the difference between the proton bombarding energy and the energy threshold (2.0 Mev). They are therefore useful for determining thresholds for reactions of the type (n-p) or (n-α). In this manner the threshold for the reaction $Al^{27}(n\text{-}p)Mg^{27}$ has been found at 2.6 Mev. This agrees with the value calculated by adding the maximum energy of the electrons from Mg^{27} (2.05 Mev)[3] to the energy of the gamma-rays (1.3 Mev) and subtracting the mass difference (n-H^1). Work is now in progress on other elements.

[1] L. A. DuBridge, Phys. Rev. **55**, 603(A) (1939).

[2] J. E. Hill and G. E. Valley, abstract 34, New York Meeting Feb. 24, 1939.

[3] M. C. Henderson, Phys. Rev. **48**, 885 (1935).

39. On the Temperature Dependence of the Scattering of Slow Neutrons in Ferromagnetics. F. Bloch, *Stanford University*.—In the earlier derivation of the magnetic scattering we assumed that the neutron wave, scattered by magnetic interaction of the neutron moment and the atomic electrons, has an amplitude proportional to the saturation magnetization. It is shown that this result holds rigorously for the coherent scattering but that there is besides an incoherent scattering. This is small only because kT_C (T_C = Curie temperature) is large compared to the initial and final energy of the neutron, considering in the latter a possible transfer of ferromagnetic energy into kinetic energy of the neutron. In the other extreme case of small T_C this incoherent scattering would be so big as to make the quadratic term in the magnetic cross-section temperature independent.

40. The Scattering of Neutrons by Helium Nuclei. W. E. Shoupp, P. Gerald Kruger, F. W. Stallmann and G. R. Gamertsfelder, *University of Illinois*.—The scattering of neutrons of mean energy of 2.6 Mev by helium nuclei has been studied by observing recoil helium nuclei in a cloud chamber filled with helium. Three thousand pictures yielded 940 tracks of which 475 had the proper momentum to have come directly from the source. As in other studies of this type[1, 2] it was necessary to make corrections for random tracks and azimuthal angle. Within the limits of experimental error, the resultant angular distribution of recoil helium nuclei, in the center of mass system, indicates a deviation from spherically symmetrical scattering.

[1] Kruger, Shoupp and Stallmann, Phys. Rev. **52**, 678 (1937).

[2] Kruger, Shoupp, Watson and Stallmann, Phys. Rev. **53**, 1014 (1938).

41. The Production of Artificial Radioactivity by α-Particles. L. D. P. King, W. J. Henderson and J. R. Risser, *Purdue University*.—The 16×10^6-volt doubly charged helium ions accelerated by the Purdue Cyclotron are being used to investigate the production of artificial radioactivity. The ion beam is about 1/30 microampere corresponding to 10^{11} particles per second. Pure graphite when bombarded becomes radioactive with a half-life of 2.1 minutes; the activity is undoubtedly O^{15} produced by $C^{12}(\alpha, n)O^{15}$. This reaction has not been reported with α-particle energies up to nine Mev. From the mass of O^{15} found from $O^{15}-N^{15}+e^+$ the above reaction becomes energetically possible at between eight and nine million volts. Silver becomes radioactive with a half-life of 26.8 minutes; the activity has been chemically identified as an isotope of indium and is assigned to In^{110} produced by $Ag^{107}(\alpha, n)In^{110}$. Rhodium exhibits strongly the 24.5-minute silver period reported by Pool.[1] When quartz is bombarded, a half-life characteristic of P^{32} is found.[2] This radioactive isotope is well known from other reactions. The process here is $Si^{29}(\alpha, p)P^{32}$. Other elements in which radioactivity has been observed are (with approximate half-lives): Selenium (6 hr., 1 hr., 1 to 2 min.); Gold (4 min., $3\frac{3}{4}$ hr.); Columbium (3 hr., 2 shorter periods); Sulphur (1.1 hr.); Molybdenum (85 to 90 min.). Accurate measurements of the half-lives and chemical identification of the radioactive isotopes are in progress.

[1] M. L. Pool, Phys. Rev. **53**, 116 (1938).

[2] Fahlenbach, Zeits. f. Physik **96**, 503.

42. Disintegration of the Isomers of Ag^{106}. T. Enns, *University of Rochester*. (*Introduced by Charles V. Strain*.)—Palladium bombarded by high energy protons gives several radioactive periods of which two are the known isomers of Ag^{106} resulting from the reaction

$$Pd^{106}+p\rightarrow Ag^{106}+n.$$

One of the isomers decays to Pd^{106} by positron emission. The half-life is 25 minutes. The proton excitation curve shows a threshold of 3.8 Mev, which is in agreement with the positron energy limit obtained by M. L. Pool.[1] The other isomer decays to Pd^{106} by K-electron capture. The radiation consists chiefly of γ-rays. The half-life has previously been reported as 8 days.[1] The proton excitation curve gives a threshold of 3.9 Mev. X-ray absorption measurements indicate the presence of $K\alpha$-radiation. The energy level difference of 3.1 Mev between the Pd^{106} ground state and the Ag^{106} state giving the long period disintegration makes the existence of excited states of Pd^{106} possible.[2] The K-electron capture accompanied by the emission of a low energy neutrino leaves the Pd^{106} in an excited state. The ground level is reached by descent to successively lower energy states accompanied by γ-emission.

[1] M. L. Pool, Phys. Rev. **53**, 116 (1938).

[2] N. Feather and J. V. Dunworth, Proc. Roy. Soc. **A168**, 566–585 (1938).

43. Absence of New Exchange Forces in H_2 as Shown from Band Spectra. H. Beutler, *University of Chicago*.—M. Goldhaber suggested that scattering experiments could be quantitatively explained by the assumption of new forces between the protons giving an energy effect of about 80 cm^{-1} for protons at the distance apart equal to that in the ground state of H_2. If these forces be *spin-dependent*, the terms of para-H_2 should be found shifted with respect to those of ortho-H_2. The magnitude of that shift in any H_2-term should depend on its internuclear distance r. The transitions from $2p\sigma\,{}^1\Sigma_u$ ($v'=3$ and $v'=10$) to $1s\sigma\,{}^1\Sigma_g$ ($v''=0$ to 14) show conclusively that for $r=0.75$A to

$r=1.6$A no such shift larger than ± 3 cm^{-1} occurs. In addition, the positions of the ground levels of ortho- and para-H_2 have been determined relative to the dissociation level. There is no shift between the ortho- and para-H_2 larger than ± 10 cm^{-1}. If any new, *spin-independent* forces were active in H_2 they could be found (as M. Goldhaber suggested) by a comparison of the dissociation energies of H_2 and D_2. Spectrograms taken by the writer around 850A show that the energies of dissociation D_0 of H_2 and D_2 are 36116 ± 6 cm^{-1} and 36745 ± 25 cm^{-1}, respectively. With the usual extrapolation for the zero-point energy and the formulas for the isotope effect, the results for D_e are 38292 ± 8 cm^{-1} and 38290 ± 25 cm^{-1}, respectively. Although there is thus no evidence for the presence of new forces, it will be necessary to have a more rigorous theoretical treatment of the potential energy function of H_2 and D_2 around the minimum in order to exclude effects which may be hidden by the methods of calculation used.

44. The Infra-Red Absorption Spectrum of Methylamine. Ralph G. Owens and E. F. Barker, *University of Michigan.*—The infra-red absorption spectrum of methylamine (CH_3NH_2) has been investigated for the gas between 2.9μ and 20μ with a grating spectrometer. For wave-lengths below 14μ a rocksalt fore prism was used, and for longer waves a prism of potassium bromide. Of the fourteen bands observed twelve are assigned to fundamental vibrations of the molecule. In appearance they resemble the parallel and perpendicular bands of a symmetrical molecule, indicating that the asymmetry is not great. As in the case of the methyl halides, there is an interaction between the levels ν_1 and $2\nu_4$. The CH_3 frequencies are of the same magnitude as those of methyl fluoride. The parallel band ν_5, due to mutual oscillation of the methyl and amino groups, is found at 1045.23 cm^{-1}, and is completely resolved. From its fine structure the average value of the two largest moments of inertia is found to be 37.6×10^{-40} g·cm^2. An unusual feature of this band is the enhancement of certain lines apparently due to superposition of a widely spaced set. If these should be interpreted as due to a nondegenerate perpendicular vibration, the indicated moment of inertia C with respect to the symmetry axis would be 7.2×10^{-40} g·cm^2. The frequencies observed in the gas agree very well with those reported by Kohlrausch for the Raman spectra of the liquid.

45. The Normal Electron Configuration of Singly Ionized Cerium. W. E. Albertson and G. R. Harrison, *Massachusetts Institute of Technology.*—All levels from the configuration $4f^2(^3H)6s$ and $4f^2(^3H)6p$ have been discovered and identified with the aid of Zeeman effect data. The great intensities of the lines involved, their low temperature classes, and the near Lande "g" values for the levels indicate that in all probability the configuration $4f^26s$ is the lowest in Ce II. The lowest levels from $4f5d6s$ probably occur a few thousand wavenumbers above the ground state, combining with $4f^26s$ to give intense lines in the infra-red beyond 10,000A. More than 2700 Ce II lines have now been classified as arising from various transitions between 240 known energy levels.

46. The Lyman Lines of Hydrogen in Solar Emission. Henry Hemmendinger, *Princeton University Observatory.* (*Introduced by Henry Norris Russell.*)—It has previously been shown[1] that there exist in the solar atmosphere regions of abnormally high excitation, characterized by an intensification of the helium and hydrogen lines in the chromosphere, and of the unidentified line λ5303 in the corona. A photometric study of the chromosphere on Harvard-MIT 1936 eclipse spectra reveals further details of the difference between "normal" and "excited" regions. The ratios of intensities of various metallic lines, for a given chromospheric level, remain substantially constant from one point to another, with the exceptions of λ4554 of Ba^+ and λ4226 of Ca. In excited regions the former of these is markedly weakened, the latter slightly weakened. The second ionization potential of Ba is two-tenths of a volt below Ly_α, that of Ca two-tenths below Ly_β; no other of the eleven metals with observed lines have first or second ionization potentials similarly placed with respect to early Lyman lines. An ultraviolet solar appendage has frequently been proposed to explain various phenomena, terrestrial and solar; present observations suggest the hypothesis that at least the variable part of the appendage does not consist of continuous radiation, but rather of line emission,[2] and specifically Lyman line emission. The lines of Ba^+ and Ca would thus be weakened in excited regions by a resonance process causing second ionization.

[1] G. G. Cillié and D. H. Menzel, Harvard Circular 410 (1935).

[2] M. N. Saha, Proc. Roy. Soc. London **A160**, 155 (1937).

47. The $L_{II}L_{III}$ Spin Doublet and the Value of the Fine Structure Constant. Raymond T. Birge, *University of California.*—Sommerfeld ("*Atombau*") assumed a value of the fine structure constant α, and found for the $L_{II}L_{III}$ interval, as determined from the $L\beta_1\alpha_2$ doublet only, that from $Z=41$ to 92 the screening constant s was apparently constant, aside from irregular fluctuations. Weighted average values of the $L_{II}L_{III}$ interval, for the elements $Z=29$ to 92, have now been obtained, after a critical study of all available x-ray data. As many as eight different measured doublets may be used, in some elements, for an evaluation of the interval. The resulting values of s, calculated with Sommerfeld's assumed $1/\alpha=137.17$, but with his original closed equation for the energy levels L_{II} and L_{III}, instead of the approximate expression actually employed by him in this work, are very definitely not constant. They do, however, form a well-defined curve, when plotted against Z. The values of s increase rapidly from about 3.33 at $Z=29$ to 3.45 at $Z=41$, then more slowly to a maximum of 3.52 at $Z=63$, and finally fall slowly to 3.46 at $Z=92$. By changing the assumed value of $1/\alpha$ to 136.70, one gets a simpler curve, in which the values of s rise from 3.37 at $Z=29$ to a final constant value of 3.63 holding for the range $Z=71$ to 92. Whether 136.70 is to be interpreted as a true or merely an apparent value of $1/\alpha$ can be decided only after a detailed study of the proper formula for the $L_{II}L_{III}$ interval, on the basis of modern quantum mechanics.

48. Relative Intensities of Singlet-Singlet and Singlet-Triplet Transitions. G. W. King, *Yale University*, and J. H. Van Vleck, *Harvard University*.—The ratio of the intensities of singlet-triplet to singlet-singlet transitions can be calculated by means of Houston's[1] formulae in two ways: (a) from the deviations from the interval rule, and (b) from the distance of the singlet level from the center of gravity of the triplet levels. These calculations give the right order of magnitude, but the former gives results high, and the latter results low by a factor of about two. If Houston's formulae were strictly obeyed they would give, of course, the same value. The discrepancy indicates that the integral of the radial functions between the singlet and triplet differs from that for triplet with triplet, say by a factor λ. (On account of a zero in the matrix, the integral for the singlet with singlet does not occur.) The new parameter λ is evaluated ($\sim$0.75) from the positions of the four levels, and gives intensity ratios in good agreement with the observed.[2]

[1] Wm. V. Houston, Phys. Rev. **33**, 297 (1929) and Condon and Shortley, *Theory of Atomic Spectra*, p. 271.

[2] G. Wolfsohn, Zeits. f. Physik **83**, 246 (1933).

49. Experimental Study of Intensities in Benzene Vapor Absorption in the Region 2200–2600A. C. A. Beck and W. F. Radle, *Catholic University of America*.—Evidently, with temperature increase of a molecular system, intensities of ground state absorption bands decrease, while those starting in vibrational levels increase to an inversion temperature, then decrease. Comparison of intensity measurements of the most important bands agrees with the level assignments of Sponer, Nordheim, Sklar and Teller. Ground state bands decrease with temperature while the band at 37,482 cm^{-1} (B_0^0) shows an increase with temperature to a certain point as is expected from its assignment to 606 cm^{-1}. The temperature range is -30 to 250° C. These data are supported by calculations of state populations at various temperatures.

50. The Absorption of Thiocyanates in the 4.8μ Region. Dudley Williams, *University of Florida*.—Previous investigations of the infra-red spectra of organic isothiocyanates have revealed the presence of an intense absorption band near 4.8μ, while two Raman lines have been observed in the same frequency range. Thus further study of the broad infra-red band seemed desirable in order to detect possible complexities. The results of the present study indicate the existence of at least two absorption maxima near 4.8μ. Although the two bands could not be completely resolved, the frequencies of the oscillations giving rise to the band are shown to lie between 2100 cm^{-1} and 1950 cm^{-1}. These frequencies are somewhat lower than those of the observed Raman lines. Badger's explanation of the multiple frequencies of the mustard oils is discussed.

51. Band Spectra of Heavy Nitrogen and the Spectra of $N^{15}H$ and $N^{15}D$. R. W. Wood and G. H. Dieke, *Johns Hopkins University*.—Spectra of the isotope N^{15} of nitrogen, $N^{15}H$ and $N^{15}D$ have been photographed in the second-order spectrum of a 21-foot aluminum grating ruled with 30,000 lines to the inch. The spin of N^{15} was determined by shielding the upper half of the spectrum band at 3580 (where the band head of N^{15} is uncontaminated by other bands) with a rotating disk provided with an open sector of adjustable width. Equality of intensity between the strong lines of the upper spectrum and the weak intermediate lines of the lower was obtained with an aperture of 120°, which gave the spin value $\frac{1}{2}$, corresponding to an intensity ratio of 3 : 1 for the strong and weak lines. The gas was prepared from ammonium chloride containing 70 percent of the heavy isotope, supplied by Professor Urey of Columbia University.

52. The Ultraviolet Absorption of Substituted Benzenes. A. L. Sklar,* *The Catholic University of America*. (*Introduced by K. F. Herzfeld*.)—The weak benzene band at 2600A, which arises from the forbidden transition $A_{1g}-B_{2u}$, is greatly intensified by certain substitutions. Theoretically two effects are possible: a migration of a π electron (node in the plane of the ring) from the substitution into the ring, and the so-called induction effect which consists of a mixing of the levels. The latter effect turns out to be unimportant. A formula giving the effect of this migration upon the intensity of absorption has been developed. The strength of the 2600 band is proportional to that of the strong 2000 band with coefficients depending upon the extent of migration. These latter turn out to be large only if the wave functions of the ring and group overlap sufficiently and if the ionization energy of the group is sufficiently low. In those groups like NH_2 and OH which show strong intensification the low ionization energy must be due to the effect of the charge distribution in the NH and OH bond.

* This research was supported by a grant from the Penrose Fund of the American Philosophical Society.

53. Physical Factors Governing Biological Action of Radiation. F. S. Brackett and Alexander Hollaender, *Division of Industrial Hygiene, National Institute of Health*.—A method is described for determining efficiency and relative absorption from action spectra obtained over a wide range of concentrations (number of organisms per cubic centimeter). Maximum efficiency of lethal action on bacteria is determined as a function of irradiation wave-length (2180–2950A) by establishing optimal concentrations for each wave-length. Optimal concentrations are shown to be a function of the gross absorptive power of the organism. Approximate effective absorption spectra are deduced from the action spectra at low concentration by correction for wave-length efficiency. Contributions to efficiency by screening action of less sensitive materials and quantum efficiency are discussed. Absorption spectra obtained directly are compared with those deduced from the action spectra and contributory uncertainties such as scattering discussed. It is pointed out that action spectra necessarily vary widely with concentration, and that most of the data in the literature cannot be strictly interpreted. In those cases where only clearly thin cells or low concentrations have been used, both efficiency and absorption contribute, and the two factors cannot be separately evaluated.

54. Properties of Type II Photronic Cells Affecting Photometric Measurement. HAROLD S. STEWART, JR. AND BRIAN O'BRIEN, *Institute of Optics, University of Rochester.*—A 1-kw 115-volt projection tungsten lamp, maintained at 95.00 volts ±0.01 volt by a suitable regulator, and provided with cooled water filters, serves as light source. The desired spectral region is isolated by filters which, with a type II Photronic cell under test, are enclosed in a temperature-controlled force draft ventilated chamber. Current output of the cell through an external resistance which may be adjusted for any desired negative as well as positive value is recorded by a graphic potentiometer arrangement readable to about 1/40 percent. Short-period fatigue and dark recovery can be recorded to about this accuracy with a time resolving power of one second. Fatigue and recovery have been studied with a number of cells for several spectral regions including the near ultraviolet to determine circuit conditions yielding greatest constancy. Recovery can be reduced by applying an external direct potential while cell is dark, but performance is erratic. By application of suitable low frequency alternating potential during illumination, fatigue can be largely eliminated. Particularly striking is the great reduction of temperature coefficient by this means.

55. Optical and Photoelectric Properties of Potassium at Liquid-Air Temperatures.* DONALD M. PACKER,† *Institute of Optics, University of Rochester.*—For the first time, the same free surface of a metal has been investigated for its optical and photoelectric properties. Optical constants of opaque potassium films, formed in vacuum on optical flats cooled with liquid air, were determined visually, by using Drude's polarimetric method, at the principal mercury arc lines from 5780 to 3131A. Photo-current measurements were made at same time as optical observations with Pliotron amplifiers. Extinction coefficient and reflection curves dropped from high values in visible region to very low ones near 3500A. Refractive index curves were oppositely directed with values of 0.10 to 0.20 in visible region and rising to high values beyond the critical frequency. The latter occurred at 3250A, shifting to longer wavelengths with increasing age of surface. Maxima near 4300A, found in all the spectral photoelectron yield curves, shifted slightly toward the ultraviolet with aging surfaces. These maxima were also present in the spectral curves of photoemission per unit absorbed energy, shifting to higher frequencies, but not decreasing in relative magnitude as was expected from theory. These results were in general agreement with those reported by Ives and Briggs[1] after this work was completed.[2] All surfaces changed too rapidly, despite good vacuum conditions, for measurements to be repeated on any one surface.

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* Read by title.

† Now at Washington University School of Medicine.

[1] H. Ives and H. B. Briggs, J. Opt. Soc. Am. 28, 330 (1938).

[2] This work presented as partial fulfilment of requirements for Ph.D. degree, June, 1938, University of Rochester.

56. The Townsend Coefficients for Ionization by Collision in Pure and Contaminated Hydrogen as a Function of the Cathode Material. DONALD H. HALE, *University of California. (Introduced by Leonard B. Loeb.)*—The Townsend coefficients for ionization by collision were measured for mercury free hydrogen and hydrogen contaminated by sodium and NaH vapor. Cathodes of platinum and sodium and NaH-coated platinum were used. The values of α/p at the lower values of X/p are found to be smaller for pure hydrogen than for hydrogen contaminated with mercury vapor. The curves of β/α and γ for the platinum cathode plotted as functions of X/p show peaks at the lower values of X/p. The curves for the NaH cathode show a narrow and remarkably high peak at an X/p of 10. These peaks indicate a relatively large photo-emission effect $(\eta\theta g)/\alpha$ at the cathodes at the lower values of X/p. The values of β/α and γ for the platinum cathode show a general increase at the higher values of X/p because of secondary electron emission by positive ion bombardment. In the case of the sodium hydride surfaces the values of γ show little increase at the higher values of X/p. The values of γ as found in this work are used to calculate a sparking potential curve which is compared with the curve experimentally determined by Ehrenkrantz.[1]

[1] Florence Ehrenkrantz, Phys. Rev. 55, 219 (1939).

57. The Definition of the Sparking Potential. LEONARD B. LOEB, *University of California.*—Analysis of static spark breakdown based on recent data indicates that the sparking criterion of Townsend taken from $i=i_0e^{\alpha x}/(1-\gamma(e^{\alpha x}-1))$ with $1-\gamma(e^{\alpha x}-1)=0$ is meaningless. The condition for *self-sustaining discharge,* that $\gamma e^{\alpha x}=1$, sets a *lower* limit or threshold for accumulation of space charges which *may* or *may not* lead to the discontinuous transient phenomenon with change of current called the spark. Above the threshold *only one* initiatory *electron* is *needed.* A spark will not occur unless that electron by a proper sequence of events blazes a conducting channel across the gap which generates a cathode mechanism leading to discharge. With potentials at which $\gamma e^{\alpha x}=1$ such sequences are extremely rare. Higher potentials are needed to ensure sufficient frequency of spark producing sequences for convenient observation. *Conventional,* experimentally observed, sparking potentials are values arbitrarily fixed by convenience of measurement, which may be well above the threshold determined by $\gamma e^{\alpha x}=1$. Dependent on the photo-currents used observed sparking potentials represent those at which about one in 10^6 photoelectrons succeeds in initiating a spark. Studies of the number of photoelectrons required to initiate a spark at different potentials are needed to give significance to sparking potential measurements.

58. Cloud Chamber Studies of Positive Point-to-Plane Discharge in Air at Atmospheric Pressure. STERLING GORRILL, *University of California.*—A study of positive point-to-plane discharge in air at atmospheric pressure was made with a Wilson cloud chamber for observation of the distribution of ions and chemical nuclei formed. Studies were made both of discharges from sharp points at high voltages near the spark-over value, and of discharges from dull points at voltages very close to the onset value for corona discharge. For observation of the corona onset discharges, a mechanism was used by means of which the initiation of the discharge itself resulted in operation of the cloud chamber and the rapid cutting off of the high voltage on the gap. The study of the observed discharge streamers led to considerable detailed information concerning streamer characteristics. Experiments were performed to determine the characteristics of the large ion clouds observed in the region of the gap, and to investigate the mechanism by which they are produced. A mechanism is postulated explaining the formation of the clouds on the basis of diffuse photo-ionization throughout a considerable region, multiplication by collision of the ions thus produced, and subsequent movement of the ions in the existing fields to the positions in which they are observed.

59. Negative Point-to-Plane Corona Studies. ARTHUR F. KIP, *University of California.*—Investigations of the negative point-to-plane corona in air started by Trichel[1] have been continued. The linear relationship between current and frequency of current pulses is found to hold accurately only when pulses are periodic. For large points, pulses may be random and too far apart to provide a self-sustaining process. The positive ions necessary for starting these random pulses are produced by a hitherto unobserved discharge of much smaller magnitude than the pulse process above onset and presumably due to highly localized fields caused by dust, etc., on point surface. For a given voltage, the current is largest when pulses are periodic. Ultraviolet light produces two effects working in opposite directions; it tends to *increase* the current by insuring periodic pulses (caused by the constant photoelectron source at point), and it tends to *decrease* the current by the production of low mobility ions in air. Either effect may predominate, depending on size and surface condition of the point. Increasing the voltage does not materially increase the size of the active spot on the point. The maximum size of a single active spot is about 0.2 mm in diameter. Larger observed spots do not give single frequency of pulse, and are probably caused by several more or less separate spots, acting alternately.

[1] G. W. Trichel, Phys. Rev. **54**, 1078 (1938).

60. Offset and Breakdown Potentials in Point-to-Plane Corona Discharge in Air as a Function of Pressure up to 30 Atmospheres. G. G. HUDSON,* *Department of Physics, University of California, Berkeley.* (*Introduced by Leonard B. Loeb.*)—The breakdown and offset potentials for positive and negative point-to-plane coronas were studied in air at pressures up to 37 atmospheres with cylindrical hemispherically capped points of about 0.4 mm diameter as a function of pressure. The gaps were 3 mm for the negative points while they were 8 mm for the positive points in air. A sharp rise in breakdown potential with pressure was followed by a drop in potential to about half the value with a subsequent rise above 10 atmospheres in air for the positive point. The current-pressure curve roughly paralleled the potential curve while the onset potential showed a dip of about 10 percent. The breakdown potential for the negative point showed a dip of less than 10 percent at a pressure slightly above 10 atmospheres. The negative point current pressure curve was relatively little affected and the offset potential showed no change. Analogous results were reported by H. C. Pollock and F. S. Cooper,[1] and by Goldman and Weil,[2] at about 8 atmospheres. Data are insufficient to give an explanation for the nature of the sharp drop in air.

* Research Corporation Fellow at the University of California.

[1] H. C. Pollock and F. S. Cooper, Bull. Am. Phys. Soc. **13**, 7, Dec. (1938).

[2] Goldman and Weil, Zeits. f. Tech. Phys. of the U.S.S.R.

61. The Temperature Dependence of the Electrical Breakdown in Single Crystals. R. C. BUEHL AND A. VON HIPPEL, *Massachusetts Institute of Technology.*—Experimental difficulties had until now prevented the measurement of the breakdown strength of single crystals over a wide temperature range. This information on the other hand seems of decisive importance for the interpretation of the phenomena observed at room temperature. The authors therefore developed an apparatus, in which the breakdown strength can be measured between −180°C and +400°C, and the current-voltage characteristic up to the breakdown point can be recorded. The first results of these experiments are presented, showing as the most interesting fact a steep decrease in the breakdown strength with falling temperature. This new effect can be explained by a decrease in scattering probability of the electrons with decreasing lattice vibrations.

62. The Atomphysical Interpretation of "Lichtenberg Figures" and Their Application for Studying Electric Discharge Phenomena. F. H. MERRILL AND A. VON HIPPEL, *Massachusetts Institute of Technology.*—The extremely fine, detailed drawing in Lichtenberg figures offers an unusually clear record of the early stages of discharge phenomena. The interpretation of these records in terms of electronic ionization, space charge, plasma formation and recombination is presented in this paper. After establishing the "normal" history of a gas discharge by a study of nitrogen between 5 mm and 30 atmospheres of pressure the admixture of CCl_4 shows the decisive influence of the electronic affinity of Cl on the development of the phenomena. A study of "Freon gas" follows clearing up the reasons for the usefulness of those new gases in suppressing corona discharges. Striking similarities exist between the surface discharges in the figures and space-charge discharges of thunderclouds. Finally figures in liquids link the field of gas discharges with that of the electrical breakdown of liquid insulators.

63. The Mechanism of the Lightning Discharge. J. M. MEEK, *University of California.* (*Introduced by Leonard B. Loeb.*)—A new physical picture of the observed leader/main stroke sequence of the lightning discharge is given by taking into consideration the change of resistance in the discharge channel due to recombination of ions. The current in the pilot streamer is calculated to be of the order of 0.1 amp., the radius to be 0.3 cm. The observed speed of the pilot streamer is 2×10^7 cm/sec. so that the ion density in its tip may be calculated to be 10^{11} per cm^3; this explains the fact that the pilot streamer has not been photographed directly, as streamers of such ion densities are only weakly detectable in the laboratory. The ion density in the tip of the step leader, which can be photographed, is considered as 10^{14} per cm^3. Calculation of the resistance of the leader channel as a function of time shows that, with the current of 0.1 amp. which flows to the pilot streamer, the voltage gradient exceeds the breakdown value of 30 kv per cm at the cloud end of the channel when the time interval since the previous step is 50 microseconds, the average observed time interval between steps.[1] A further step leader then propagates down the partly ionized channel to reach the tip of the advancing pilot streamer. The high velocity of 10^9 cm per sec. for the step leader is accounted for, since the ion density ahead of its tip is of the order of 10^{10} per cm^3.

[1] B. F. J. Schonland, D. J. Malan and H. Collens, Proc. Roy. Soc. **A152**, 595 (1935).

64. Electrodisintegration of Beryllium. G. B. COLLINS, B. WALDMAN AND W. POLYE, *University of Notre Dame.*—The authors have previously[1] reported the disintegrations of beryllium by electrons. The experimental details of this investigation will be given. We have also obtained the threshold for the photodisintegration of beryllium induced by x-rays. The value obtained is about 1.63 Mev which is, within experimental error, identical with the threshold for electrodisintegration. This value also agrees well with the value 1.65 Mev obtained indirectly by Allison.[2] An excitation curve for the electrodisintegration of beryllium has been obtained which rises very rapidly. The shape of this curve is not inconsistent with what would be expected if the cross section for electrodisintegration were proportional to the square of the electron energy in excess of the threshold. If this relation is used to obtain the integrated effect of the electrons in the beryllium target, the cross section previously reported for 1.72 Mev electrons is increased to about 10^{-30} cm^2.

[1] G. B. Collins, B. Waldman and W. R. Polye, Phys. Rev. **55**, 412 (1939).

[2] S. K. Allison, E. R. Graves, L. S. Skaggs and N. M. Smith, Jr. Phys. Rev. **55**, 107 (1939).

65. Evidence for the Composite Character of the N^{13} β-Ray Spectrum. ERNEST M. LYMAN, *University of Illinois.*—Radioactive N^{13} decays with the emission of positrons and 280-kv γ-radiation. According to Richardson,[1] about 0.4 γ-rays are emitted per positron. The maximum energy of the positrons is 1.20 Mv. The presence of the 280-kv γ-rays naturally suggests that the positron energy spectrum is a composite one consisting of two superposed spectra, one with an endpoint at 1.20 Mv, the other with its endpoint at 0.92 Mv. The emission of a positron belonging to the latter spectrum is followed immediately by the emission of the 280-kv γ-ray; consequently either γ-β coincidences or γ-γ coincidences should be detected. The latter have been found by means of a coincidence counter arrangement which counted only γ-rays emitted from the source at an angle of less than 90° with respect to each other. The ratio of the number of 280-kv γ-rays to the total number of positrons is estimated to be 0.20 ± 0.15. In a similar experiment with C^{11} γ-rays, the coincidence rate was found to be negligible. Analysis of the shape of the N^{13} β-ray spectrum[2] shows that if it is resolved into two component spectra with endpoints at 1.20 Mv and 0.92 Mv, each approximately following the Fermi theory, then the ratio of the number of positrons from the 0.92-Mv spectrum to the total number is 0.25.

[1] J. R. Richardson, Phys. Rev. **55**, 609 (1939).

[2] E. M. Lyman, Phys. Rev. **55**, 234 (1939).

66. Further Experiments on the Recoil of the Nucleus in Beta-Disintegration. J. HALPERN AND H. R. CRANE, *University of Michigan.*—Experiments[1] on the recoil of the nucleus in the disintegration of Cl^{38} have been continued. The fact (which we found as a result of our work last year) that momentum is not conserved in the system consisting only of the nucleus and the emitted electron has been confirmed. By measuring the momenta of the electron and nucleus we have been able to ascertain the direction of emission of the neutrino with respect to the direction of the electron in each case. Theoretical predictions according to both the Fermi and the K.U. theory are available. The experimental data agree slightly better with the Fermi than with the K.U. theory, but it is not safe to attach much significance to the results obtained so far, because of the possibilities for rather large experimental errors. An investigation into the manner in which droplets in the cloud chamber are produced by the recoil atom has been carried out. Evidence will be offered which indicates that the products resulting from dissociation of the gas molecules act as centers for condensation. This effect, in addition to ionization, accounts for the droplets observed.

[1] H. R. Crane and J. Halpern, Phys. Rev. **53**, 789 (1938).

67. Coincidences Between Beta-Rays and Gamma-Rays in Indium and Manganese.* LAWRENCE M. LANGER, ALLAN C. G. MITCHELL AND P. W. McDANIEL, *Indiana University.*—Using two reliable high speed counters in a coincidence circuit of resolving time, $t=3.4\times10^{-7}$ min., coincidences have been recorded between the beta- and gamma-radiation from radioactive indium (54 min.) and manganese (148 min.) produced by slow neutron bombardment with a 200-milligram radium-beryllium source. By interposing various thicknesses of aluminum between the source and the beta-ray counter, the ratio of beta-gamma coincidences to single beta-counts was observed as a function of the energy of the beta-rays. For indium, this ratio remains constant, whereas for manganese the ratio is dependent on the beta-ray energy. The results indicate that in both Mn and In there are gamma-rays time-correlated with the emission of beta-rays of all energies.[1] The results are also consistent with the idea that in In the beta-spectrum is simple, whereas in Mn the observed distribution is a composite of at least two modes of disintegration.[2]

Measurement of time-correlated gamma-gamma coincidences indicates that the average number of gamma-rays per beta-ray for In is more than one. No gamma-gamma coincidences could be detected for Mn.

[*] Supported by a grant from the Penrose Fund of the American Philosophical Society.

[1] A. C. G. Mitchell and L. M. Langer, Phys. Rev. **52**, 137 (1937).

[2] M. V. Brown and A. C. G. Mitchell, Phys. Rev. **50**, 593 (1936).

68. Fission of Uranium and Production of Delayed Emission by Slow Neutron Bombardment. E. T. BOOTH, J. R. DUNNING AND F. G. SLACK, *Columbia University.*—The maximum range in air of the fission products of uranium has been determined by a differential ionization chamber and found to be 2.3[1] cm. The distribution in energies among the fission particles has been studied by measurement of the total ionizations produced by the individual fission particles in argon. Amplified ionization pulses were photographically recorded by means of an oscillograph, and compared with the amounts of ionization produced by uranium α-particles. Oscillograph records have also been made of the delayed neutron emission[2] from uranium after an exposure to a strong neutron source. The decay is found to have half-lives of about 3–14 seconds and 45 seconds. The cross section for delayed neutron emission produced by slow neutrons has been compared with the fission cross section for slow neutrons and found to be about 1/100 of the latter value, which our measurements indicate to be 2.5 to 3×10^{-24} cm^2.

[1] Anderson, Booth, Dunning, Fermi, Glasoe and Slack, Phys. Rev. **55**, 511 (1939).

[2] Roberts and Wang, Phys. Rev. **55**, 510 (1939).

69. Scattering of Slow Neutrons by Uranium. H. H. GOLDSMITH, V. W. COHEN AND J. R. DUNNING, *Columbia University.*—The total cross section (scattering+capture) of U for thermal neutrons has been redetermined[1] by using a Rn-Be "howitzer" source, a highly collimated neutron beam, analyzed samples of U_3O_8 containing less than 0.05 percent H_2O and a BF_3 detecting chamber. We obtain a value for the total cross section of $20\pm2\times10^{-24}$ cm^2, neglecting possible non-additive effects in the molecule.[2] The scattering cross section may be estimated to be about 15×10^{-24} cm^2 from the value of $2\text{-}3\times10^{-24}$ cm^2 for the fission cross section,[3] a value for the radiative capture cross section of $\sim3\times10^{-24}$ cm^2 obtained by assuming a reasonable width of the 25-volt resonance.[4] To obtain an independent determination of the scattering cross section use is made of the fact that the absorption processes (fission +radiative capture) exhibit a $1/v$ type of variation whereas the scattering process is independent of the velocity for slow neutrons. This means that in the region of 1 ev the total cross section is almost entirely due to scattering and therefore the cross section for D neutrons should be slightly less than 20×10^{-24} cm^2. Preliminary measurements confirm this.

[1] Dunning, Pegram, Fink and Mitchell, Phys. Rev. **48**, 265 (1935).

[2] Whitaker and Beyer (see abstract 72, this meeting).

[3] Anderson, Booth, Dunning, Fermi, Glasoe and Slack, Phys. Rev. **55**, 511 (1939).

[4] Meitner, Hahn and Strassmann, Zeits. f. Physik **106**, 249 (1937).

70. The Radioactivity of the Fission Products from Uranium Bombarded with Slow Neutrons. G. N. GLASOE AND J. STEIGMAN, *Columbia University.*—An experiment, suggested by Fermi and independently by Joliot and by Meitner and Frisch,[1] was performed to observe the radioactivity of the fission products from uranium. These products were collected in a Cellophane foil and the activity measured by placing the foil around a G-M counter. The uranium, in the form of uranium oxide electrolytically deposited on thin copper sheet, and the Cellophane were mounted with a separation of about 2 cm in an evacuated aluminum cylinder placed in paraffin near the cyclotron. Neither irradiation of the chamber containing no uranium nor leaving it evacuated for several days with no neutron bombardment showed any activity in the Cellophane. Two minutes after the end of a 30-minute irradiation several thousand counts per minute were observed. The decay was followed for four days and showed a long half-life of about 40 hours. A preliminary analysis of this decay showed other periods of about 6 hours, 80 minutes, 20 minutes and 10 minutes with the possibility of several shorter periods. Volatile products from irradiation of uranium in solution were collected in a vessel cooled with liquid nitrogen and showed periods of the order of 80 minutes and 10 minutes.

[1] L. Meitner and R. Frisch, Nature **143**, 471 (1939).

71. Mechanism of Nuclear Fission. N. BOHR, *Institute for Advanced Study,* AND JOHN A. WHEELER, *Princeton University.*—An estimation of the energy required to separate the nuclei of thorium and uranium into two or more parts of comparable mass and charge shows conclusively that the fission process cannot be attributed to a quantum mechanical effect analogous to alpha-particle emission from the ground state of a heavy nucleus but that we have to do with an essentially classical effect arising from the possibility of comparatively large deformations of the excited compound nucleus.[*] The electrostatic repulsion of the nuclear particles will, in fact, for the heaviest nuclei nearly compensate the effect of the short range forces in opposing such deformation and a simple calculation shows that the energy required for a critical deformation is of the same order as the neutron binding energy. From the arguments familiar from the theory of monomolecular reactions, the disintegration constant for the system when excited with the energy E is given by $N^*(E-E_c)/h\rho(E)$, where ρ is the density of energy levels in the original state of the excited nucleus, E_c is the potential energy of deformation in the critical state, and $N^*(E^*)$ is the number of energy levels in that state with energy less than E^*. On these lines the dependence of fission probability on energy, and the statistical distribution in size and mass of the fragments and their initial excitations, are estimated.

[*] L. Meitner and R. Frisch, Nature **143**, 239 (1939). See also N. Bohr, Nature **143**, 330 (1939) and Phys. Rev. **55**, 418 (1939).

72. An Experimental Study of the Additivity of Slow Neutron Cross Sections. MARTIN D. WHITAKER, *New York University,* AND HAROLD G. BEYER, *Columbia University.*—The results of our recent experiments[1] on the transmission of slow neutrons through paramagnetic salts showed such unexpectedly large differences in the cross sections of the salt and the additive cross sections of the constituent elements that we have extended our original investigation to include other combinations of elements. The results to date are shown in Table I. The cross section measurements for the elements and the compounds studied were made under essentially the same conditions with careful consideration of purity of samples and their water content. It is interesting to note that the difference between the observed cross section and the additive cross section is sometimes positive and sometimes negative. The sulfide of zinc (ZnS) shows a larger cross section than zinc oxide although the oxygen cross section is twice that of sulfur.

TABLE I. *Total neutron cross sections for scattering + capture.*

MATERIAL	MEASURED $\times 10^{24}$ cm^{-2}	ADDITIVE $\times 10^{24}$ cm^{-2}	DIFFERENCE
Ni	20.0	—	—
Cu	10.5	—	—
S	2.0	—	—
O^2 (Gas)	4.1	—	—
Zn	4.5	—	—
Fe	12.0	—	—
CuO	16.2	14.5	1.7
Cu_2O	29.5	25.0	4.5
CuS	16.5	12.6	3.9
Cu_2S	27.7	23.1	4.6
ZnO	7.7	8.5	−0.8
ZnS	9.7	6.5	3.2
Permalloy (Ni (78) Fe (22))	12.8	18.2	−5.4

Permalloy gives the most striking result yet obtained. As a matter of fact the measured cross section for 78 permalloy is smaller than is to be expected from the nickel content alone. Some data on the transmission of slow neutrons by large crystals will be presented.

[1] M. Whitaker, H. Beyer and J. Dunning, Phys. Rev. **54**, 771 (1938).
[2] H. Carroll and J. Dunning, Phys. Rev. **54**, 541 (1938).

73. On Neutron Scattering in Crystals and Alloys. OTTO HALPERN, M. HAMERMESH AND M. H. JOHNSON, *New York University.*—The customary assumption of additivity of nuclear scattering cross sections[1] has to be modified if the scattering is coherent and has Laue maxima in addition to the trivial diffraction in the forward direction. Specially marked deviations are to be expected in the case of chemical compounds or real mixed crystals if the nuclei of the constituents form *one* lattice and happen to scatter with opposite phases. Apart from the influence of the change in lattice distance and the appearance of sublattices these effects would always lead to a diminution of the cross section for coherent scattering. Thermal motion of the lattice which produces an incoherent background can give rise to deviations from the additivity in both directions. The influence of nuclear spins, isotopes and preferred orientations is also discussed. Characteristic differences are expected to appear if because of a change in composition or differences in the method of preparation, the constituents group themselves in separate microcrystals. Experiments in this field promise to give information about the relative phases of the nuclearly scattered waves as well as about the physical constitution of the solid state. Values for nuclear cross sections require redetermination as a consequence of these calculations. The arguments presented here are also of importance for the interpretation of experiments in the field of magnetic scattering and particularly of polarization phenomena in ferromagnets.

[1] See the preceding experimental paper by M. Whitaker and H. Beyer.

74. Hyperfine Structure in the Spectrum of Indium III. J. S. CAMPBELL AND J. R. DAVIS, *Institute of Optics, University of Rochester.*—Vacuum spectrograms made with a five-meter 15,000-line/inch grating and a hot spark source resolve the In III lines λ1748.77 $5s\,{}^2S_{\frac{1}{2}}-5p\,{}^2P_{\frac{1}{2}}$ and λ1625.26 $5s\,{}^2S_{\frac{1}{2}}-5p\,{}^2P_{\frac{3}{2}}$ as hyperfine doublets having the separations 3.78 cm^{-1} and 3.55 cm^{-1}, respectively. Using the nuclear moment (9/2) of indium, and the theoretical ratio between the splitting factors of the two P states, these line separations give the separation of the S levels as 3.66 cm^{-1} and that of the $P_{\frac{1}{2}}$ levels as 0.35 cm^{-1}. The splitting factor for the $5s$ electron is 0.73, in fair agreement with the value 0.707 obtained by applying the Goudsmit-Bacher relations to the total splitting factors of the $5s\cdot ns$ terms of In II.[1]

[1] F. Paschen and J. S. Campbell, Ann. d. Physik **31**, 29 (1938).

75. The Absorption Coefficient of Gases for Light of Wave-Length 1215.7A. WILLIAM M. PRESTON, *Harvard University.*—It is well known that air is relatively transparent to light in the region between 1200 and 1350A. Because of the abundance of hydrogen in the chromosphere and in solar prominences, it is possible that the earth may receive an intensity at 1215.7A (first line of the Lyman series) far greater than at neighboring wave-lengths, which might penetrate far enough to influence the lower layers of the ionosphere. An apparatus, built for another purpose, has been used to measure accurately the absorption coefficients of the constituents of air at this wave-length. The source was a hydrogen discharge; the absorption cell had LiF windows; the light was analyzed by a one-meter grating and the intensity measured by a photoelectric cell. The results were, for the absorption coefficient per centimeter path reduced to normal temperature and pressure: air (dry, CO_2 free) 0.063; oxygen 0.28; nitrogen 0.005; carbon dioxide 2.01; water vapor 395. The absorption coefficient of air appears to increase with the pressure. At low pressures, a column of dry, CO_2 free air equivalent to 16 cm at NTP will reduce the intensity by a factor $1/e$.

76. Zeeman Effect at Fields of 100,000 Gauss. GEORGE R. HARRISON AND FRANCIS BITTER, *Massachusetts Institute of Technology.*—A new electromagnet of the type recently described[1] has been used to obtain Zeeman resolution of spectral lines at fields up to 99,830 gauss. Though power consumption at highest fields is 1800 kilowatts, current through the magnet can be held constant to within 0.1 percent over several hours. The field is uniform to one percent throughout a volume of 25 cc. An arc has been constructed to operate with arc stream parallel to the lines of force, and light can be removed transversely. Use of rare earth and other oxide powders in a horizontal arc is made possible by electrodes compressed with silver powder by Professor John Wulff. Excitation temperatures in the arc are apparently increased by the presence of the field. The arc is dimmed slightly in intensity when the field is applied, apparently because a shorter gap must be used. Photographs of strong lines can be obtained in five minutes with a 35-foot concave grating. Typical patterns of cerium and europium will be shown.

[1] F. Bitter, Rev. Sci. Inst. **7**, 482 (1936).

77. Analysis of a Queer Zeeman Effect Pattern in Tungsten. J. H. ROBERSON AND J. E. MACK, *University of Wisconsin.*—Although the tungsten arc line λ4659 (transition between the level 21453, $J=1$, and the normal level, $J=0$) has previously been reported as an ordinary simple triplet, investigation in magnetic fields up to $4.28\cdot 10^4$ c.g.s. shows that, while the pattern remains approximately symmetric, the line wanders bodily toward higher frequencies, verifying the equation given by J. E. Mack and O. Laporte.[1] The constant K for the interaction of levels 21448_2 and 21453_1 is tentatively evaluated at $6\cdot 10^{-2}$.

[1] J. E. Mack and O. Laporte, Phys. Rev. **51**, 291 (1937).

78. Theory of the Paschen-Back Effect for Intermediate Coupling. J. B. GREEN AND J. F. EICHELBERGER, *Ohio State University.*—General spectroscopic theory has been applied to the Paschen-Back effect and simplified methods developed for determining the positions of the energy levels and intensities of lines for cases of intermediate coupling. They are expressed in terms of *LS*-coupling as the zero-order functions. The description of the results in words is then very simply and easily stated in terms of the *LS*-coupling designations and the transformation coefficients.

79. Sensitized Fluorescence of Lead. J. GIBSON WINANS, FRANCIS J. DAVIS AND VICTOR A. LEITZKE, *University of Wisconsin.*—The sensitized fluorescence of lead in mercury vapor was observed with simplified apparatus[1] using 2536 or 1854 for excitation. With five to ten-minute exposures, twelve lead lines were obtained including the five observed by Kopferman.[2] With a seven-millimeter nitrogen atmosphere, the higher energy lead lines 2613, 2873, 2802, 2663 were stronger with respect to the lower energy lines 2833, 3683, 3639, 4058 for 2536 excitation as well as for 1854 excitation. Additional lead lines observed were 3739, 3572, 2823, 3260? and 2577. 3260 may be due to cadmium. Impurity lines from thallium were also present. A Tesla discharge through the mercury lead mixture showed a narrow continuous type band with short wave edge at the lead line 2833. This band is analogous to one observed at 2768 for thallium and it is probably due to Pb_2. A drop of liquid mercury was found to produce strong evaporation of lead or thallium from a hot drop of the metal. The evaporated lead or thallium forms black clouds of condensed metal.

[1] J. G. Winans and R. M. Williams, Phys. Rev. **52**, 930 (1937).
[2] H. Kopferman, Zeits. f. Physik **21**, 316 (1924).

80. The Response of Several Fluorescent Materials to Short Wave-Length Ultraviolet Radiations. N. C. BEESE, *Westinghouse Electric & Manufacturing Company.*—A quartz monochromator has been used to measure the relative response of several synthetic phosphors in the region of 2200A to 3150A. The deactivating effect of copper and nickel on certain substances is represented graphically. With a vacuum grating spectrograph the response characteristics of zinc silicate and calcium tungstate have been extended to the Schumann ultraviolet region.

81. Energy Distribution of OH Molecules in Sensitized Fluorescence. ELISABETH REED LYMAN, *University of California.* (*Introduced by F. A. Jenkins.*)—Photometric intensity measurements were made of the OH spectrum excited by sensitized fluorescence. Mixtures of gases in the fluorescence tube which were used were $Hg+H_2O$, $Hg+H_2O+N_2$, $Hg+H_2O+He$. Metastable $^3P_0$ Hg atoms impart their energy by collisions of the second kind to the OH molecules first formed with little if any rotation. Thermal distribution of rotational energies was not obtained in any fluorescence spectrum of OH. Too large energies in the high rotational states were found probably arising, as in the case of HgH,[1] in the excitation process and in collisions during the lifetime of the excited molecule. In the (0,0) λ3064 and the (1,0) λ2811 bands there is a sudden drop of intensity to zero above the rotational level $J'=17\frac{1}{2}$ for the (0,0) band and $J'=11\frac{1}{2}$ for the (1,0) band. The energies for $J'_{(0,\,0)}=17\frac{1}{2}$, 37444 cm^{-1}, and $J'_{(1,\,0)}=11\frac{1}{2}$, 37501 cm^{-1} agree with the energy for $^3P_0$ Hg atoms, 37642 cm^{-1}. The intensities of lines from $J'_{(0,\,0)}=16\frac{1}{2}$, $17\frac{1}{2}$ and $J'_{(1,\,0)}=10\frac{1}{2}$, $11\frac{1}{2}$ are slightly enhanced. The enhancement may be explained as due to the large cross section for energy transfer by collision for states of nearly the same energy as $^3P_0$. Measurements of the (0,0) and (1,0) bands for molecules undergoing collisions with N_2 indicate a transfer of molecules from the vibrational level $v'=1$ to high rotational levels of $v'=0$ with increasing pressures of N_2, as well as some reduction of rotational energy towards thermal values. Collisions with helium appear much less efficient than collisions with N_2 in removing vibrational, rotational, or kinetic energy from the OH molecules.

[1] F. F. Rieke, J. Chem. Phys. **4**, 513 (1936).

82. Quenching and Depolarization of Mercury Resonance Radiation by Foreign Gases. LEONARD O. OLSEN, *Case School of Applied Science.*†—The polarization of mercury resonance radiation excited by the plane-polarized light from a water-cooled mercury arc is affected by a foreign gas in the resonance bulb and by an external magnetic field. Experimental results have been secured for the gases, nitrogen, deuterium, carbon dioxide and helium, their effects on the polarization having been studied as a function of gas pressure in zero applied field and as a function of applied field intensity at fixed gas pressures. The rotation of the plane of polarization produced by magnetic fields has also been observed for fixed gas pressures. These results have been used to calculate quenching and depolarization cross sections. The cross sections so determined agree well with the percentage polarization as a function of gas pressure data. The agreement with the magnetic field data is not as good. The indication is that there is a dependence of effective mean life on the intensity of the applied magnetic field.

† Experimental work performed at the University of Iowa Physical Laboratory.

83. A Variable Oscillator for Ultra-High Frequency Measurements. RONOLD KING, *Harvard University.*—A fundamental theorem regarding coupled ultra-high frequency circuits is explained together with its experimental verification. The importance of the theorem in the measurement of current and voltage is discussed. The conditions of the theorem are applied to determine the design of a variable oscillator for use in the ultra-high frequency measurement of current, voltage, resistance, reactance, dielectric constant, permeability, etc. in the range from 50 to 300 megacycles. The circuit, construction, and frequency characteristics of the oscillator are described. Its usefulness for purposes of measurement and demonstration is outlined.

84. Supersonics and the Effect of Water Vapor on Molecular Vibrations in CO_2. W. H. PIELEMEIER AND D. TELFAIR, *The Pennsylvania State College.*—Acoustic interferometer measurements were made at approximately 28°C and atmospheric pressure from which the wave velocity and the absorption in CO_2 were computed. About twenty H_2O concentrations were used with each of ten frequencies ranging from 284 to 1595 kc/sec. At each frequency, μ (the absorption per wave-length) rises with increasing humidity to a maximum of approximately 0.27 and then drops slowly, but at the lower frequencies it also passes through a *minor* peak before saturation is reached. As the major absorption peak is approached and passed the *velocity* drops nearly ten meters/sec. and a one-meter/sec. drop occurs near the minor peak. As the frequency f is increased the critical (major peak producing) H_2O concentration h increases also; i.e. $f_m=[60+8(10)^4h]$ kc/sec. For the minor peaks $f_{m'}=[54+2(10)^4h]$ kc/sec. These relationships show that there are at least two types of vibration within the CO_2 molecule differing widely in the manner that water vapor effects their rate of adjustment to the periodic temperature changes associated with supersonic waves. Previously only *one* adjustment rate for a given humidity had been found although Eucken[1] and others have searched for more.

[1] A. Eucken and E. Nümann, Zeits. f. physik. Chemie **B36**, 163 (1937).

85. Effect of Temperature on Supersonic Velocity in CO_2. C. J. OVERBECK AND E. WILER, *Northwestern University.*—Reports on experimental work in supersonics, relating to the anomalous absorption and dispersion in gases, CO_2 in particular, show conflicting results. There is support for both the resonance theory[1] and the collision theory[2] as the explanation of the anomalous effect. This led the authors to the task of attempting to find the reasons for the experimental discrepancies. Apparatus was built quite similar to that used in the earlier work and tests were conducted as changes were instituted. The probable cause of the conflicting experimental evidence has been located as a gas contamination, namely gases released from the Bakelite, rubber and cork elements used in the earlier gas chambers, and possibly also to a trace of water vapor from the CO_2 supply. Data will be presented giving the velocity values in CO_2 at 90 kc for a temperature range from 20°C to 418°C, obtained using a complete metal and glass chamber with special precautions to reduce the water vapor content. The experimental evidence supports the collision theory; the slope of the curve, however, is considerably less than that reported earlier.

[1] See H. L. Penman, Proc. Phys. Soc. **47**, 543 (1935).
[2] See G. W. Warner, J. Acous. Soc. Am. **9**, 30 (1937).

86. Theory of Secondary Peak for Sound Absorption in CO_2. HAROLD L. SAXTON, *Pennsylvania State College.*—Use of approximate formulas for absorption of supersonic waves in CO_2 has previously yielded surprisingly good results over a limited range of frequency. The error introduced by such approximations will be discussed. The data obtained by Pielemeier and his co-workers by varying the water vapor content of a gas cover a much greater range of the ratio of period to "mean lifetime of a quantum" and display a secondary peak not as yet observed by others, and not predicted by the simplest theory. This peak is explained by treating the gas as "3-state" in the δ mode and "2-state" in the valence mode of vibration. Characteristic curves of this theory will be presented and the check with experimental results will be demonstrated.

87. Transmission of Sound Through Plates at Oblique Incidence. F. H. SANDERS, *National Research Council, Ottawa, Canada.*—The transmission of high frequency sound through plates of brass and nickel has been studied for angles of incidence ranging from 0 to 70 degrees. Effective plate thicknesses varied from one-twentieth of a wave-length to around one wave-length. In addition to strong transmissions in the region below the normal critical angle very sharp and intense transmission maxima have been observed at angles of incidence greatly in excess of the critical angle. These transmission maxima fall within three clearly defined angular regions: (1) angles between zero and the critical angle for longitudinal waves; (2) angles between the critical angle for longitudinal waves and the critical angle for transverse waves; and (3) angles above the critical angle for transverse waves. In regions (1) and (2) the observed data are in satisfactory agreement with a recent theory due to Reissner[1] and good values of the elastic constants are obtained. By an extension of Lamb's[2] theory for flexural vibrations in bars the results in region (3) can be interpreted.

[1] Reissner, Helv. Phys. Acta **XI**, 140–155.
[2] Lamb, *Dynamical Theory of Sound*, second edition, Section 45, p. 122.

88. Recording of Critical Frequencies of the Ionosphere. OLOF RYDBECK, *Harvard University.* (*Introduced by H. R. Mimno.*)—A double-detection sweep-frequency receiver and recording amplifier has been designed for recording the signals from the laboratory's variable-frequency transmitter. The receiver is flexibly built, with easily exchangeable cam disks and plug-in coils. The mechanical tuning has no back-lash and mechanical synchronization is easily obtained with a friction drive on the motor shaft. No ground wave is necessary for synchronization and the receiver is therefore especially suited for long base recording. The radiofrequency gain is approximately constant over the tuning range, its average value being 10^6. The audiofrequency system is of unusual design. The strongest pulses received are recorded with a minimum of distortion and transients. The circuit elements are determined not only by the frequency range desired but also by the maximum amplitudes handled. Various records obtained with the equipment will be discussed. Unusual echoes, probably arriving from very distant sunrise regions in the ionosphere, have been recorded over the frequency range.

89. The Apparent Motion of Clouds of Abnormal *E* Region Ionization. J. A. PIERCE AND H. R. MIMNO, *Harvard University.*—Previous researches have indicated that abnormal *E* region ionization appears in patches which may be very small or may have lateral dimensions of hundreds of kilometers, and which may or may not appear fixed with respect to the earth. Occasionally radio echoes are returned from such clouds even when they are not directly overhead. It is possible, in some of these cases, to estimate the vertical thickness of the clouds and to measure the lateral distance to the reflecting surface as a function of time. These measurements indicate that a typical ionized region of this sort is not more than a few kilometers thick and passes the observer with a speed which may be as great as 500 kilometers per hour. It is suggested that this apparent motion may be the result of an ionizing beam which sweeps across the atmosphere liberating electrons which disappear quickly after the passage of the beam.

90. Velocity of Light Apparatus.* WILMER C. ANDERSON, *Harvard University.*—A number of improvements and changes in the velocity of light apparatus[1] utilizing radiofrequency interferometry have been made recently. Principal changes have been made in the method of modulation of the light beam, the control of the modulation frequency, the receiving system, the substitution of a recording system for visual observation, and the use of a new optical system to lessen end-point errors. Preliminary records and pictures of the apparatus are shown.

* Partly financed by Carnegie Corporation of New York.

[1] W. C. Anderson, Rev. Sci. Inst. 8, 239 (1937).

91. Scattering of Light by Water as a Function of Angle. L. H. DAWSON AND E. O. HULBURT, *Naval Research Laboratory.*—According to theory of scattering of light by isotropic particles that are small with respect to the wavelength of light, the scattered intensity at angle θ to the direction of propagation varies as $1+\cos^2\theta$. Measurements of the scattered intensity for pure water were made at $\theta=45°$, 90° and 135° for wave-lengths from about 3660 to 7000A. An excess forward scattering was observed in three ways, visually, photographically and with photoelectric counter. The intensity at 135° was about 60 percent greater than at 45°; theory would put the intensities equal for the two angles. It appears difficult to determine whether the difference was a property of pure water, and related to polarization defect, due to anisotrophy of the scattering centers, or was caused by slight optical impurities in the water.

92. Multilayer Films of High Reflecting Power. C. HAWLEY CARTWRIGHT AND A. FRANCIS TURNER, *Massachusetts Institute of Technology.*—By alternately depositing films of high and low indices of refraction on glass such that each film has an optical thickness $nd=\lambda_0/4$, the reflecting power for any pre-selected wave-length, λ_0, can be increased to over 80 percent. A monochromator is formed by reflecting white light from two or more such filters and the wavelength of the reflected light can be varied somewhat by changing the angle of reflection. By suitably choosing the film thicknesses, a color separation filter was made which reflected 85 percent in the green and transmitted 90 percent in the red. Films of titanium dioxide ($n=3.0$) separated by films of cryolite ($n=1.3$) were found to be quite rugged. The films of TiO_2 were deposited either by evaporating TiO_2 in a high vacuum or by converting hot $TiCl_4$ vapor in air to a TiO_2 film. The cryolite films were deposited by evaporation in a high vacuum. However, it seems possible to replace the cryolite by SiO_2 deposited in air from $SiCl_4$ vapor.

93. Integrating Meters for Ultraviolet Radiation. J. B. H. KUPER, *Washington Biophysical Institute,* AND F. S. BRACKETT, *Division of Industrial Hygiene, National Institute of Health.*—Integrating meters for recording the amount of solar ultraviolet received have been developed in cooperation with Dr. H. C. Rentschler and used for over a year in connection with a study of the influence of climate on epidemiology. The meters consist of photo-cells with pure titanium cathodes (threshold about 3200A) in connection with fixed condensers and cold-cathode gas-filled tubes ("trigger tubes"). These are sealed in evacuated extensions of the photo-cell envelopes for protection against moisture. Each discharge of a trigger tube is recorded on a telephone message register which may be located a considerable distance from the cell. The circuit used was chosen to give the greatest possible reliability without overloading batteries or tubes, and the meters operate with no skilled attention except for routine calibration checks every few months. An unskilled observer reads the message register daily, but automatic photographic registration could be used instead, if desired. The spectral response of the photo-cells is chosen to give a good approximation to the erythemal curve. Geometric factors in the photo-cell response, and reliability of the calibration will be discussed and some preliminary data on seasonal variations in solar ultraviolet will be presented.

94. Binding Energy of Li^7. K. G. CARROLL, *Yale University.*—Calculations have been made on the stability of the Li^7 nucleus in its ground state by employing the symmetric interaction in its usual form: $V_{ij}=-Ae^{-r_{ij}^2/a^2}\times[w+mP_{ij}+bQ_{ij}+hP_{ij}Q_{ij}]$. Similar to results for Li^6,[1] the simple Hartree approximation yields less than a third of the observed binding (39 Mev). With two variation parameters (corresponding to pre-formed "shells") this may be considerably improved, but still remains far from the true value. By means of a second-order perturbation calculation the effect of improving the ground state function with higher members of a complete set of oscillator functions is calculated. Convergence is found to be more rapid than for Li^6. An upper bound to the second-order perturbation including all members of the set is obtained. Convergence is estimated by means of a third-order calculation. For the most favorable choice of nuclear parameters, the binding energy of the ground state appears to fall short of the experimental value by at least 25 percent. The use of parameters recently suggested by Breit[2] increases the discrepancy. The results agree with those for He^5 [3] and Li^6 in indicating a systematic failure of the present interaction for nuclei beyond He^4.

[1] H. Margenau and K. G. Carroll, Phys. Rev. **54**, 705 (1938).
[2] G. Breit, Phys. Rev. **55**, 603 (1939).
[3] W. A. Tyrrell, New York Meeting, Feb. 23–25, 1939.

95. Nuclear Excitation of Indium by X-Rays. B. WALDMAN, G. B. COLLINS, E. M. STUBBLEFIELD, *University of Notre Dame*, AND M. GOLDHABER, *University of Illinois.*—It has been shown recently that the stable nucleus In^{115}, when excited by x-rays, may be left in a metastable excited state, designated by In^{115*}, from which it decays, emitting negative electrons, with a half-life time of approximately four hours.[1, 2] As the transition from the ground state of In^{115} directly to In^{115*} is highly forbidden, the process can be described as an excitation from the ground state to a higher level ("activation" level) and the subsequent return to the metastable state, In^{115*}. We have obtained a yield curve by measuring the activity of indium as a function of the energy of the electrons producing the x-rays. This curve shows a threshold at 1.2±0.1 Mev and an abrupt change of slope at 1.55±0.1 Mev, indicating the existence of two "activation" levels.

[1] Pontecorvo and Lazard, Comptes rendus **208**, 99 (1939).
[2] Collins, Waldman, Stubblefield and Goldhaber, Phys. Rev. **55**, 507 (1939).

96. Nuclear Energy Levels in B^{10}. P. GERALD KRUGER, F. W. STALLMANN AND W. E. SHOUPP, *University of Illinois.*—A previous[1] examination of the gamma-rays from Be^9 bombarded with one-Mev deuterons revealed six gamma-ray lines. Two thousand new cloud-chamber pictures taken with a stereoscopic camera give data which show twenty-seven γ-ray lines between 0.29 Mev and 4.71 Mev. Twenty-six lines are observed by Compton recoil electrons from a thin mica foil. Seventeen lines are confirmed by the measurement of thirty-three ± pairs which were formed in the gas in the cloud chamber. In all cases where ± pair energies are available the gamma-ray energies from those measurements are considered more reliable than those from the Compton recoil electron groups, though in most instances the two values agree to ±0.04 Mev. From these lines it appears that nine levels in the B^{10} nucleus have been established. By using the calculations of Feenberg and Wigner[2] one obtains the following classification of the levels: $^3S_1$ as the ground state (relative energy zero); $^3D_{123}$ at 0.29 Mev, 0.44 Mev and 0.57 Mev; $^1S_0$ at 1.45 Mev; $^1D_2$ at 1.98 Mev; $^3F_{234}$ at 2.89 Mev; $^3D_{123}$ at 3.65 Mev; $^1D_2$ at 4.71 Mev.

[1] P. G. Kruger and G. K. Green, Phys. Rev. **52**, 773 (1937).
[2] E. Feenberg and E. Wigner, Phys. Rev. **51**, 95 (1937).

97. Distribution in Angle of Protons from the Deuteron-Deuteron Reaction. A. ELLETT, J. A. VAN ALLEN AND D. S. BAYLEY, *University of Iowa.*—The fore and aft asymmetry reported earlier[1] has been found to be due to low energy deuterons in the incident beam arising from grazing collisions with the walls of the capillary tube through which the beam entered the gas target chamber. Substitution of a series of thin diaphragms eliminates this scattering and the consequent asymmetry. We find that the distribution in angle reduced to the center of mass reference system may be represented by $I(\theta)=1+A\cos^2\theta$ and that the value of A depends upon the bombarding energy as in the table below:

Bombarding energy kev	330	250	200	133
A	1.45	1.2	1.05	0.9

[1] A. Ellett and R. D. Huntoon, Phys. Rev. **54**, 87 (1938).

98. On the Photoelectric Effect of the Deuteron. L. EISENBUD, *Princeton University.*—The experiment of von Halban[1] indicates that the ratio of the intensities of the photo-neutrons from deuterium in the direction of the incident thorium C″ γ-rays and at right angles to this direction is in contradiction with the ordinary theory of the deuteron. Theory gives the value 0.25 for the ratio of the intensity of the ^1S wave (arising in the photomagnetic dipole transition) in the direction of the γ-ray, to the intensity of the ^3P wave (produced by the photoelectric dipole transition) at right angles to the γ-ray beam. This number is to be compared with the ratio obtained by experiment which is between 0.01 and 0.13. In an effort to understand the discrepancy the effect of the introduction of a neutron-proton interaction, which contains, in addition to the usual terms, a vector-vector and a tensor-tensor interaction, has been investigated. This leads to a coupling of waves of different orbital angular momenta, and also to coupling between triplet and singlet waves. In particular the ground state of the deuteron will contain both ^3S and ^3D waves. On these assumptions there is a possibility of explaining von Halban's results in two ways. (1) Electric dipole transitions from the ^3S wave of the ground state lead to a ^1P wave through the coupling of this wave with ^3P. The ^1P wave can interfere in the forward direction with the ^1S wave which comes from the ^3S in the ground state by magnetic dipole transition. (2) Electric dipole transitions from the ^3D wave in the ground state to ^3P can increase the neutron intensity at right angles to the γ-ray beam. The conclusions which can be derived without detailed information on the exact forms of the interactions will be discussed.

[1] H. von Halban, Nature **141**, 644 (1938).

99. Search for Excited State of C^{13}. J. REGINALD RICHARDSON, *University of Illinois.*—An excited state of C^{13} at about 270 kv is suggested by the gamma-radiation[1] from N^{13}. It would seem possible for the product nucleus to be left in this excited state in the reaction $C^{12}(d,p)C^{13}$, provided there is no selection rule forbidding the transition. The existence of the excited state would be indicated in the energy distribution of the emitted protons.[2] A more detailed search was made for group structure in these protons, as produced by the bombardment of a thin target of carbon by 900-kv deuterons from the cyclotron. No evidence of group structure was found. The results indicate that the probability that the C^{13} nucleus be left in such an excited state compared with the probability that it be left in the ground state is less than five percent, provided the energy of the excited state is 180 kv above ground, or greater. Efforts are being made to decrease these limits.

[1] J. R. Richardson, Phys. Rev. **55**, 609 (1939).
[2] J. D. Cockcroft and W. B. Lewis, Proc. Roy. Soc. **A154**, 261 (1936).

100. The Meson Theory of Nuclear Forces and the Quadrupole Moment of the Deuteron. H. A. BETHE, *Cornell University.*—Kemmer[1] has proposed a theory of nuclear forces based upon the emission and reabsorption of neutral and charged mesons, the theory being symmetrical in all these types of mesons (S-theory). An alternative theory is possible which involves only neutral mesons (N-theory). To explain the saturation of nuclear forces and the attraction between nuclear particles in the singlet state, the forces must be spin-dependent. It is simplest to assume spin-dependent forces only. The theory diverges at small distances and requires "cutting off." The interaction makes the ground state of the deuteron a mixture of a ^3S and a $^3D_1$ state, and thus predicts an electric quadrupole in the N-theory moment of the deuteron. The sign of this quadrupole is in agreement with the observations of Kellogg, Rabi, Ramsey and Zacharias[2] ("cigar shape"), in the S-theory it is opposite. The cutting-off radius r_0 and the value of the quadrupole moment Q can be determined from the requirement that the energies of both the singlet and the triplet state of the deuteron be given correctly. This gives $Q=1.27\cdot10^{-27}$ cm² on the N-theory and $\sim-4\cdot10^{-27}$ cm² on the S-theory, as compared with about $2\cdot10^{-27}$ observed. Q is insensitive to the way in which the potential V is cut off.

[1] N. Kemmer, Proc. Cambr. Phil. Soc. **34**, 354 (1938).
[2] Kellogg, Rabi, Ramsey and Zacharias, Phys. Rev. **55**, 318 (1939)

101. β-Decay and Spin of N^{13}. B. O. GRÖNBLOM, *Cornell University.* (*Introduced by H. A. Bethe.*)—Richardson[1] has shown that the β-decay of N^{13} leads to two states of C^{13} with an energy difference of 285 ± 20 kv, about 80 percent of all transitions leading to the excited state. Similar conclusions were reached theoretically by Bethe, Hoyle and Peierls.[2] Assuming that the C^{13} states are components of a ^2P level,[3] and that N^{13} behaves analogously, the original Fermi theory would predict a transition to only one of the C^{13} states. We must use instead the spin-dependent modification of the Fermi theory proposed by Gamow and Teller,[4] which is also required[5] by the large probability of the β-transition $He^6 \rightarrow Li^6+\beta+n^0$ (probably a $^1S-{}^3S$ transition). From the ratio of the transition probabilities the spins of the various states of C^{13} and N^{13} can be deduced using the Gamow-Teller theory. If both nuclei have a $^2P_{\frac{1}{2}}$ ground state[3] 75 percent should lead to the excited state of C^{13} in good agreement with the experiment. All other assumptions lead to disagreement, e.g. if both ground states are $^2P_{\frac{3}{2}}$, the figure should be 23 percent. The conclusion is in agreement with the calculations of Bethe and Rose. From the observed lifetime of N^{13} we obtain for the β-decay constant $\tau_0=0,\ 5\cdot10^4$ sec. (previous value 1, $1\cdot10^4$ sec.[6]).

[1] J. R. Richardson, Phys. Rev. **53**, 610 (1936).
[2] H. A. Bethe, F. Hoyle and R. Peierls, Nature **143**, 200 (1939).
[3] M. E. Rose, H. A. Bethe, Phys. Rev. **51**, 205 (1937).
[4] G. Gamow and E. Teller, Phys. Rev. **49**, 895 (1936).
[5] M. Goldhaber, unpublished.
[6] H. A. Bethe and C. L. Critchfield, Phys. Rev. **54**, 248 (1938).

102. Slowing Down of Neutrons by Heavy Nuclei. G. PLACZEK, *Cornell University.* (*Introduced by H. A. Bethe.*)—A rigorous solution of the integral equation for the slowing down process by collisions with nuclei of masses higher than the neutron mass has been obtained. In particular, for neutron energies E small compared to the original energy, the solution assumes the form:

$$\rho(E)dE=\frac{ql\left(\frac{m}{2}\right)^{\frac{1}{2}}(1-p)}{1-p(1-\log p)}E^{-\frac{3}{2}}dE.$$

(ρ neutron density, q number of neutrons produced per second, l mean free path, $p=(M-m/M+m)^2$.) The results are applied to the discussion of experiments studying nuclear energy levels with neutrons slowed down in heavy substances. Furthermore, the possibility of detecting small capture cross sections by slowing down experiments is discussed.

103. The Exponential and Meson Potentials. S. SHARE, L. E. HOISINGTON AND G. BREIT, *University of Wisconsin.*—Recent experiments[1] on the scattering of protons by protons permit the determination of the range of force acting between two protons on the supposition that the potential is not velocity dependent.[2] They also allow the elimination of fixed potentials with certain shapes. The exponential potential used in the calculations of Rarita and Present on H^3 and He^4 has a correct average range but a wrong shape. For it the phase shift increases relatively too rapidly at low and too slowly at high energies. This is due to too much interaction at large distances. The meson potential $Ce^{-r/a}/(r/a)$ can be made to fit experiment nicely using $a=.42e^2/mc^2$, $C=-89.6mc^2$. The range corresponds to the mass of the heavy electron of 330 m. Such a determination of mass is affected by a possible velocity dependence.

[1] R. G. Herb, D. W. Kerst, D. B. Parkinson and G. J. Plain, **55**, 603(A) (1939); N. P. Heydenburg, L. R. Hafstad and M. A. Tuve, **55**, 603(A) (1939).
[2] The *a priori* possibility of velocity dependent potentials for nuclear particles has been pointed out by J. A. Wheeler.

104. The Vibration-Rotation Energies of Tetrahedrally Symmetrical Molecules. W. H. SHAFFER, H. H. NIELSEN AND L. H. THOMAS, *Ohio State University.*—The complete quantum mechanical Hamiltonian for the oscillating and rotating xy_4 type molecule has been derived perfectly generally to second approximation. It is convenient to transform $H=H_0+H_1+H_2$ by a contact transformation THT^{-1} into $H_0+H_1'+H_2'$ so that H_1' contains to second approximation only the coriolis interaction terms arising from the degenerate oscillations. Linear combinations of the zeroth-order eigenfunctions may always be found such that the matrix H_1' will have elements only along the principal diagonal. These functions have been found for the ground state and for the states ν_1, ν_2, ν_3, ν_4, $2\nu_3$, $2\nu_4$, $\nu_1+\nu_3$, $\nu_1+\nu_4$, $\nu_2+\nu_3$, $\nu_2+\nu_4$, $\nu_3+\nu_4$. Our results in first approximation are in agreement with those of earlier investigators except for the state $\nu_3+\nu_4$ which splits up into nine component levels in general where $\zeta_3\neq 0$ and $\zeta_4\neq 0$, ζ_3 and ζ_4 being the moduli of the angular momentum vectors due to the degenerate oscillations ν_3 and ν_4. Using the above eigenfunctions the vibration-rotation energies are evaluated in terms of the potential energy constants for these states to second approximation from H_2'. Our results show that in general the second-order energies depend also upon the quantum number K, an effect which becomes important not only for the state ν_4, as Jahn has shown, but also for all harmonic and combination bands of ν_4. Selection rules and quantum amplitudes of the dipole moments have also been determined.

105. Viscosity in Two-Dimensional Systems. EDWARD BOYD AND WILLIAM D. HARKINS, *University of Chicago.*—Interesting relations are exhibited in the viscosity of monolayers, such as those of acids and alcohols on aqueous subsolutions. For liquid monolayers: (1) The relation between viscosity (σ) and pressure (f) is

$$\log\sigma=\log\sigma_0+Kf. \qquad (1)$$

(2) If the molecules are oriented perpendicular to the surface, the viscosity rises rapidly with the length of the molecule. Increase of lateral pressure may cause a change to a "plastic-solid" state in which: (3) The viscosity is almost independent of pressure, and (4) Decreases rapidly as the length of the chain increases. Thus: (5) The increase of viscosity near the transition pressure is very great for short, and very small for long molecules. (6) The viscosity increases rapidly with the closeness of molecular packing. Thus with the same number of carbon atoms an alcohol of area 21.8 has about 30 times the viscosity of an acid of area 24.4 sq. A per molecule. Our Eq. (1) is analogous to Eq. (3) of Moore and Eyring

$$\log\sigma=\log\frac{h}{a}+\frac{\Delta F^{\ddagger}}{k'T},$$

from which it can be shown that our K has a calculated value 0.058 in absolute units while the experimental values for the 14 to 20 C atom acids range from 0.022 to 0.076.

106. On the Electromagnetic Field Produced by an Electron. V. F. WEISSKOPF, *University of Rochester.*—An analysis of the electric and magnetic field in the immediate neighborhood of an electron has been made by computing the electric field energy $U_{\mathrm{el}}=1/8\pi\int E^2dv$ and the magnetic energy $U_{\mathrm{mag}}=1/8\pi\int H^2dv$. The evaluation of these expressions for a single electron gives

$$U_{\mathrm{mag}}\cong\lim_{a=0} e^2\frac{(h/mc)^2}{a^3},$$

where a is the critical electron radius. U_{mag} is equal to the energy of the field of a magnetic dipole density concentrated in a volume of linear dimensions a, so that we can identify U_{mag} as the energy of the field of the spin. U_{el} contains, apart from the electrostatic field of the charge, another term U_{el}' which is the energy of an alternating solenoidal field. This latter field is produced by the well-known fluctuating rotatory motion of the electron, which is responsible for the spin. The calculation gives $U_{\mathrm{el}}'=U_{\mathrm{mag}}$, so that the total contribution $1/8\pi\int(E^2-H^2)dv$ of the spin to the self energy vanishes. The theory of the positron leads to different results: one gets $U_{\mathrm{mag}}\cong e^2(h/mc)/a^2$, which can be shown to be the field energy of a dipole density spread over a finite region in the same way as the charge of an electron in positron theory.[1] A direct proof of this spread of the magnetic polarization M can be given by calculating $M(r-\xi/2)M(r+\xi/2)$, which is finite for $\xi\neq 0$ and is proportional to the charge distribution $\rho(r-\xi/2)\rho(r+\xi/2)$. The electric field energy U_{el} is negative in positron theory: $U_{\mathrm{el}}=-U_{\mathrm{mag}}$. This is explained by the fact that the fluctuating oscillatory motion of the electron is according to the exclusion principle in opposite phase to the fluctuating motion of the vacuum electrons. The presence of the electron decreases the electric field energy of the vacuum electrons by destructive interference. The contribution of the spin to the self energy does not vanish in positron theory. It leads, together with the energy of the oscillations produced by fluctuations of the radiation field, to a logarithmically divergent term.

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[1] See abstract of a paper given at the meeting of the A. P. S. in New York, Feb. 23–25, 1939.

107. A Modification of Special Relativity. CHESTER H. PAGE, *Lafayette College.*—Time observations in a laboratory are made by using clocks which have been synchronized while at rest beside each other, and then transported to observation points. Such observed times, and velocities based thereon, have the subscript 0 to distinguish them from "basic" times and velocities. "Basic" times are those indicated by clocks transported infinitely slowly. We postulate: (1) Position measurements are independent of clock transport velocity. (2) $c_0{}^2=c^2+w_0{}^2$, where c_0 is the observed velocity of light, w_0 is the observed clock transport velocity, and c is the basic velocity of light. From these postulates we immediately derive the slowing down of a clock in motion:

$$T_0=T\left(1+\frac{w_0{}^2}{c^2}\right)^{-\frac{1}{2}}=T\left(1-\frac{w^2}{c^2}\right)^{\frac{1}{2}},$$

where w is the basic velocity of transport. By considering the setting back of a clock while being transported to the position of an event, we find that the positions and basic times of an event referred to laboratories (reference systems) having a basic relative velocity V are interrelated by the Lorentz-Einstein transformations, although positions and observed times are not. With available transport velocities, the difference is experimentally indistinguishable.

108. Nuclear Spins and Magnetic Moments by the Alpha-Particle Model. R. G. SACHS, *Johns Hopkins University.*—Some properties of the light nuclei of the type

$n\alpha \pm 1$ have been calculated[1] on the basis of the α-particle model. By means of this description, spins and magnetic moments of the same nuclei are calculated. The results for the magnetic moments of many of the nuclei are undetermined within a certain range of possible values since the relative order of magnitude of the spin-orbit coupling and the separation of rotational levels is unknown. This ambiguity does not appear in the Hartree model,[2] so that the magnetic moments as calculated by the two models are somewhat different. The most notable difference occurs for the spins of C^{13}, N^{13}, which have not yet been measured; the Hartree model predicts a spin of $\frac{1}{2}$ for them, but the α-model yields a spin of $\frac{3}{2}$. The α-model appears to give slightly better agreement for those magnetic moments that have been measured.[3]

[1] L. R. Hafstad and E. Teller, Phys. Rev. **54**, 681 (1938).
[2] M. E. Rose and H. A. Bethe, Phys. Rev. **51**, 205 (1937).
[3] H. A. Bethe, Phys. Rev. **53**, 842 (1938).

109. Groups of Quantum-Mechanical Contact-Transformations and the Degeneracy of Energy-Levels. J. M. JAUCH,* *University of Minnesota. (Introduced by E. L. Hill.)*—It is well known that the invariance of the Schrödinger equation under the three-dimensional rotation group is not sufficient to give an explanation of the degeneracy of the energy-levels in the hydrogen atom. The "accidental" degeneracy with respect to the quantum number l remains unexplained. It is now possible to set up a continuous group of quantum-mechanical contact-transformations such that under this group the space of an energy-level transforms according to an irreducible representation of this group. For the hydrogen atom this group is isomorphic to the four-dimensional rotation group, a result already stated by Fock[1] and Bargmann.[2] The group has been determined in the case of the two-dimensional hydrogen atom and the two- and three-dimensional oscillator. The transformations have an analogy in classical mechanics and represent there transformations of one orbit in phase space into another orbit of the same energy.

* Swiss Exchange Fellow of the Institute of International Education.
[1] V. Fock, Zeits. f. Physik **98**, 145 (1936).
[2] V. Bargmann, Zeits. f. Physik **99**, 576 (1936).

110. Born's Reciprocity and Mie's Theory of Field and Matter. ALFRED LANDÉ, *Ohio State University.*—Born's theory of reciprocity concerning an upper limit to the corpuscular momentum is transferred to the electromagnetic field. The classical Mie theory of field and matter points to a normalization and then to a limitation of the vector potential which leads to a quantum theory of the field including charge and current. Its first application is the quantization of the charge itself ($C = ne$) replacing the explanation by means of a spherical model in a modified Maxwell field. The principal objection to Born's reciprocity was that "nobody would be able to move" if there were such a small upper limit to the momentum as is Born's b. This objection is removed by the result that there is an upper limit to the velocity ($0.999992 \cdot c$) for all masses rather than a common upper limit to the momentum.

111. Parameters More Fundamental Than the Space-Time Coordinates. ENOS E. WITMER, *University of Pennsylvania.*—It is well known that the true quantities belonging to the Lorentz group are spinors, of which tensors form only a special class. This leads to the idea that it might be possible and advantageous to express physical quantities as functions of fundamental spinors instead of the fundamental vector x, y, z, ct. Let[1]

$$x = (\xi^1\bar{\xi}^2 + \xi^2\bar{\xi}^1) - (\bar{\eta}_1\eta_2 + \bar{\eta}_2\eta_1),$$

$$y = -i(\xi^2\bar{\xi}^1 - \xi^1\bar{\xi}^2) + i(\bar{\eta}_2\eta_1 - \bar{\eta}_1\eta_2), \text{ etc.}$$

Here ξ^1, ξ^2, $\bar{\eta}_1$, $\bar{\eta}_2$ are the fundamental spinors. In terms of these parameters the operators $\partial_{r\bar{s}}$ of spinor analysis become very symmetrical expressions. Thus

$$\partial_{1\bar{1}} = \frac{2}{S}\begin{vmatrix} \dfrac{\partial}{\partial\bar{\xi}^1} & \dfrac{\partial}{\partial\bar{\eta}^1} \\ \xi_1 & \eta_1 \end{vmatrix},$$

where

$$S = 2\begin{vmatrix} \xi^1 & \eta^1 \\ \xi_1 & \eta_1 \end{vmatrix}.$$

S is the "complex interval." The use of these parameters might be a step forward in dealing with the basic problems in physics today. It seems improbable that our present concept of space-time will be forever satisfactory. Therefore, even if these particular parameters do not represent an advance, the idea that physics may some day require the use of more basic independent variables than the ones now in use should not be abandoned. This is in accord with the general idea that even our most basic concepts may be replaced by others still more fundamental.

[1] G. Rumer, Physik. Zeits. **32**, 619 (1931).

112. Devitrification Temperatures of Aqueous Solutions.* BASILE J. LUYET, *Saint Louis University.*—Using the method of immersion in liquid air in thin layers I could vitrify solutions of inorganic substances: chlorides, sulfates, nitrates, hydrates, etc. and of organic compounds such as formaldehyde, ethylene glycol, glycerol, glucose, sucrose, dextrin, gums, agar, amino-acids, gelatin, albumin, etc. These solutions devitrify, i.e. crystallize and become opaque when their temperature is raised. Contrary to what is usually thought, the curves of the devitrification temperatures in terms of time turn parallel to the time axis within a narrow range of temperatures. This contradicts the view that any glass should finally crystallize if enough time is allowed. The solutions investigated have devitrification temperatures which range in increasing order when the substances dissolved are arranged in the order of increasing molecular complexity. At very high concentrations there is no devitrification at any temperature (a property of interest for the study of bound water); at an intermediate range of concentrations (for example, 2.4 M for sucrose) devitrification occurs according to a certain pattern and at certain temperatures; at a lower range (1 to 2 M for sucrose) the devitrification pattern is different and the temperatures are considerably higher. Within such a range (from 1 M to 2 M for sucrose) a large increase in concentration causes little lowering of the devitrification temperatures.

* Read by title.

113. Experimental Test of the Statistical Theory of Scaling Circuits. HAROLD LIFSCHUTZ AND O. S. DUFFENDACK, *University of Michigan.*—Extending previous work on the statistical theory of counting losses in Geiger-Müller counters and recorders, the parallel method[1] was used to determine the losses in a Cenco counter fed by a vacuum tube scale-of-eight. The Cenco counter was compared against a vacuum tube frequency meter. The experimental efficiency curve thus obtained was checked against the theory of Aloaglu and Smith. To do this the resolving times, σ and τ, of the G-M circuit and Cenco counter were found by observing the maximum *random* rate from the G-M tube and the maximum *periodic* rate of counting of the Cenco counter. These maxima were 400,000 and 4080 counts per minute, respectively. The theoretical curve thus obtained agreed well with the experimental curve up to input rates to the system of 38,000 counts a minute where the Cenco counter exhibited losses of 65 percent. At still higher counting rates the experimental curve appears to show a somewhat more rapid choking of the counter than predicted by the (idealized) theory. The Cenco counter shows negligible counting losses up to 17,000 counts a minute for the above values of σ and τ. Its useful speed is thus increased by a factor 400 over its speed when employed in a scale-of-one, in agreement with the theoretical prediction.

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[1] H. Lifschutz and O. S. Duffendack, Phys. Rev. **54**, 714 (1938).

114. The High Frequency Modulation of Geiger Counters. J. N. SHIVE, *Johns Hopkins University.* (*Introduced by J. A. Bearden.*)—From a study of the current theories of the Geiger-Müller counter breakdown it seems plausible to expect that if an a.c. voltage is superimposed on the d.c. threshold of a counter, an ionizing particle arriving during the positive half-cycle will produce a complete breakdown, while for a particle arriving during the reverse half-cycle the discharge can proceed no further than the first Townsend avalanche. The consequent halving of the normal plateau counting rate under these conditions has been looked for in a number of variously constructed counters, and has been observed in some counters for modulation frequencies up to three mc. Experiments with a modulated x-ray source have shown that with source and counter in phase opposition, the counting rate is in these cases substantially one-half the normal background rate up to modulation frequencies of 300 kc. This investigation was undertaken in an attempt to establish a workable method for measuring speeds of neutrons in homogeneous groups of high energy. With a counter and neutron source modulated at 300 kc, having a separation of one meter, it should be possible to measure the velocities of neutrons of 10,000 v energy.

115. The Detection of Single Positive Ions, Electrons and Photons by a Secondary-Electron Multiplier. JAMES S. ALLEN, *University of Minnesota.*—A secondary-electron multiplier tube has been developed and used successfully for counting single positive ions, electrons and photons. This tube has 12 electrodes covered with a thin layer of beryllium. Tests have shown that with 300 volts per stage this tube will multiply the primary ion current by a factor of 10^5. The use of guard ring insulation and electrostatic shielding for the final collecting electrode has reduced the background current to an extremely low value. The last electrode was connected to the grid of the first tube in a linear amplifier. In order to count single positive ions the tube was waxed to the end of a simple mass-spectrograph. A few microamperes of electron current in the ion source were sufficient to produce large numbers of positive ions. The pulses produced were so large that only a few of the stages of the thermionic amplifier were necessary to amplify them sufficiently to be seen on the screen of a cathode-ray oscillograph. The multiplier tube has an extremely low background counting rate. Ions having energies from 50 to 20,000 volts and masses from one to 32 were detected. By increasing the gain of the thermionic amplifier, electrons could be counted. With still more gain single photons were counted. The height of the pulses due to electrons was about one-seventh that of the positive ion pulses, while the photon pulses were much smaller.

116. An Automatically Recording Geiger-Müller Counter Circuit. LYNN J. BRADY, *The Pennsylvania State College.* (*Introduced by Wheeler P. Davey.*)—A circuit has been developed by which the intensity of x-rays as registered by a quantum counter may be recorded automatically on a moving roll of paper. This circuit, which has been considerably modified from that of Gingrich, Evans and Edgerton, automatically corrects for changes in x-ray intensity due to any reasonable variation in x-ray tube current, and records the rate of arrival of impulses from the quantum counter in the form of the customary Intensity *vs.* Angle curves. Statistical fluctuations are nearly ironed out without loss of resolution. Easy adjustment of sensitivity and of location of zero is provided. The whole circuit is a.c. operated.

117. Discharge Counters of Unconventional Geometry. SANBORN C. BROWN AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—This paper reports a successful general method for removing the geometrical restrictions from discharge counter design. In a previous paper[1] we discussed the operation of the coaxial cylinder discharge counter using a modification of the parallel circuit introduced by Neher and Harper[2] to quench the discharge from outside the counter. This method has now been extended to the cases of counters with parallel plate, parallel ring, parallel wire and concentric sphere electrodes. These geometries all function as true discharge counters as do Geiger-Müller tube counters, and are therefore sensitive to gamma-rays and beta-rays as well as the heavily ionizing particles. The general electrical characteristics of all the different geometrical types are similar. The counting rate is dependent on the applied voltage in the operating range, but this does not prove to be a serious disadvantage if an efficient potential stabilizer is used. The counters operate satisfactorily at voltages between 500 and 1500 when filled with dry air at pressures between 0.5 and 3.0 cm of Hg. The performance is independent of the material of which the electrodes are made. The removal of geometrical restrictions for discharge counters means that it is no longer necessary to design an experiment to suit the conventional tubular Geiger-Müller geometry, but the discharge counters can be given a geometry which is optimum for the particular detection problem at hand.

[1] Brown and Evans, Phys. Rev. **53**, 914(A) (1938).
[1] Neher and Harper, Rev. Sci. Inst. **7**, 441 (1936).

118. Improvements in the Counting Rate Meter. Robley D. Evans and Robert L. Alder, *Massachusetts Institute of Technology*.—The counting rate meter as originally described[1] had the defect of nonlinearity which was particularly severe at high counting rates. Without modifying the general principles involved, several changes have been made in the original circuit which make it adaptable to high speed counting. These changes involve (a) use of the Neher-Pickering[2] circuit adapted for a reasonable drain on the neon stabilized high voltage supply by the use of 10^7-ohm resistors in the grid and cathode circuits, (b) the multi-vibrator stage is inverted to receive a positive pulse, and its time constant greatly reduced by lower values of its resistors and capacitors, and (c) the tank circuit pulses, which now are of much shorter duration, retain their former high microcoulomb values through the use of an output tube having a high mutual conductance, such as the 6L6 or 1852.

[1] Gingrich, Evans and Edgerton, Rev. Sci. Inst. **7**, 450–456 (1936).
[2] H. V. Neher and W. H. Pickering, Phys. Rev. **53**, 316 (1938).

119. A Simple Circuit of Short Resolving Time for Coincidences. Louis A. Turner, *Princeton University*.—The wires of two self-extinguishing alcohol-filled Geiger-Müller counters[1] are connected in parallel to the grid of a 57 tube and to the grid bias through a resistance (30,000 ohms) and a radiofrequency choke (0.085 *H*). The extremely rapid onset of current in one of the counters produces a damped oscillation of high frequency in the grid circuit. Coincident discharge of both counters produces an oscillation of double amplitude when the counter voltages have been adjusted so that both give impulses of the same size. The grid may be biased so far past cut-off that no current whatsoever flows in the tube unless the double pulse of a coincidence occurs. The output of this tube may be applied directly to a thyratron or further amplified. With counters having cylinders six cm long and two cm in diameter and applied voltages 150 volts above threshold, a grid bias three volts larger than that for cut-off is necessary for making the tube insensitive to single counts, a bias of 4.5 volts greater than cut-off is suitable for recording coincidences. The resolving time for accidental coincidences is determined by the frequency of the oscillation. With the above choke and resistance it is found to be 3×10^{-6} sec. The same principle may be used in connection with ordinary counters and the Neher-Harper circuit for improving the resolving time for coincidences. A closely similar method was developed independently and applied in this manner by Maze.[2]

[1] A. Trost, Zeits. f. Physik **105**, 399 (1937).
[2] R. Maze, J. de phys. et rad. **9**, 162 (1938).

120. A Camera for the Study of Nuclear Scattering. T. R. Wilkins and G. Kuerti, *University of Rochester*.—We have utilized the fact that suitable photographic emulsions record the tracks of alpha-rays, protons and deuterons and designed a camera to study the scattering of sharply limited beams of these particles brought out from a cyclotron to a position where the magnetic field is negligible. The camera is about 30 cm in diameter and four cm in depth. Foils of various elements placed at the center scatter the particles through small holes in a circular ring. Plates are placed at five-degree intervals around the circumference so that the particles enter these plates at a glancing angle (4°) and give flat tracks distributed over a very restricted area (1×0.1 cm). The narrowness of these patches makes it possible to view the complete patch-width when the plate is examined by a microscope with a 16-mm objective. Shutters make it possible to close off any of the apertures if exposures of differing times are desired or if different scattering foils are used with some of the plates. The parallelism and characteristic lengths of the tracks serve to eliminate all strays and make energy distribution studies possible while the differential grain spacing of protons and deuterons[1] may prove of considerable importance in the study of deuteron scattering. The new emulsions developed for these studies will shortly be generally available.

[1] T. R. Wilkins and H. J. St. Helens, Phys. Rev. **54**, 783 (1938).

121. The Ionization Produced in Thimble Chambers by Fast Neutrons. Paul C. Aebersold* and Gladys A. Anslow,† *University of California*.—Experiments with thimble ionization chambers were conducted using a collimated beam of fast neutrons[1] for which the contribution to the measured ionization due to gamma-rays is relatively small.[2] The effects of varying the wall material, the enclosed gas, the gas pressure, and the collecting field were observed. The Bragg-Gray relationship between the ionization in a gas cavity inside a medium to the energy absorbed in the medium was tested. Chambers small enough and with gas pressure low enough to allow C, N, or O recoils from the walls to lose only a fraction of their energy in crossing the chamber, as demanded by the relationship, were not feasible. However, the conditions demanded for the validity of the relationship hold approximately for protons ejected from hydrogenous walls, and when the ionization due to recoil protons alone is determined by comparison of hydrogenous and carbon-walled chambers satisfactory agreement with the relationship is obtained. It is noted that the ratio of the stopping power of hydrogenous material to that for air is greater for protons than for electrons and that this ratio increases with decrease of particle velocity. The consequences of this in the use of thimble chambers for measuring the relative ionization in biological material with neutrons and x-rays is considered.

* Finney-Howell Research Foundation Fellow.
† Research participated in while on sabbatical leave from Smith College.
[1] P. C. Aebersold, Phys. Rev. **55**, 596 (1939).
[2] P. C. Aebersold and G. A. Anslow, Bulletin of American Physical Society **14**, No. 1, 14 (1939).

122. A Device for Compounding Sine Functions. LOUIS R. MAXWELL, *Bureau of Chemistry and Soils.*—A device has been constructed for evaluating the series $\Sigma A_n \sin a_n x$ where the coefficients A_n and a_n are freely adjustable. For each term there is constructed one compounding element composed of three coils; a long solenoid (primary, 60-cycle a.c.) within which are mounted two short secondary coils, one a rotor (order of 1/5 r.p.m.) and the other a stator. Current in the primary is made proportional to A_n while the slow angular speed of the rotor is governed by a_n. The mutual inductance between the primary and rotor varies as the sine of the angle $a_n x$ of rotation. The voltages (60-cycle) induced in the rotor and stator are in phase during the first half-turn of the rotor and 180° out of phase during the second half-revolution giving a resultant peak voltage whose variations are proportional to $A_n \sin a_n x$. Variations of the resultant r.m.s. voltage from all of the elements about a constant value are proportional to the sum of the series. A record of the sum is then made on photographic paper by means of a vacuum tube voltmeter circuit. Tests have been made on a two-element system by adding $\sin x + \sin 2x$; also $\sin x + 2 \sin 2x$ for x values up to 30 radians. Positions of the maxima and minima obtained agree with the calculated values within less than 0.09 radian and the complete curves were also closely reproduced. $\operatorname{Sin} x + 1.77 \sin 1.45x$ was satisfactorily traced by the compounder. Extension to many terms simply involves a repetition of the present units with sets of interchangeable gears. The compounder can be used in connection with structure determinations of gas molecules by electron diffraction, and it has been found to work satisfactorily for CO_2.

123. An Electron Lens Type of β-Ray Spectrometer. C. WITCHER, E. HAGGSTROM, J. S. O'CONOR AND J. R. DUNNING, *Columbia University.*—A β-ray spectrometer has been constructed utilizing the lens action of a long solenoid, 152 cm long, 25 cm diameter. The radioactive source and the G-M counter for detecting the β-rays are located 86 cm apart on the axis of the solenoid. A baffle system consisting of aluminum disks and rings is interposed between source and counter to restrict within specifiable limits the dimensions of the helical paths which electrons may traverse in passing from source to counter. The magnetic field of the solenoid is homogeneous within approximately 1.0 percent over the region between source and counter, and its maximum value under present operating conditions is 1200 gauss, corresponding to a β-ray energy of 5.0 Mev. There appear to be four major advantages inherent in a spectrometer of this form. (1) The relatively great distance between source and counter greatly reduces background from gamma-rays. (2) The total thickness of absorbing material in the electron path consists solely of the counter window, which may be made as thin as one or two microns. (3) Theory indicates, and preliminary experimental results verify, that a better combination of intensity and resolution can be obtained with this type of instrument than with the conventional type. (4) Sources in the form of disks 2.0 cm in diameter may be used.

124. An Electron Spectrograph. W. T. HARRIS, *Princeton University.*—A magnetic spectrograph embodying some new features has been constructed. The magnet, constructed of Armco iron and Alnico, maintains a permanent field of 4000 oersteds or less in a pole gap $15 \times 15 \times 2$ cm. For studying a spectrum the magnetization can be changed in large steps by energizing the windings for a few seconds, and in fine steps by using iron shunts. Two deflection chambers have been constructed for use interchangeably. One is of the 180° photographic type to be used for survey work. The other is of the 90° type for use with counters. This latter type has some advantages over the 180° type. For the same $H\rho$ only half as large a magnet is required, the source and detector are separated farther, and are both well away from the magnet where space is plentiful. The solid angle of the beam is 2×10^{-3} steradian. The resolution (dispersion/spread) is $(2/\alpha^2)(\Delta H\rho/H\rho) = 0.13$, where α, half the angle of divergence of the beam from the source, equals 10° and $\Delta H\rho/H\rho = 0.019$, as calculated for the slit width of 0.6 cm and ρ of 11 cm used. The same result would be obtained with a 180° spectrograph of like aperture.[1]

[1] W. E. Stephens, Phys. Rev. **45**, 55 (1934).

125. Beta-Spectra Associated with Iodine. GERALD F. TAPE, *University of Michigan.*—Continuing the detailed investigation of the radioactive isotopes of tellurium and iodine, the momentum distributions of beta particles emitted from several radioactive iodine isotopes have been studied. Activated samples mounted on filter paper were placed inside of a large hydrogen-filled cloud chamber. The inspection upper limit of I^{128} (25 minutes) has been checked at 2.2 Mev. This value is in agreement with the findings of other investigators.[1] The iodine isotope associated with the 8-day half-life[2] was chemically separated from a deuteron-activated Te sample. By inspection the upper limit was found to be 0.74 Mev. This is to be compared with a value of 0.80 Mev by extrapolation on a K-U plot. I^{126} produced by $(n,2n)$ reaction from I^{127} has been chemically concentrated for cloud-chamber work. The upper limit of this spectrum was observed at 1.17 Mev.

[1] Alichanian, Alichanow, Dzelepow, Physik. Zeits. Sowjetunion **10**, 78 (1936); Bacon Grisewood, van der Merwe, Phys. Rev. **54**, 315 (1938).

[2] Tape and Cork, Phys. Rev. **53**, 676 (1938); Livingood and Seaborg, Phys. Rev. **53**, 1015 (1938).

126. Gamma-Rays from Aluminum Due to Proton Bombardment. G. J. PLAIN, R. G. HERB AND R. E. WARREN, *University of Wisconsin.*—A study has been made of the excitation of gamma-rays from thin films of aluminum bombarded by protons in the energy region 0.45 Mev to 2.59 Mev. Practically all of the radiation in the lower half of the energy region is due to resonance excitation. The resonance peaks are sharply defined and are comparable in half-width to those observed from fluorine. In the upper part of the energy region the resonances are too closely spaced for good resolution, but peaks are still distinct up to the maximum proton energy. The average spacing between resonance peaks is considerably less than that observed from fluorine. More than thirty distinct peaks have been established.

127. The Beta- and Gamma-Ray Spectra of Cu^{64} and Eu^{152}. A. W. TYLER, *University of Michigan. (Introduced by J. L. Lawson.)*—The radiations emitted from Cu and Eu have been studied with a magnetic spectrometer having a resolving power of about two percent. Cu^{64} has been reported[1] to decay with a half-life of 12.8 hours by either positron or electron emission. This has been verified. The observed upper limits of the positron and electron spectra are 0.659 ± 0.003 and 0.578 ± 0.003 Mev, respectively. The positron spectrum having the higher upper limit is in definite disagreement with the previously published values.[1] There is no definite indication of an associated gamma-ray other than the positron annihilation radiation. Eu^{152} gives rise to a continuous electron spectrum with an upper limit of $1.88^5\pm0.015$ Mev and a half-life of 9.2 hours. There are also several gamma-rays present in addition to those previously reported.[2] One of them is internally converted. The *K* and *L* peaks are easily resolvable above the continuous electron spectrum and indicate a gamma-ray energy of 122 ± 1 kev. A possible energy level diagram of Gd^{152} is proposed.

[1] S. N. Van Voorhis, Phys. Rev. **50**, 895 (1936).
[2] J. R. Richardson, Phys. Rev. **53**, 942 (1938).

128. The Beta-Ray Spectra of Radioactive Phosphorus, Sodium and Cobalt. J. L. LAWSON, *University of Michigan.*—The momentum distributions of emitted particles associated with a few artificially induced radioactivities have been obtained by means of a magnetic spectrometer of high resolution. These distributions have been corrected for window absorption, counter efficiency, source decay, and the spectrometer resolution. The effect of back-scattering from various source mountings is demonstrated. The beta-ray spectra of radioactive phosphorus and sodium obtained with sources weighing approximately three mg per square cm are shown. The observed endpoints are $7210H\rho$ and $6150H\rho$, respectively. The positron spectrum of radioactive cobalt (18 hours half-life) has also been obtained, indicating an upper limit of $6500H\rho$. An example of an internally converted gamma-ray occurring in indium demonstrates the resolution of the spectrometer. The *K* and *L* shell conversion electrons occur in well-separated groups.

129. The Gamma-Radiation from Radioactive Cobalt. B. R. CURTIS, *University of Michigan.*—The energy of the gamma-radiation produced by radioactive cobalt obtained by bombarding iron with deuterons[1] has been investigated using a large hydrogen-filled cloud chamber. The momentum distribution of the electron ejected from a carbon radiator of 35 mg/cm^2 thickness shows that in addition to the annihilation radiation due to the positive electrons from the 18-hour activity of cobalt, there is a strong line of 0.8 Mev and evidence of a weaker line of 1.2 Mev, the relative observed intensities of the three lines being 1, 0.5 and 0.1, respectively. Preliminary results from the momentum distribution of electrons emitted from a lead radiator of 20 mg/cm^2 thickness indicate that at least two additional lines are present of 0.1×4 and 0.22 Mev energy, with equal intensities of 0.1 and 0.1.

[1] B. T. Darling, B. R. Curtis and J. M. Cork, Phys. Rev. **51**, 1010(A) (1937).

130. Radioactivities Induced in Molybdenum by Fast Protons. DOUGLAS EWING, TOM PERRY* AND RALPH MCCREARY, *The University of Rochester.*—Radioactivities of half-lives 53 ± 3 minutes and 110 ± 10 hours are obtained when molybdenum is bombarded with 6.5-Mev protons. They give rise to β-particles whose maximum energies are 2.3 and 0.6 Mev, respectively. Both activities are accompanied by γ-rays. The 110-hour activity is found to follow the chemistry of element 43. Excitation functions for the two reactions will be shown.

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131. Radioactivity in Cadmium and Indium. J. M. CORK AND J. L. LAWSON, *University of Michigan.*—When cadmium is bombarded with 7.5-Mev deuterons several radioactive isotopes of cadmium and indium are formed. The inter-relation of these isotopes and the energies of their radiations have been studied by means of an ionization chamber, a cloud chamber, and a magnetic beta-ray spectrometer of high resolution. There now appear to be four radioactive cadmium isotopes and at least eight indium activities. Two of the periods in indium grow in chain reactions from the cadmium. There is evidence that both stable indium isotopes of mass 113 and 115 may exist in excited states. Gamma-rays associated with these activities are largely internally converted and are beautifully resolved on the beta spectrometer. The energies of certain of the beta-spectra and at least five gamma-lines have been precisely determined.

132. The Heat of Dissociation of Carbon Monoxide. HOMER D. HAGSTRUM AND JOHN T. TATE, *University of Minnesota.*—A mass spectrometric study of the C^+ and O^- ions produced in CO by electron impact indicates, in complete agreement with Lozier,[1] that the following processes occur:

$$CO\rightarrow C+O^- \quad \text{at 9.5 volts,}$$
$$CO\rightarrow C^++O^- \quad \text{at 21 volts,}$$
$$CO\rightarrow C^++O \quad \text{at 22.8 volts.}$$

As pointed out by Lozier these results in themselves, because of uncertainty about the states of excitation of the products formed, do not discriminate between 9.6 and 11.6 volts as a possible value for D(CO). In the present work the formation of O^+ ions was examined. The absence of C^- ions precludes the process $CO\rightarrow C^-+O^+$. If the process is assumed to be $CO\rightarrow C+O^+$, our measurements indicate that after deducting the kinetic energy of the products an upper limit for the energy involved is 23.55 volts. This leads to the conclusion that D(CO) is less than 10 volts and therefore, in connection with the results noted above, fixes the heat of dissociation of CO at 9.6 volts. This value is in reasonable agreement with thermochemical data and fixes the heat of sublimation of carbon at 5.9 volts (136 cal.). This result also indicates that the O^- ion formed in the above processes has an excitation energy of about 2.2 volts.

[1] W. W. Lozier, Phys. Rev. **46**, 268 (1934).

133. Separation of Gas (Isotope) Mixtures by Irreversible Processes. L. ONSAGER, *Yale University.*—The potentialities and limitations of processes like diffusion and thermal diffusion as means of separating gas mixtures (isotopes) are brought out by the observation that the physical laws which govern such a process impose an upper bound for its *entropy efficiency*, just like the small ratio of reversible to irreversible heat limits the efficiency of power production by thermopiles. In separating two gases by differential diffusion, the ratio of the decrease in the entropy of mixing, $S_m = R(-N_1 \log c_1 - N_2 \log c_2)$, to the entropy of expansion $\Delta(R \log V)$ will be at most $(c_1c_2/4) \times (\Delta D/D)^2$, proportional to the square of the relative difference between the coefficients of diffusion. In the case of thermal diffusion, the decrease of S_m is to be compared to the increase $S_\lambda = (Q/T_1) - (Q/T_2)$ due to heat conduction, and $-\Delta S_m/S_\lambda \leqq \alpha^2(c_1c_2/4)(PD/\lambda T)$, where P = pressure, λ = heat conductance and $\alpha = d \log (c_1/c_2)/d \log T$. The ratio $(PD/\lambda T) = (R/C_v)(D/D_\lambda)$ varies but little for simple molecules; it never exceeds $\frac{1}{3}$. While the fundamental efficiency of this method is low (10^{-6} to 10^{-9}), it can be approached remarkably well by simple means (50–70 percent times Carnot factor). To this end, an even compromise must be struck between quality and quantity of the product, and the low concentration of the desired component in the first stages of extraction must be compensated by greater numbers of units in parallel. Since the efficiency depends on the concentration, the necessary power is not measured by the entropy, but instead by the change of the function $\Sigma((N_1 - N_2) \log (c_1/c_2))$.

134. Theory of Isotope Separation by Thermal Diffusion. W. H. FURRY AND R. CLARK JONES, *Harvard University*, AND L. ONSAGER, *Yale University*.—A description is obtained for the convection and diffusion processes occurring in a continuous flow apparatus such as that of Clusius and Dickel,[1] and Brewer and Bramley,[2] which consists of two concentric tubes, the inner one heated and the outer one cooled. An expression is found for the net transport of a single isotope which is valid for arbitrary macroscopic properties of the gas, and can readily be put in finite terms if viscosity and heat conductivity are proportional to temperature, which is usually a good approximation. The positive term in the transport is proportional to the fractional difference of molecular masses and to p^2a^3, where p is pressure and a is difference in radii of the tubes. This term essentially determines the speed of production at any specified concentration. The separation factor obtainable with a given length depends on the ratio of this positive term to the sum of the negative, or remixing, terms. One of these is proportional to p^4a^7, and the other is independent of p and proportional to a. A sizable temperature difference is necessary, but application of extreme temperatures would not be advantageous. Calculated separations and speeds indicate that the method should be a useful one.

[1] K. Clusius and Dickel, Naturwiss. **26**, 546 (1938).
[2] A. K. Brewer and A. Bramley, Phys. Rev. **55**, 590(A) (1939).

135. The Diffusion of Hydrogen Through Oxygen Free Copper. W. R. HAM, *The Pennsylvania State College*.—A precise determination has been made of the diffusion of hydrogen through copper that is spectroscopically oxygen free. The range of temperature is from 450°C to 1050°C. The copper appears perfectly homogeneous over the entire range, the equation followed being Rate $= Ap^yT^ze^{-b/T}$, where p is pressure, T absolute temperature, and A and b constant characteristics of copper. The value of z is about $+0.5 \pm 0.2$ as was found in pure nickel. The principal point to be noted is that $y = 0.50 \pm 0.01$ even at 450°C. It is well known that copper containing any appreciable amount of oxygen shows isotherms in this region with a value of y as large as 0.8 in some instances when log R is plotted against log p. It now appears that the removal of all traces of oxygen from copper has the same effect on low temperature hydrogen diffusion isotherms as the removal of all carbon from iron and nickel, *viz.*, these isotherms become perfectly normal, the rate varying exactly as the square root of the pressure. A chemical theory applicable to the variation of the slope of hydrogen diffusion isotherms in contaminated iron, nickel and copper will be found in another paper by Ham and Simons.

136. The Diffusion of Gases Through Metals from a Chemical Point of View. J. H. SIMONS AND W. R. HAM, *The Pennsylvania State College*.—On the basis of chemical equilibria existing in the interior of the metal and without reference to the surface conditions the usual laws of diffusion are derived. Fick's linear diffusion law is shown to be a consequence of the hypothesis. The theory is then applied to the diffusion of a diatomic gas through a metal in the case where the rate of diffusion at constant temperature equals KP^y and y is greater than $\frac{1}{2}$. Further consequences of the theory are discussed and it is applied to additional examples.

137. Repulsive Forces in Van der Waals Adsorption. W. G. POLLARD, *University of Tennessee*.—The Hamiltonian for an atom with one valence electron in the surface field of a metal is averaged with a determinantal wave function completely antisymmetric in the positional and spin coordinates of the outer electron of the atom and of all the electrons in the conduction band of the metal. The resulting expression includes the usual Coulomb, exchange and overlap terms common to molecular binding. The exchange and overlap terms appear as summations over each electron in the metal with the same spin as that in the visiting atom. The terms are evaluated approximately for a simple free electron model of the conduction band by replacing these summations in the usual way by integration consistent with the exclusion principle. The exchange terms are repulsive and depend on a parameter which is proportional to the ratio of the radius of the "*s* sphere" in the solid to the mean radius of the electron cloud in the visiting atom. The results are applied to H_2 and He by using the classical image force for the attractive Coulomb terms and the above terms for the exchange repulsion.

138. Van der Waals Forces in Helium. HENRY MARGENAU, *Yale University*.—Different methods for computing the dispersion forces in helium give widely discordant results. In view of current interest in the low temperature properties of helium, a fairly accurate knowledge of these forces is desirable. The most important parameter in the force law $V=Ae^{-\lambda r}-c_1r^{-6}-c_2r^{-8}$ is c_1. Previous calculations have led to values for c_1 ranging from 1.20 to 1.60×10^{-60} erg cm^6. In the present investigation it has been calculated with the use of Wheeler's[1] absorption f values, the result being $c_1=1.49\times10^{-60}$. This happens to be in exact agreement with the formula of Slater and Kirkwood. It turns out, however, that the same f values give the result $\alpha=2.11\times10^{-25}$ cm^3 for the static polarizability, whereas the best empirical value appears to be 2.02×10^{-25} cm^3. To obtain a correct result for α, Wheeler's f values were corrected by suitably changing the relative weights of the discrete and the continuous spectrum, leaving the sum rule valid and assuming the same trend of the f's in the continuous spectrum. Recalculation with these adjusted f values yields $c_1=1.39\times10^{-60}$. The coefficient c_2 may be taken from the work of several investigators, all of whom agree sufficiently well. A and λ have been calculated by Slater. We conclude that the best expression for V is, in the face of present evidence,

$$V=\{770\,e^{-4.60\,R}-1.39\,R^{-6}-3.0\,R^{-8}\}10^{-12}\text{ erg},$$

if R is measured in A.

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[1] J. E. Wheeler, Phys. Rev. 43, 258 (1933).

139. Electrolytic "Polishing" of Tungsten. J. M. Hughes and E. A. Coomes, *University of Notre Dame.*—Electrolytic polishing as described by Vernon and Stroud[1] has been carried out for tungsten, as a possible method for the preparation of filaments for electron emission studies. Sodium hydroxide was used as electrolyte. The process was studied for 50-mil rods, and 0.7-cm×0.7-cm bars as well as three-mil wires, and over a range of concentrations from about 0.02 to 2.0 normal. The form of the current density *versus* voltage curves was essentially the same as that previously reported, and appeared to be independent of the geometry of the specimen, the concentration of solution, and the spacing of the electrodes. All of the curves exhibit a steep initial rise and a fairly sharp maximum, followed by a plateau. Polishing takes place at the constant current density represented by the plateau; on other parts of the curve etching is observed. For specimens in which the surface imperfections are small compared to the total area there is a definite current density at a given concentration, regardless of the shape or size of the specimen. In the case of fine wires apparently a much higher current density is necessary. The time required for polishing decreases with current density, and bears an approximate inverse proportion to it. A 50-mil tungsten rod polishes in 30 minutes at a current density of 32 ma per cm^2 (0.25 normal solution), and in 20 minutes at a current density of 52 ma per cm^2 (0.5 normal solution). The polishing time depends directly on the area of surface exposed to the electrolyte, and is very short for fine wires.

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[1] W. H. J. Vernon and E. G. Stroud, Nature 142, 477 (1938).

140. The Equation of State of the Frozen Rare Gases. Brother Gabriel Kane, *Catholic University of America.* (*Introduced by K. F. Herzfeld.*)—The constants in the expression for the potential energy between two atoms of the rare gases, neon and krypton, were calculated from the lattice distance and the heat of sublimation. The form of energy function used was $-\mathrm{A}r^{-6}\div AB\exp -r/\rho$. For ρ, the values 0.2091A and 0.345A were taken, the former having been found theoretically by Mayer and Bleick for neon, the latter being the value applicable in alkalihalide crystals according to Born and Mayer. In addition argon was recalculated. The results are:

	$\rho=0.2091$			$\rho=0.345$		
	NEON	ARGON	KRYPTON	NEON	ARGON	KRYPTON
$NA\times10^{35}$	1.486	5.27	8.924	0.844	7.55	12.61
$B\times10^{-48}$	1270	9500	14700	6.9	12.8	15
θ (Calc.)	60.1	105	91.1	52.7	80.5	68
θ (Exp.)	64	80	63	64	80	63

Here θ is the characteristic Debye temperature. With the above data, the equation of state of the crystals was calculated, treating them as completely ordered.

141. Specific Heat, Heat of Sublimation, and Vapor Pressure Constant of Tantalum. D. B. Langmuir and L. Malter, *RCA Manufacturing Co., Inc.*—The specific heat C_p of tantalum between 1650°K and 2800°K was determined by measurements of the ripple in the light output and in the electron emission of a tantalum filament heated with alternating current. Within the limits of experimental error, the specific heat over this range is expressed by $C_p=(0.0264+8.5\times10^{-6}\,T°\mathrm{K})$ cal./gram. The results of these measurements together with existing data for lower temperatures were combined with vapor pressure data[1] to determine the heat of sublimation at absolute zero and the vapor pressure constant from the relation

$$\log P-\frac{5}{2}\log T+\frac{1}{4.573}\int_0^T\frac{dT}{T^2}\int_0^T C_p dT=-\frac{l_0}{4.573T}+i,$$

where l_0 is the heat of sublimation at absolute zero, i is the vapor pressure constant and P the vapor pressure in atmospheres. Between 2200°K and the melting point, P is given by: $\log P=6.978-\dfrac{39{,}780}{T}$. The values obtained were $185{,}100\,\dfrac{\text{cal.}}{\text{mole}}$ for l_0, and 2.46 for i. In the computations a value of 250°K for the Debye temperature was used. This is the mean of values computed from melting point[1] and compressibility data.

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[1] D. B. Langmuir and L. Malter, Phys. Rev. April 15, 1939.

142. The Vapor Pressure and Rate of Evaporation of Barium Oxide.* J. P. Blewett, H. A. Liebhafsky and E. F. Hennelly, *General Electric Company.*—The most extensive investigations[1, 2] reported in the literature of the rate of evaporation of barium oxide are in serious disagreement. In these experiments the oxide was allowed to evaporate from an exposed surface into a vacuum, a method which for this particular case may involve large temperature uncertainties. Consequently the method of Knudsen has been applied; the oxide escapes through a small aperture in the wall of a "blackbody" at a rate so small that the equilibrium vapor pressure is not sensibly disturbed. The final results are in exact agreement with those of Claassen and Veenemans.

* Supplementary Program Paper No. 181 is to be called for after Paper No. 142.

[1] A. Claassen and C. F. Veenemans, Zeits. f. Physik **80**, 342 (1933).

[2] G. Herrmann, Zeits. f. physik. Chemie **35B**, 298 (1937).

143. A Method of Determining Thermal Conductivity Suitable for Solid or Molten Metals. Values for Zinc from −250°C to 720°C. C. C. Bidwell, *Lehigh University*.—A metal rod or hollow graphite cylinder containing molten metal is packed in silocel contained in an outer iron cylinder. Downward heat flow is established and vertical gradients measured differentially by thermojunctions in quartz tubes together with radial temperature drops across the silocel at all levels. At low temperatures the iron cylinder is surrounded by constant temperature baths, at high temperatures by additional silocel contained in magnesia pipe lagging. The differential junction measurements were obtained by raising one junction progressively while the other was left at the bottom. High temperatures were obtained by a heater winding directly on the specimen or graphite cylinder but insulated electrically. For either low or high temperature arrangements the gradient changes are found to be constant, meaning that radial temperature drops across the silocel are constant from bottom to top. This was checked experimentally. The equation is

$$k_x A\,dG/dx = K k_s \Delta T.$$

G is the gradient at level x, k_s the thermal conductivity of silocel at the particular temperature, k_x the desired thermal conductivity. Previously published values for solid zinc are verified and extended through the melting point to 730°. The drop in conductivity at the melting point agrees with data of Konno[1] (the only data found in the literature). The values in the liquid state decrease slightly with temperature. Konno's data suggested this but did not extend far enough to prove it.

[1] Konno, Phil. Mag. **40**, 542 (1920).

144. On Thermal Dependence of Elasticity in Solids. Léon Brillouin, *Collège de France, Paris, France*.—A rigorous analysis of thermal agitation[1] in a strained solid body is necessary to give correct information on the whole thermodynamics of solids and especially on the influence of temperature on elasticity coefficients. The general results are the following: (1) The microscopic elasticity coefficients which rule the propagation of hypersonic waves (thermal agitation) are given by the derivatives of the elastic potential energy and will be affected only in an indirect way by the thermal expansion. They should accordingly show a slow decrease with increasing temperature. (2) The macroscopic elasticity coefficients as measured in the propagation of acoustical or suprasonic waves are to be derived from the free energy instead of from the purely potential energy. These coefficients are directly influenced by thermal agitation. It is rather difficult to predict the variation of the λ-coefficient but the rigidity coefficient μ should show a very peculiar decrease with increasing temperature. This decrease, while slow at low temperatures, should become faster and faster as the temperature increases. For room temperature and for solids not too near their melting points the decrease is of the order of 50 to 100 times RT/V. The rigidity should decrease very rapidly and fall to zero at the melting point. However, this is true only for the macroscopic rigidity, whereas the microscopic rigidity would be but little affected. Thus the specific heat should remain nearly $3R$ as for solids. There is good experimental evidence for the correctness of these predictions.

[1] L. Brillouin, Phys. Rev. **54**, 916 (1938).

145. The Specific Heat of Monatomic Liquids. W. J. Archibald,* *Yale University*.—If one assumes that the law of force between two spherically symmetrical molecules is known, then it is possible to derive an expression for the translational part of the partition function of such a molecule in the liquid state. For the case of a monatomic liquid, this partition function yields immediately all the equilibrium properties of the liquid. The law of force between two argon atoms as determined from experiments on the gaseous and crystalline state[1] enables one to calculate the specific heat of argon by the above proceedure. The computed values agree satisfactorily with the experimental values (allowance being made for the uncertainties in the law of force used) except near the melting point where the measured specific heat is larger than that given by the present theory. This discrepancy may be due to the neglect of the internal energy due to disorder which exists in this region.[2]

* Sterling Fellow.

[1] R. A. Buckingham, Proc. Roy. Soc. **168**, 264 (1938).

[2] J. E. Lennard-Jones and A. F. Devonshire, Proc. Roy. Soc. **169**, 317 (1939).

146. Determination of Quenching Rates in an Aluminum Alloy of the Duralumin Type.[1] Hugh L. Logan, *National Bureau of Standards*.—The quenching rate used in the heat treatment of an aluminum alloy of the duralumin type has a very important influence on some of the characteristics of the finished material, particularly its corrodibility. Such rates have been calculated from photographically recorded time-temperature cooling curves obtained by means of an Einthoven string galvanometer connected in series with a thermocouple that was peened into the sample material.[2] A commercial aluminum alloy having the nominal composition Cu 4.4 percent, Mg 1.5 percent, Mn 0.5 percent, was used in this work. Samples of this sheet material were quenched from the solution temperature, 493°C±5°C, into water at temperatures ranging from 22°C to 100°C. Susceptibility to intergranular corrosion was determined, after age-hardening at room temperature, by metallographic examination of samples exposed to accelerated corrosion in an oxidizing sodium chloride solution. Samples quenched through the range 485°C to 125°C at a rate in excess of 1200°C/sec. were immune to intergranular corrosion, whereas comparison samples quenched at an appreciably slower rate were severely attacked. The time required to transfer the sample under treatment from the heat-treating furnace to the quenching bath must be sufficiently short so that the temperature of the sample does not fall below 415°C before the sample enters the bath if the material is to be immune to intergranular corrosion.

[1] This report is to be published in the *National Bureau of Standards Journal of Research.*

[2] H. J. French and O. Z. Klopsch, Trans. Am. Soc. Steel Treating **6**, 251 (1924).

147. The Momentum of Electrons in a Metal Crystal. W. V. Houston, *California Institute of Technology.*—The interpretation of Peierls' conservation theorem in the theory of electrons in metals has been obscured by the fact that the electron wave functions ordinarily used do not represent precise values of the momentum, and the ion lattice is usually treated as fixed. This has made it difficult to recognize the theorem as that of the conservation of momentum. This becomes easier when it is realized that the theorem imposes no restrictions whatever on the distribution of momentum over the possible values represented in an electron function. When the Hamiltonian function for the whole system is written down, a number of other conservation theorems can be established, and it becomes evident that Peierls' "umklapprozesse" represent the transfer of momentum to the lattice from a single electron without the excitation of a vibration. It also becomes evident that such processes can take place involving a large number of electrons. On this account no restrictions are imposed on the form of the electron energy as a function of wave-number because of the observed resistance at low temperatures.

148. The Effect of High Pressure upon the Order-Disorder Transformation in Cu-Zn and Cu-Au Alloys. Thomas C. Wilson, *Yale University.*—Since the change of entropy with pressure is equal to the negative of the change of volume with temperature, a definite prediction may be made of the effect of pressure upon the order-disorder transformation. By using electrical resistance as an index of disorder, these predictions have been examined over a temperature range of 40°C to 430°C and over a pressure range of 0 to 10,000 kg/cm^2. Two copper-zinc and two copper-gold alloys (75 and 50 atomic percent copper) were used. In all cases, the resistance decreased more rapidly with pressure as the temperature was raised. The definite but relatively small change observed in beta brass is to be expected, but the similar result in alpha brass unexpectedly suggests an ordered phase stable only at high pressures and temperatures. Similar abnormalities in the copper-gold alloys were noticeable at low temperatures and became very large as the transition point was approached, confirming prediction. Moreover, in the case of both these alloys the transition point was raised by approximately 15°C at maximum pressure. Clapeyron's equation when applied to the Cu_3Au alloy gives a value for the volume change consistent with x-ray measurements of Jones and Sykes,[1] using a value of 1.3 cal./g for the latent heat. In Cu-Au the same simple treatment leads to an anomalous result.

[1] Jones and Sykes, Proc. Roy. Soc. June (1938).

149. The Dependence of Internal Friction in Metals on Grain Size. R. H. Randall, F. C. Rose and C. Zener, *College of the City of New York.*—Experiments have been performed to test the theory previously developed* for that part of the internal friction of polycrystalline metals which arises from the flow of heat back and forth between adjacent crystals. Measurements were made upon annealed strips of brass and zinc, with a range of grain size of 0.0006 to 0.4 cm. These specimens were kindly prepared by the American Brass Company and the New Jersey Zinc Company. The strips were set into longitudinal vibration by means of an electromagnetic driver of variable frequency. A symmetrical pickup, with amplifier, was used to measure the response. The frequency of measurement was varied from the first to the sixth harmonic (6000 to 36000∼). The internal friction was found to be a maximum for those combinations of grain size and frequency where the vibration is half isothermal and half adiabatic. The experiments indicate that at room temperatures that part of internal friction in annealed, non-ferrous, polycrystalline metals which arises from microscopic thermal currents is of a larger order of magnitude than that due to all other causes, barring possible macroscopic thermal currents.

* Phys. Rev. **53**, 97 (1938).

150. The Anisotropy of Electric Conductivity of Metals. E. M. Baroody, *Cornell University.* (*Introduced by H. A. Bethe.*)—A theoretical investigation of the contributions of various factors to the observed anisotropy in the conductivity of the divalent, hexagonal close-packed metals has been begun. The source of this anisotropy is to be sought in the dependence of (1) the electron energy and (2) the scattering probability on the direction of the electron wave vector. The second effect will be due partly to the anisotropy of the electron wave functions and partly to that of the lattice waves. If we assume that the directional dependence is due to the lattice waves only, the conductivity at low temperatures should be largest in the direction of smallest velocity of sound. This is the opposite of Houston's theory[1] of 1928. For cadmium and zinc the result is of the order of magnitude of the observed effect and in the opposite direction. For magnesium it follows from the values of the elastic constants that the lattice waves are themselves isotropic. We therefore believe that the anisotropy of the electron wave functions and energy is important for the effect and a study of its influence has been begun.

[1] W. V. Houston, Zeits. f. Physik **48**, 449 (1928).

151. Excited Electronic States and Compressibility of Metallic Beryllium. A. G. Hill and Conyers Herring,* *Massachusetts Institute of Technology.*—Results of a calculation of the binding energy of metallic beryllium have already been reported.[1] Now calculations of the energies of electronic states near the top of the Fermi distribution have been made in sufficient detail to give an approximate picture of the form of the Fermi surface and the variation of energy E with wave vector k. It is noteworthy that the wave functions of the upper of the two filled energy bands are rather less like plane waves than those of the lower. Calculations have been made of the lattice constant and compressibility, but these calculations cannot be made as precise as for monovalent metals, for two reasons: (a) the shape of the Fermi surface is irregular and varies considerably with lattice constant; (b) the deviations from the usually assumed formula $E=\alpha k^2$ are large. The importance of (b) is illustrated by the fact that the compressibility calculated assuming $E=\alpha k^2$ is 4 to 5 times the value 0.80×10^{-12} cm^2/dyne (at room temperature) observed by Bridgman,[2] whereas a calculation using the directly calculated energies of electrons near the top of the Fermi distribution gives a value near the experimental.

152. A Dynamic Measurement of the Elastic, Electric and Piezoelectric Constants of Rochelle Salt. W. P. MASON, *Bell Telephone Laboratories*.—The elastic, electric, and piezoelectric constants of Rochelle salt have been measured at low field strengths by measuring the resonant frequencies and impedance of vibrating crystals. It is shown experimentally that the resonant and anti-resonant frequencies of the crystal are both considerably below the natural mechanical resonant frequency of the crystal in disagreement with the usual derivation of the frequencies of a piezoelectric crystal. By assuming that the piezoelectric stress is proportional to the charge density on the electrodes rather than the potential gradient as usually assumed, theoretical frequencies are obtained which agree with those found experimentally. This theoretical derivation together with the measured frequencies supplies values for the piezoelectric constants. The elastic constants measured dynamically show some differences from those measured statically. A large difference is found for the dynamically measured piezoelectric constants from those statically measured, which may be attributed to the finite relaxation time for the piezoelectric elements.

153. Crystallization and Melting of Rubber at High Pressure. R. B. DOW, *The Pennsylvania State College*.—The normal rate of crystallization of crude rubber at atmospheric pressure is retarded by application of pressure. Bekkedahl has shown previously that the transition from amorphous 1 to crystalline 1 is completed normally in about 13 days at 0°C, the volume decrease being 2.2 percent for crude smoked sheets. At a pressure of 8000 $\mathrm{kg/cm}^2$ a sample of smoked sheet kept at 0° for 14 days showed no detectable change of volume. If the curve for rate of crystallization *vs.* temperature is merely shifted by pressure, an increase of 8000 $\mathrm{kg/cm}^2$ would lower the rate to a negligible amount at 0°. The inhibition of crystallization is due doubtless to high viscosity since it is known that the pressure coefficient of viscosity increases with molecular weight. The transition of crystalline I to amorphous I, however, appears to be an equilibrium phenomenon. Crystallized smoked sheet melted at 77.5°C at 1270 $\mathrm{kg/cm}^2$, giving $dT_m/dp = 0.0484$ on the assumption that the normal transition point is 16°C.

154. The Dependency of the Stress-Strain Relationship for Rubber Upon the Rates of Stretching. F. E. DART AND E. GUTH, *University of Notre Dame*.—The influence of the rate of stretching upon the stress-strain curves was investigated for a pure gum compound and for a loaded stock at three different degrees of vulcanization for each. A photographically recording stress-strain apparatus was used. Rates of stretching of 2.5, 5, 10, 20 (standard testing speed), 45, 90, 180 and 1200 inches per minute were used. For all speeds but the last the rate of stretching was uniform. For very high speeds a non-uniformity of the rate of stretching is not as serious as it is for lower speeds. Hysteresis curves for first extensions and for repeated stretchings were taken at the lower speeds. The high speed curves lie, in general, above the low speed ones. For purely elastic deformation such a behavior is to be expected according to thermodynamics. The ratio of the adiabatic to the isothermal modulus which is equal to the ratio of the specific heats at constant force and constant elongation respectively, is larger than one. This relationship is expected to hold only for cases without hysteresis. In all cases there is the possibility of obtaining polytropics instead of adiabatics and isothermals. From truly adiabatic and isothermal stress-strain curves the complete free energy function of stretched rubber can be obtained without any caloric measurements. The influence of the rate of stretching upon the stress-strain relationships is, therefore, important not only from the point of view of routine testing, but also for the basic physical properties of rubber.

155. The Dielectric Properties of Dielectrics Dispersed in Water and Anomalous Dispersion in Bound, (Oriented) Water. HUGO FRICKE, *The Biological Laboratory, Cold Spring Harbor, New York*.—Over the last few decades there are found scattered through the literature dielectric observations on various kinds of dispersed systems showing the occurrence of anomalous dispersion in the low radio and audible frequency range. These observations have generally been explained on the basis of either solute ions bound electrostatically at the interphases (Debye-Falkenhagen effect) or—for the case of colloids—revolving dipolar colloidal particles. We have carried out an extensive investigation of this phenomenon which shows its general occurrence in dispersed systems and evidence is given to show that it originates in the multimolecular layer of oriented water molecules at the interphases. This effect becomes less pronounced as we pass into the range of molecular dispersion, but it is still present quite strongly in solutions of the dispersion of proteins and it appears to account essentially for the high polarizability of gelatin at low frequency, to which many investigators have recently drawn attention. The importance of this phenomenon for the dielectric properties of many systems of wide interest such as soil, living cells and hygroscopic electric insulators of the gelatinous or fibrous type is remarked upon.

156. An Experimental Method for Measurement of Shearing Stresses in Turbulent Air Flow. HAROLD K. SKRAMSTAD, *National Bureau of Standards*.—In turbulent air flow, the shearing stress due to velocity fluctuations is given by: $\tau = -\rho\overline{u'v'}$, where τ is the shearing stress, ρ the density of the fluid, u' and v' the fluctuations from the

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* National Research Fellow.

[1] New York Meeting, Feb. 1939, Abstract No. 8.

[2] P. W. Bridgman, Proc. Am. Acad. Arts Sci. **68**, 27 (1933).

mean value of the velocity components in the direction of the mean flow and in the direction of the gradient respectively, the bar representing a time average. This shearing stress may be measured by a special type of hot-wire anemometer, consisting of a short, fine wire at about 45° to the direction of the mean velocity mounted on a holder which permits the wire to be placed in various planes with respect to the direction of the velocity gradient. The velocity fluctuation of the air is converted into an alternating current which is amplified and whose mean square value is measured by a thermal type milliammeter. For small fluctuations, the response in the position of maximum reading may be regarded as proportional to $Au'+Bv'$, and in position of minimum reading to $Au'-Bv'$, where A and B are experimentally determined constants of the wire. The difference between the mean square values of these expressions multiplied by $\rho/4AB$ is equal to the shearing stress. The apparatus has been used to measure the distribution of shearing stress in the boundary layer of a flat plate. This work is being done in cooperation and with the financial assistance of the National Advisory Committee for Aeronautics.

157. Refinements in Atmospheric Transmission Measurement for Solar Constant Determination. BRIAN O'BRIEN, *Institute of Optics, University of Rochester.*—The spectral transmission of the atmosphere which enters into determination of the solar constant introduces the chief uncertainty because of variations in transmission during a set of observations. The greatest variations occur in the lower half (by weight) of the atmosphere because of higher dust and water content. An airplane instrument has been developed to measure the intensity of the direct solar beam at two wave-lengths, in the ultraviolet and red, respectively, with relatively high precision. Two barrier layer photo-cells are provided with filter systems transmitting the desired spectral regions. A temperature-controlled housing surrounds both cells and filters. Means are provided for maintaining a constant state of fatigue of the cells. By synchronizing observations with identical measurements from the ground, transmission of that part of the solar radiation path between airplane and ground station can be determined with some precision. By combining this with the measurement of transmission of the total atmosphere by conventional methods from the ground, much of the uncertainty in solar energy determination can be eliminated. Preliminary flight tests have been completed and an observing procedure developed.

158. The Approach to Saturation of Iron and Nickel. A. R. KAUFMANN, *Massachusetts Institute of Technology.* (*Introduced by F. Bitter.*)—A new arrangement for measuring magnetization in high fields has been developed by which all systematic errors are reduced sufficiently to allow a relative accuracy of one part in 50,000 to be obtained. The apparatus consists of a large air-cored solenoid at the center of which are two similar search coils connected in opposition. The specimen in the form of a long, thin rod extends through one of the search coils and entirely through the solenoid. Observations are made by jumping the field from some standard high value to any desired lower field. The ballistic charge from the search coil is counteracted by simultaneously breaking a current through a mutual inductance in the circuit, the degree of compensation being observed with a ballistic galvanometer operating as a flux meter. The results show that the magnetization curve in fields between 600 and 7000 oersted can be accurately represented by an equation of the form: $I=I_s-(a/H)-(b/H^2)+CH$, where I_s is the intrinsic saturation value at room temperature. The coefficients a and b are found to vary greatly with the treatment of the sample but C is relatively constant. The theoretical value for b agrees satisfactorily with experiment but the measured value of C is about 10 times greater than the calculated value. The constant a is purely empirical.

159. Susceptibility Measurements of Cu-Fe Alloys in Fields from 0–40,000 Gauss. F. BITTER AND A. R. KAUFMANN, *Massachusetts Institute of Technology.*—An air core water-cooled solenoid will be described in which fields of the above magnitude can be kept constant to about ±20 gauss for indefinite periods of time. The solenoid has an inside diameter of $1\frac{1}{8}''$ and can dissipate 500 kw. Susceptibility measurements on copper containing 0.003 percent, 0.094 percent, and 0.71 percent of iron have been made at room temperature using the Gouey method. These measurements will be continued at high and low temperatures in order to follow in detail the process of solution and precipitation. In all samples there is a ferromagnetic, and one or more para- or diamagnetic constituents. The results are summarized below. The annealed samples were heated to 850°C (which supposedly put all the iron into solution) and were then slowly cooled. The above saturation values indicate, in confirmation of earlier results by Tammann and others, that only a small fraction of the total iron present is ferromagnetic. In general the ferromagnetic constituent is characterized by the following: (a) remanence small compared to the saturation intensity I_s, (b) initial susceptibility $\sim I_s\times 10^{-3}$ and more or less constant in fields up to a few hundred gauss, and (c) saturation not complete until the field reaches 10–20,000 gauss.

	COLD WORKED SAMPLES			ANNEALED SAMPLES		
Total iron content	.003%	.094%	.71%	.003%	.094%	.71%
Saturation moment of ferromagnetic constituent	.0042	.0050	1	.002%	.002	.042
Total para- or dia-magnetic-volume susceptibility $\times 10^6$	−.714	.22	?	−.709	.221	3.7

160. Ferromagnetic Anisotropy in Nickel-Iron Alloys near Ni$_3$Fe. E. M. GRABBE AND L. W. MCKEEHAN, *Yale University.*—The effect of heat treatment on the magnetic anisotropy and saturation magnetization in nickel-iron alloys near the composition Ni$_3$Fe has been investigated.

Oblate spheroids of axial ratios greater than 15 to 1 were prepared from single crystals of alloys containing 65, 70 and 75 percent by weight of nickel. High precision measurements using a pendulum magnetometer showed differences between magnetization curves for different directions even for very small anisotropies. The changes observed can be explained by order-disorder transformations. Specimens cooled rapidly from 720°–750°C had the anisotropy reported by Kleis.[1] Baking at temperatures from 430°–500°C for long periods of time produced an increase in saturation magnetization. The maximum increases in saturation values are greater than those first reported,[2] amounting to 5.8, 4.2 and 3.4 percent respectively for the 75, 70 and 65 percent alloys. A 75 percent specimen having negligible anisotropy when rapidly cooled had anisotropy of the type characteristic of nickel when baked, with $K_1 = -2.30 \cdot 10^4$ erg cm^{-3} and $K_2 = 1.65 \cdot 10^4$ erg cm^{-3}. For lower nickel content [100] is the direction of most difficult magnetization at low fields. Near saturation the [100] curve crosses the [110] and [111] curves and becomes the direction of easiest magnetization. Several other crossovers not reported previously have been observed on curves which are nearly coincident.

[1] J. D. Kleis, Phys. Rev. **50**, 1178–1181 (1936).
[2] L. W. McKeehan and E. M. Grabbe, Phys. Rev. **55**, 505 (1939).

161. The Hall Effect and Change of Resistance in a Magnetic Field. L. Davis and W. V. Houston, *California Institute of Technology.*—Change of resistance in a magnetic field cannot be interpreted in terms of a free electron picture. Since such a change is observed in the alkalis it is of interest to see if it can be understood as a small departure from the free electron situation. A rigorous formulation of this idea can be obtained by expanding the electron energy and the relaxation time as a series of spherical harmonics that have the symmetry of a cubic crystal. This permits the necessary integrals to be carried out to any desired degree of approximation. When only the first two harmonics are retained, the computed change of resistance and Hall effect are close to the observed values. However, contrary to the available observations, the ratio of the transverse to the longitudinal change of resistance shows a minimum value of about four. It seems improbable that this result could be changed in any material way by the inclusion of higher series members, so that if the experimental results are to be taken as reliable, doubt is thrown on the general method of treatment.

162. Investigations of Ferromagnetic Impurities in Metals. F. W. Constant and J. M. Formwalt, *Duke University.*—As previously described, a method has been developed whereby a permanent magnetic moment as small as 10^{-7} per cc may be measured. Practically all the various metals tested by this method showed slight ferromagnetic impurities. To determine whether the impurity was a surface or volume one, the specimens were dissolved away in successive steps in various acids. In many cases the effect was only a surface one, in others partly so, but in the case of copper, brass and silver a linear relationship between magnetic moment and volume was found. With aluminum the volume impurity appeared to be nonmagnetic but could be dissolved out in HCl and deposited on the surface in a ferromagnetic state. Further measurements have also been made on the character of the hysteresis curves for the impurities in copper, brass and silver, on their Curie temperatures and on the effect of annealing. Heat treatment appears to dissolve ferromagnetic impurities into a nonmagnetic state and to render what little is still magnetic much "softer."

163. The Isotopic Constitution of Iron and Chromium. Alfred O. Nier, *University of Minnesota.*—A study of the isotopic constitution of iron and chromium has been made with a mass spectrometer similar to that previously described.[1] Although the apparatus had sufficient sensitivity and resolving power to detect extremely rare isotopes, none was found. In a search for isotopes of chromium it was possible to set the following upper limits for abundances relative to Cr^{52}: Cr^{56}, 1/100,000; Cr^{55}, 1/15,000; Cr^{51} and Cr^{49}, 1/100,000. A trace of calcium present as an impurity prevented a search for Cr^{48}. For iron the following upper limits of abundances relative to Fe^{56} were found: Fe^{60}, 1/30,000; Fe^{59}, 1/7000; Fe^{55}, 1/20,000; Fe^{53} and Fe^{52}, 1/50,000. The relative abundances measured for the known isotopes are given in the tables. The positive ions of iron were formed by bombarding a molecular beam of iron vapor with electrons. In the case of chromium it was found that by merely heating chromium metal in a tantalum furnace to about 1200°C positive ions were emitted.

Stable Isotopes of Chromium

Mass Number	50	52	53	54
Relative Abundance	5.36	100	11.26	2.75

Stable Isotopes of Iron

Mass Number	54	56	57	58
Relative Abundance	6.6	100	2.30	0.31

[1] A. O. Nier, Phys. Rev. **53**, 282 (1938).

164. Some Evidence for the Existence of Higher Hydrates of Gamma and Alpha Ferric Oxide.* Lars A. Welo, *Tottenville, Staten Island, New York,* and Oskar Baudisch, *Saratoga Springs Authority, Saratoga Springs, New York.*—On heating ferromagnetic gamma ferric oxide along with water in sealed tubes the susceptibility (concentration of gamma oxide) decreases linearly with time. Depending on the temperature, within the range 40°C to 70°C, the entire curve may consist of one, or two, or even three straight-line segments. The transformations (reactions), being of zero order, must occur by way of transition between intermediates which are considered to be the well-known monohydrates and the higher hydrates, heretofore unobserved, that are needed to complete the analogy between the oxide and oxide hydrate systems of iron and aluminum.[1] All but two of the slopes (rates) so far observed group themselves upon three separate straight lines on plotting their logarithms against temperature. At 41°C the susceptibility decreases to 87 percent of its initial value and then ceases to change. At 56° and 69°C the times to near zero susceptibility are, respectively, 325 and 80 days. In open tubes, at the temperatures of

225° to 250°C necessary for comparable transformation rates, the susceptibility is an exponential, not a linear, function of time.

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* These experiments were performed in the Research Laboratory of the Consolidated Gas, Electric Light and Power Company of Baltimore.

[1] F. Haber, Naturwiss. **13**, 1007 (1925).

165. Thermionic Constants of Tungsten for Various Crystallographic Directions. Myron H. Nichols, *Massachusetts Institute of Technology.* (*Introduced by W. B. Nottingham.*)—By a suitable heat treatment,[1] a long single tungsten crystal has been grown in a five-mil tungsten wire. One of the face diagonals of the unit cube lay along the axis of the wire. The single crystal wire was mounted so that it could be rotated in front of suitable collimating slits. The variation of emission around the wire was measured and showed perfect cubic crystal symmetry. Richardson and Schottky plots were made for each maximum and minimum found in the polar plot. The data were fitted to the empirical formula $i=AT^2\exp(-e\varphi_0/kT)$, thus determining A and φ_0. Preliminary calculations gave the following values for A and φ_0:

Miller Indices	110	111	112	116	001
φ_0	4.65	4.38	4.66	4.35	4.53
A	15	38	125	56	117

These results show that the values of A and φ_0 obtained from the usual measurements on polycrystalline wire are characteristic of a weighted average of the properties of the various crystal surfaces, and have, therefore, only empirical value indicating that all attempts to relate observed to theoretical values of emission constants have so far no great significance.

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[1] R. B. Nelson, M.I.T. Doctor's Thesis.

166. A New Circuit for Accurate Control of Current-Intensity and Time Used in Spot-Welding. W. B. Nottingham, *Massachusetts Institute of Technology.*—As a result of experience with the use of a spot-welder control designed to give accurate timing of the welder current over the range from zero up to one-half of a sixty-cycle wave,[1] it became evident that accurate control of timing for much longer periods of time than this is needed in order to fabricate the metal parts used in research. Such a circuit has been developed which can be constructed from parts which may be purchased at reasonable cost. The timing control is a unit which operates from the 115-volt a.c. lines and, by means of vacuum tube circuits, it controls the starting of two pool-type mercury arcs connected parallel-inverse so that current is delivered to the welder any arbitrary number of half-cycles from one to sixty. Circuit constants may be chosen so that only even numbers of half-cycles are used if that is desired. The pool-type mercury tubes used control peak currents up to 150 amp. in circuits with a line voltage of 230 volts a.c. or more.

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[1] T. S. Gray and W. B. Nottingham, Rev. Sci. Inst. **8**, 65 (1937).

167. A Mechanical Model for Electron Motion in a Uniform Magnetic Field. Albert Rose, *RCA Manufacturing Company, Inc.* (*Introduced by B. J. Thompson.*)—A mechanical model in the form of a gyroscope may be used to trace the path of an electron in a uniform magnetic field, acted upon by transverse electric fields. In using the model to find the electron path the following substitutions are employed: the uniform magnetic field vector is replaced by the spin velocity vector of the gyroscope, the electric fields are replaced by magnetic fields which give the same field configuration, the electron is replaced by one pole of a permanent magnet mounted on the axis of the gyroscope. Depending upon the dimensions of the gyroscope, the strength of the permanent magnet, the spin velocity of the gyroscope, and the scale factor used in setting up the mechanical model, the strength of the magnetic field in the model is adjusted to correspond to the strength of the electric field in the actual case. The path described by the magnetic pole then corresponds to the actual path of the electron. Since the error involved in identifying the equations of motion of the gyroscope with those of the electron is of the order of θ^2 where θ is the half-angle of the cone through which the spin axis is allowed to move, the range of observations must be restricted accordingly. By periodically reversing the current through the field magnets, a qualitative picture of the path of the electron in an alternating electric field may be obtained. Some familiar structures for which electron paths may readily be obtained are deflection plates in a uniform magnetic field, a diode in an axial magnetic field and a split-anode magnetron.

168. Limiting Currents in a Ring Discharge. C. G. Smith, *Raytheon Manufacturing Co., Medford, Massachusetts.*—Currents from 50 to 800 amperes were passed through mercury vapor in a large ring discharge at a frequency of 980 cycles and at pressures between 10^{-3} and 10^{-4} mm. About 5 volts e.m.f. were used. A definite limit to current flow accompanied by very high electronic temperature (up to 250,000°K) was encountered. Current carrying capacity of the gas seems to be in approximate agreement with observations by A. W. Hull on current through constrictions in mercury vapor.[1] Saturation current at about 2×10^{-4}-mm pressure seems to be 4 amp. per sq. cm. At the ultimate currents sharp fluctuations with a frequency of approximately 50,000 per sec. were observed. A permanent type of gaseous clean-up was encountered, and also a temporary type as observed by Kenty.[2] At the high electronic temperatures the two forbidden lines of mercury λ2655.8 and λ2269.8 were observed. Spectra of Hg II, Hg III were brilliant; Hg I was always the brightest. Hg IV was weak. The current limiting factor acts too quickly to be accompanied by changes in pressure. Evidence indicates it is not caused by magnetic fields. The phenomena occurring in a closed ring wherein the usual space charge limitations are ruled out, and electrical pumping phenomena are of no avail, make it apparently a characteristic of the gaseous medium.

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[1] A. W. Hull, Electrical Engineering, November 1934.

[2] Carl Kenty, J. App. Phys. **9**, 765 (1938).

169. Electron and Potential Distributions Near the Anode of a Mercury Discharge. LLOYD P. SMITH AND PAUL L. HARTMAN, *Cornell University*.—The electron energy distribution and potential in the plasma has been measured by means of probes located on the cathode side of the anode for various arc currents and mercury vapor pressures. At the same time the energy distribution of electrons arriving at the anode was measured by means of a collector behind a small hole in the anode. The combined results of both measurements indicate that on approaching the anode the potential first drops below the plasma potential by an amount V_m and then rises sharply to the anode potential which is considerably higher than the plasma potential. The value of V_m determines the concentration of the slow electrons in the plasma and the arc current according to the relation $i=i_0 \exp V_m e/kT$ where i_0 and T are the random current density and temperature of the plasma electrons. The measurements also indicate that some electrons arriving at the anode have energies well above that corresponding to the potential difference between anode and cathode. The lower the mercury vapor pressure the greater the number of these excess energy electrons.

170. Variation of the Anode Effect with Temperature. PAUL L. COPELAND, *Armour Institute of Technology*.—That the plates of vacuum tubes can acquire surface charges which alter the contact potential relative to a hot filament (called the anode effect) is known.[1] This effect has been studied by means of a diode in which the cathode is a straight tungsten wire and the anode is a nickel spiral, which itself may be maintained at elevated temperatures by the passage of a current through it. The most prominent feature of the results is the rapid decrease of the observed anode effect with anode temperature.

[1] W. B. Nottingham, Phys. Rev. **39**, 183 (1932); and **44**, 311 (1933).

171. The Effect of Wall Charge on the Progressive Breakdown in Long Discharge Tubes. J. R. DIETRICH,* *University of Virginia*.—The charge left on the walls of a long discharge tube after a discharge has occurred had been measured. Also its effect on the speed of negative potential propagation in subsequent impulsive breakdowns[1, 2] has been studied. The wall charge was measured with an electrometer and electrostatic pickup over a short section of a 750-cm tube of 5 mm internal diameter. The tube was surrounded by a concentric metal shield of 76 mm diameter. The charge varies with pressure in the tube, applied potential, and the time constant on the discharge circuit considered as a unit. At pressure 0.46 mm (dry air), applied potential 25.6 kv negative, the walls of the tube are left at potentials varying from 300 volts when the output end of the tube is short-circuited to 7700 volts when the output end is insulated. The corresponding variation in the speed of potential propagation is from 18×10^8 to 15×10^8 cm per sec.

* Charles A. Coffin Fellow.

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

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

172. Discharges Between a Stationary and a Moving Electrode. L. B. SNODDY AND J. W. BEAMS, *University of Virginia*.—The discharge in air at atmospheric pressure between a moving surface and a stationary rod electrode has been investigated by means of a rotating drum camera and an oscillograph. The rotating disk electrode was supported and driven in a manner previously described.[1] Surface speeds from 1 to 2×10^4 cm/sec. were used. Disks of copper, bronze, Duralumin, Dow metal and steel gave the same general results. Single impulses were applied to the rotating electrode gap from a highly damped series circuit consisting of a 1 mfd condenser, spark gap and resistance. At low currents (1 or 2 amps.) with the rotor either cathode or anode the luminous column is carried around on the rotor surface, the current decreasing during the process. Rotating film photographs show this extension to take place in a fairly continuous manner. The arc finally breaks and reforms approximately under the stationary electrode and is again carried around the rotor. This is repeated several times. The arc extension was found to depend (critically when the rotating electrode was anode) upon the gap width which indicates an effect of air currents. Also it was changed when the arc was formed to the inside surface of a rotating cup electrode. At high currents (30 amp.) the extension of the arc with rotor anode was very much less than with it cathode.

[1] Phys. Rev. **55**, 504 (1939).

173. The Positive Column of the Nitrogen Arc. ALBERT M. STONE, KARL T. COMPTON, AND EDWARD S. LAMAR, *Massachusetts Institute of Technology*.—Extending earlier work of one of us,[1] a theory of the positive column of an atmospheric arc in nitrogen has been developed from considerations of energy balance, and applied to cases where convection can be neglected; i.e. to low current arcs and to arcs in gravity-free space. Justification for applying a power extreme hypothesis as a means of determining the axial temperature is discussed. From the theory a functional relationship between the potential gradient E in volts/centimeter and the current I in amperes is obtained as $E=65.8/I$, with the axial temperature 6200°K, determined from the hypothesis above. Preliminary computations, neglecting convection, for arcs at 10 and 100 atmospheres are presented, together with a discussion of the applicability of the power extreme hypothesis to these cases. In the 10 atmosphere case, tolerable agreement with the experimental value of power input/cm and axial temperature is reached; we have available no experimental results at 100 atmospheres. Finally, attempts to include convection in a more general theory of the nitrogen positive column are discussed and some preliminary results are presented. At least one such attempt permits a theoretical check of the experimental atmospheric nitrogen arc characteristic from 0–10 amperes.

[1] E. S. Lamar, Phys. Rev. **49**, 861 (1936).

174. The Dispenser Cathode, a New Type of Thermionic Cathode for Gaseous Discharge Tubes. A. W. HULL, *General Electric Company*.—Modern oxide-coated cathodes have the characteristic that the initial high electron emission decreases gradually with time of operation. This characteristic is avoided by using initially-uncoated cathode members to which a coating material is dispensed at uniform rate from a "dispenser" located within the common heat-shield. Such cathodes, after initial aging, show an electron emission equal to the initial emission of oxide-coated cathodes, which does not decrease with time. In the cathodes which have been tested, the dispenser was a closely woven "stocking" of fine molybdenum wires, filled with granules of fused $BaO-Al_2O_3$ eutectic. It was maintained at 1150°C by current through it, and served as a radiation heater for the cathode. The electron-emitting members were clean molybdenum. These cathodes show undiminished electron emission at the end of 3-years life test with no indication of exhaustion.

175. Autoelectronic Emission in Metal Arcs. W. S. Huxford, S. G. Eskin, and R. W. Jones, *Northwestern University.*—Recent measurements by one of us* show that restriking of the arcs formed between slowly separating contacts occurs during the interruption of low voltage a.c. circuits containing non-inductive loads. These observations have been supplemented by oscillographic determinations of current, potential, and energy of these arcs for the case of silver electrodes. At a contact opening speed of 0.024 in. per sec. the probability of reignition increased with rise of current and with increase of potential from 110 to 220 volts at constant current. Seven cases of reignition were observed in fourteen trials at this speed, but none at the two higher speeds used. The potential gradient and not the potential across the gap at the instant of arcing appears to be the determining factor in reignition. In the seven cases for which measurements were made the value of the field was $0.30 \pm 0.11 \cdot 10^6$ volts/cm when restriking occurred; the potential range was from 72 volts to 170 volts. Presumably the arc is initiated by field emission of electrons from the cathode. The field required to start an arc between electrodes having a fixed separation of the order of 0.001 cm was approximately $0.20 \cdot 10^6$ volts/cm for freshly cleaned silver contacts.

* S. G. Eskin, "Effect of Contact-opening Speed on Arc Energy in a.c. Switching," Gen. Elec. Rev. **42**, 81–86 (1939).

176. The Effect of Electron Bombardment on the Electrical Conductivity of Zincblende Crystals.* Merril Distad, *University of Minnesota.*—Two opposite sides of a transparent zincblende crystal were coated with semitransparent layers of copper. A potential difference V_c was maintained between these electrodes. When the negative crystal electrode was bombarded by electrons whose energy V_e ranged from 5 to 900 electron volts, a current i_c flowed through the crystal. This current depended on the bombardment time and asymptotically approached an equilibrium value which was proportional to the bombarding current and independent of the crystal temperature. The variation of i_c with the bombardment time was apparently caused by a space charge in the crystal near the bombarded electrode. The equilibrium magnitude of this space charge was practically independent of the magnitude of the bombarding current and of the crystal temperature. It had relatively large negative values for small V_e and was practically zero for V_e greater than 400 electron volts. Electron bombardment produced a crystal current even if V_c was zero. When the positive crystal electrode was exposed to electron bombardment, small crystal currents were observed which were positive or negative depending on V_e and V_c. If the electrons entering the crystal have sufficient energy, they can also liberate other electrons in the crystal.

* Supplementary Program Paper No. 182 is to be called for after Paper No. 176.

177. Measurement of Pain Threshold with Thermal Radiation. J. D. Hardy, H. G. Wolff and H. Goodell, *Russell Sage Institute of Pathology in Affiliation with the New York Hospital, Cornell University Medical College.*—Using the following technique the threshold for pain has been studied in three normal individuals. The light from a 1000-w bulb was focused upon the blackened foreheads of the subjects. A shutter arrangement was provided to allow exposure to the radiation for exactly three seconds. The intensity of the radiation was varied until the subject barely felt pain at the end of the exposure. The intensity of the light was then measured radiometrically in cal./cm^2/sec. and called the pain threshold. The results of the studies are: (1) The intensity of radiation required to evoke a painful sensation in three seconds was 0.218 ± 0.004 g cal./sec./cm^2. (2) The threshold stimulus was the same regardless of the size of area stimulated. This lack of spatial summation is in contrast to other modalities, heat, cold, sight, touch, etc. (3) The time required to evoke pain was a function of the reciprocal of the light intensity. (4) Pain produced by this method was not dependent entirely upon how high the skin temperature was raised. (5) Changes in threshold produced by drugs were studied.

178. Displacements and Depolarization Factors of the Raman Lines of Di-Normal- and Di-Iso-Ethers. Forrest F. Cleveland, M. J. Murray, Julia Shackelford, and Herschel H. Haney, *Lynchburg College.*—The Raman spectra of di-*n*-propyl, di-isopropyl, di-*n*-butyl, di-*n*-amyl, and di-isoamyl ethers have been obtained by use of a spectrograph having a dispersion of 33A/mm at 4500A. High,[1] who previously studied all except di-*n*-butyl ether with an instrument giving less dispersion, reported only a few lines. For example, he reported only 6 lines for di-*n*-amyl ether, whereas the present investigation yielded 24, most of which were obtained with both Hg 4047A and Hg 4358A. Part of this increase is due to resolution of broad lines into two or more components. In di-*n*-amyl ether, for example, the $-CH_2$-frequency near 1450 cm^{-1} is resolved into four components and eight frequencies are observed in the region 2700–3000 cm^{-1}. The large number of lines observed in the latter region is probably due in part to resonance interactions with the first overtones of the fundamentals near 1450 cm^{-1}. The depolarization factors of the more intense lines have been determined by use of the method described in Paper No. 16. This paper covers part of a research program which has been aided by grants from the Virginia Academy of Science, Sigma Xi, and the American Association for the Advancement of Science.

[1] M. E. High, Phys. Rev. **38**, 1837–1844 (1931).

179. On Alleged Discontinuities in the Diffuse Scattering of X-Rays from Crystals at Small Angles. G. G. Harvey, *Massachusetts Institute of Technology.*—In a short note Laval[1] claims to have found that the diffuse scattering from a large number of crystals varies in a discontinuous manner as the scattering angle is increased. He used "monochromatic" radiation obtained by reflexion from a crystal and worked in regions where the Bragg law was not satisfied for the particular wave-length (Cu $K\alpha$) and scattering materials used. A large number of discontinuities are reported. We wish to point out that in every case the positions of these alleged discontinuities coincide with the positions of reflected lines of $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ the primary wave-length, which strongly suggests that the incident beam was not really monochromatic. The results may be completely explained if Laval used a potential of about 35 kv on his tube, a not unusual value for a copper target tube. (He gives no experimental details.) The experiment has been repeated photographically for the case of aluminium, for which Laval reported nine discontinuities. Weak second-order reflexions of half the primary wave-length might be mistaken for edges if one did not map out the immediate vicinity too carefully. It is suggested that the effect reported by Laval does not exist.

[1] J. Laval, Comptes rendus **201**, 889 (1935).

180. The Paschen-Back Effect in the Spectrum of Neon. J. B. Green, *Ohio State University,* and J. A. Peoples, Jr., *Lehigh University.*—The methods developed in Paper No. 78 have been applied to the spectrum of neon. The transformation coefficients in this spectrum can be easily determined since parameters have been calculated for several of its configurations. When applied to several lines of the p^5p-p^5s and p^5p-p^5d transitions, results are obtained which are in extremely good agreement with observed patterns.

181. Use of Surface States in Solids to Explain Activated Adsorption. W. G. Pollard, *University of Tennessee.*—In addition to the usual Bloch functions $e^{i\mathbf{k}\cdot\mathbf{r}}u(\mathbf{k},\mathbf{r})$ for stationary states in a solid, there exist stationary solutions with real energy of the type $e^{i(k_xx+k_yy)-\mu z}u(k_x, k_y, \mu; \mathbf{r})$ representing an electron confined to the surface of the solid. These states, first introduced by Tamn,[1] are investigated for actual solids with respect to their form, energy spectrum, and the conditions under which they can exist. Application is made to adsorption by showing that the conditions for stability of these states can be satisfied when a visiting atom gets close enough to the surface. The atom can then transfer its electron to the surface state with large decrease in total energy of the whole system. The transfer is shown to be feasible in that it gives rise to no serious electrical disturbance in the solid. The probable location in energy of these states is shown to be favorable. The extent to which exchange can take place between the two states is determined. The interactions are calculated approximately for H on a metal. An H_2 molecule with sufficient activation energy can split into two H atoms which become bound to surface states.[2] The computed binding energy leads to the right order of magnitude for the heat of activated adsorption of H_2 on various adsorbates.

[1] Ig. Tamn, Physik. Zeits. Sowjetunion **1**, 733 (1932).

[2] Lennard-Jones, Trans. Faraday Soc. **28**, 341 (1932).

182. Dielectric Anomalies of Zincblende Crystals. Merril Distad, *University of Minnesota.*—The dark current I in a zincblende crystal depends on the time T the potential difference has been on the crystal electrodes. In transparent zincblende crystals at the temperature of dry ice, it was found that the observed current agreed with the empirical equation $I=(I_f+K/T)$ for values of T from 1 to 100 minutes. K is a constant and I_f is the equilibrium dark current. The dark current in colored zincblende crystals, however, does not agree with this equation.

183. Experiments on the Condensation Rate of Mercury Vapor. Joseph Slepian and W. M. Brubaker, *Westinghouse Electric and Manufacturing Company.*—The rate of condensation of mercury vapor on to various surfaces has been investigated under conditions of cleanliness which are obtained in ordinary laboratory practice. As other investigators have found, the rate is usually much less than the maximum predicted by kinetic theory. When water-cooled, freshly sandblasted steel probes were suspended above the mercury, the observed rate of condensation was always less than eight percent of that predicted by the simple kinetic theory. If an arc was run in the chamber (as in an Ignitron) and the probe held at a negative potential with respect to the cathode, the rate of condensation increased many fold. This higher rate continued after the arc was turned off, but fell rapidly toward its initial value. The rate of fall depended upon the length of the previous conditioning period. The behavior of a nickel probe is different from that of a steel probe. Although initially the same, the yield of condensed mercury from a nickel probe has been observed to increase to approximately five times that observed simultaneously from a steel probe, when no arc was run in the chamber.