# Proceedings of the American Physical Society

MINUTES OF THE PITTSBURGH MEETING, DECEMBER 27–29, 1934

THE 36th Annual Meeting (the 196th regular meeting) of the American Physical Society was held at Pittsburgh on Thursday, Friday and Saturday, December 27, 28 and 29, 1934, in affiliation with Section B—Physics—of the American Association for the Advancement of Science. The presiding officers were Professor R. W. Wood, Vice President of the Society, Professor J. W. Beams, Dr. J. A. Becker, Professor P. W. Bridgman, Dr. K. K. Darrow, Dr. H. G. Dorsey, Professor H. A. Erikson, Dr. W. E. Forsythe, Professor L. G. Hector, Professor L. W. McKeehan, Professor D. C. Miller, Professor Alpheus W. Smith, Professor H. C. Urey, Professor J. Valasek and Professor J. W. Woodrow. There were about five hundred physicists in attendance at the meeting. Sessions were held at both the Carnegie Institute of Technology and the University of Pittsburgh.

On Thursday morning there were four parallel sessions for the reading of contributed papers.

**Annual Business Meeting.** The regular annual business meeting of the American Physical Society was held on Thursday afternoon, December 27, 1934, in the Little Theater of the Carnegie Institute of Technology at two o'clock. The meeting was presided over by Vice President Wood. The Vice President had appointed Messrs. H. A. Barton and R. T. Cox to canvass the ballots for the officers of the Society. They reported the following elections for the year 1935:

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| President | R. W. Wood |
| Vice President | F. K. Richtmyer |
| Secretary | W. L. Severinghaus |
| Treasurer | George B. Pegram |
| Managing Editor—three-year term | John T. Tate |
| Members of the Council—four year term | G. Breit<br>Karl K. Darrow |
| Members of the Board of Editors—three-year term | William V. Houston<br>Robert S. Mulliken<br>I. I. Rabi |

The Secretary reported that during the year there had been 178 elections to membership. The deaths of 14 members have been reported; 24 have resigned and 84 have been dropped. The membership of the Society as of December 21, 1934 was as follows: 2055 members, 662 fellows, 6 honorary members, total 2723.

The Treasurer presented a summary of the financial condition of the Society. It was impossible to present a final report for the year at the Annual Business Meeting because the fiscal year ends on December 31st. The Treasurer's financial report will be audited, printed and distributed.

The Managing Editor stated his appreciation of the cooperation of the members of the Society in condensing their papers and writing them concisely so that it was possible to publish a considerably larger number of papers in the same number of pages as the year before. The Managing Editor no longer makes a report on the financial condition of the publications since this is done by the American Institute of Physics.

The joint session with Section B and the American Association of Physics Teachers was held on Thursday afternoon at two-thirty o'clock in the Little Theater of the Carnegie Institute of Technology. The presiding officer was Dean Henry G. Gale, Vice President of Section B. Professor R. W. Wood, Vice President of the American Physical Society delivered an address on *Some Unusual Optical Problems*. The Retiring Vice President of Section B, Dr. C. J. Davisson, presented a paper on *Electron Optics*. This paper was read by Dr. Karl K. Darrow because the author was not able to be present.

On Thursday evening there was a trip to the Gulf Research Laboratories.

Friday morning and afternoon were devoted to a symposium on *Heavy Hydrogen and Its Compounds*. The morning session dealt with the physical aspects of the problem and the speakers were (1) Professor R. C. Gibbs of Cornell Uni-

versity on *Interferometric Studies of Alpha-Lines of Hydrogen and Deuterium;* (2) Professor G. H. Dieke of Johns Hopkins University on *The Use of Deuterium in Spectroscopic Investigations of Molecules;* (3) Professor Otto Stern of the Carnegie Institute of Technology on *Magnetic Moment of the Deuton;* and (4) Dr. M. A. Tuve of the Department of Terrestrial Magnetism, Carnegie Institution of Washington on *Nuclear Reactions Produced by High Speed Deutons.* This meeting was presided over by Dr. Karl K. Darrow of the Bell Telephone Laboratories, Inc. The afternoon session was presided over by Professor Harold C. Urey of Columbia University and the papers dealt with the chemical aspects of the subject. The speakers were (1) Professor Herrick L. Johnston of Ohio State University on *Chemical Separation of the Isotopes of Hydrogen;* (2) Professor Hugh S. Taylor of Princeton University on *Deuterium and Reaction Kinetics;* (3) Professor John R. Bates, Doctors J. O. Halford, L. C. Anderson and R. D. Swisher of the University of Michigan on *A Study of the Deuterium Exchange Reaction Involving Acetone;* and (4) Dr. F. G. Brickwedde of the Bureau of Standards on *Ortho- and Para-Deuterium.*

On Friday at four o'clock the Physical Society joined with the American Mathematical Society at the Josiah Willard Gibbs Lecture in the Little Theater. The speaker was Professor Albert Einstein of the Institute for Advanced Study, Princeton, New Jersey. The attendance at this meeting was about five hundred which was the limit of the seating capacity of the auditorium.

On Friday evening the Physical Society and the American Association of Physics Teachers held a dinner in the Webster Hall Hotel. Professor R. W. Wood, Vice President of the Physical Society, presided. The after-dinner speakers were President K. T. Compton, Dr. K. K. Darrow, Dr. Paul D. Foote, Dean Henry G. Gale, Dr. L. O. Grondahl, Dr. Paul E. Klopsteg, Professor R. A. Millikan, Dean Frederic Palmer and Professor A. G. Worthing. There were three hundred and twenty-six present at the dinner which was perhaps the largest attendance at any of the dinners of the Society.

Saturday morning was taken up with four parallel sessions of contributed papers. Saturday afternoon at one-thirty o'clock there was a joint meeting with the American Mathematical Society for the reading of invited papers on *Group Theory and Quantum Mechanics.* Professor H. P. Robertson of Princeton University presided. The authors were (1) Professor E. Wigner of Princeton University on *Symmetry Relations in Various Physical Problems;* (2) Professor J. H. Van Vleck of Harvard University on *Some Applications of Group Theory to Non-Relativistic Problems;* and (3) Professor G. Breit of the University of Wisconsin on *Some Applications of Group Theory to Dirac's Relativistic Theory.*

At two o'clock on Saturday there was a joint meeting with the Acoustical Society of America. Professor D. C. Miller of the Case School of Applied Science presided at this session. The speakers were (1) Dr. Hallowell Davis of the Harvard Medical School on *The Electrical Phenomena of the Cochlea and the Auditory Nerve;* (2) Professor Vern O. Knudsen of the University of California on *The Absorption of Sound in Gases;* and (3) Dr. E. C. Wente of the Bell Telephone Laboratories, Inc., on *Some New Instruments of Acoustical Research.*

One of the important features of the meeting was the Annual Science Exhibition. This was wide in its scope and was unanimously praised by the physicists in attendance.

**Meeting of the Council.** At the meeting of the Council held on Thursday, December 27, 1934, fifteen candidates were transferred from membership to fellowship and sixty-three were elected to membership. *Transferred from membership to fellowship:* Carl D. Anderson, Richard M. Badger, Willard H. Bennett, Charles D. Hodgman, Louis P. Granath, M. Stanley Livingston, Lewis M. Mott-Smith, Harald H. Nielsen, M. L. Pool, J. E. Shrader, Shirleigh Silverman, K. J. Sixtus, H. F. Stimson, John Strong and Lauriston S. Taylor. *Elected to membership:* Harriet W. Allen, Hubert W. Allen, Luis W. Alvarez, Walter A. Barkas, Else Bassoe, William O. Bennett, Jr., Sue Avis Blake, Robert H. Boden, Weldon H. Brandt, Richard T. Brice, M. Vertner Brown, Arthur L. Bryan, D. F. Caris, James D. Cobine, Robert Cortell, Willard R. Crout, L. A. V. DeCleene, Joy F. Dillinger, Charles S. Draper, Pol E. Duwez, Ludwig Eckstein, Franklin N.

Entwisle, Samuel H. Evans, Charles H. Fay, Nathan Ginsburg, Donald H. Hale, Ralph E. Hansen, William R. Haseltine, Robert O. Haxby, Albert G. Hill, Allen L. King, Ronold W. P. King, Israel Liben, Joseph Magliozzi, Marvin M. Mann, Jr., Thomas Mariner, Dwight P. Merrill, Jacob Millman, H. Rees Mitchell, Louis A. Morrison, Frank O. Mortlock, Donald N. Packer, J. F. Payne, William C. Price, J. Reginald Richardson, Randal M. Robertson, Fred C. Rose, John E. Rose, H. Hewell Roseberry, W. M. Rust, Jr., Hervey J. St. Helens, Milo B. Sampson, J. H. Sawyer, Jr., Robert W. Smith, Carsten C. Steffens, Rose Stewart, Albert M. Stone, Charles V. Strain, Julian L. Thompson, Gregory S. Timoshenko, H. B. Vincent, Allyn B. White and Ralph A. Wolfe.

The regular scientific program of the Society consisted of ninety-six papers. Numbers 27, 31, 49, 63 and 95 were read by title. The abstracts of the contributed papers are given in the following pages. An *Author Index* will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

## ABSTRACTS

**1. Nuclear Structure and the Negative Proton.** E. C. WESTERFIELD AND W. B. PIETENPOL, *University of Colorado.*—The negative proton is discussed and the suggestion made that it may be much more fundamental to nuclear structure than has been hitherto supposed. The working assumption is that nuclei are constructed of protons, antons, and, in the main, of a minimum number of neutrons. (It is suggested that either naton or anton be adopted as a suitable name for the negative proton, and anton is employed in the present paper.) The possible structure of simple nuclei is suggested. For example, the stability of the alpha-particle is attributed to a structure consisting of an anton surrounded by three protons. A compact structural formula for nuclei is proposed in the form $(n_p, n_a, n_n)$ where $n_p$ is the number of protons, $n_a$ the number of antons, and $n_n$ the number of neutrons. When atomic nuclei are divided into four classes according to the scheme

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| Class I | $A$ even, $Z$ even |
| Class II | $A$ odd, $Z$ odd |
| Class III | $A$ odd, $Z$ even |
| Class IV | $A$ even, $Z$ odd |

it is found that nuclei of Classes I and II may be constructed entirely of protons and antons, although paired neutrons are not excluded. Nuclei of Classes III and IV, on the other hand, may be constructed entirely of protons and antons together with a single neutron. According to Harkins, Classes III and IV comprise only about 1.8 percent of all known nuclei in the earth's crust, and this is considered possible evidence that nuclei containing single neutrons are relatively unstable. The known reactions of artificial transmutations and induced radioactivity are considered from the standpoint of this theory.

**2. Electrolytic Separation of Polonium and Ra D.** G. B. PEGRAM AND J. R. DUNNING, *Columbia University.*—By the use of a disk cathode spinning several thousand revolutions per minute, as used by Professor Colin J. Fink* for the deposition of other metals from extremely dilute solutions, polonium and Ra D can readily be very completely removed from solutions and separated from each other, even when the solutions contain various impurities. The rapidly spinning cathode method has been applied also to the deposition of other radioelements.

* Fink and Rohrman, Trans. Electrochem. Soc. **58**, 406 (1930).

**3. The Capture, Stability and Radioactive Emission of Neutrons.** J. R. DUNNING, G. B. PEGRAM AND G. A. FINK, *Columbia University.*—Measurements have been made of the number of neutrons from a Rn–Be source which are detected in an ionization chamber 25 cm distant when the source is placed in the center of solid spheres of a series of sizes, 7.6, 12.6, 20.5 and 25.7 cm in diameter. The fraction of the neutrons coming out of the 25.7 cm spheres was, approximately, for $H_2O$ 0.38, for C (coal) 0.78, for Al 0.68, for $SiO_2$ (sand) 0.87, for Cu (shot) 0.55 and for Pb (shot) 0.75. 2 cm of lead was always in front of the chamber as a gamma-radiation shield. Estimates based on the mean free path of neutrons between nuclear collisions (Phys. Rev. **45**, 586 (1934)) indicate that the probability of capture can hardly be greater than 25 percent per collision and may well be less than 10 percent for most cases. The large mechanical energy transfer probably accounts for much of the reduction in number in cases of light nuclei, and the figures for the probability of capture will be correspondingly reduced. This disappearance of neutrons appears to be no more than is called for by capture in the production of artificial radioactive atoms, by transfer of momentum on impact and perhaps by loss of energy in excitation, without supposing the neutron itself to be disintegrated by nuclear impact. Attempts with a large highly sensitive chamber to find radioactive emission of neutrons resulting from neutron bombardment of P as reported by Curie-Joliot and Preiswerk (Comptes rendus **198**, 2089 (1934)) failed to indicate any effect; similarly for Al, Fe and Cu.

**4. Metastable Nuclei Produced by the Hard Gamma-Rays from Radium B+C.** LEE DEVOL, *University of Pittsburgh. (Introduced by Dr. A. E. Ruark.)*—A theory is given of the distribution in time of the impulses from a Geiger-Mueller counter due to activating radiation if that radiation produces metastable nuclei which, at a later time,

emit radiation capable of operating the counter. An aluminum walled counter and a counter with a wall of nickel enclosed in lead glass were exposed to the radiation from radium B+C after passing through 6.25 cm of lead. The distribution of the impulses in time indicates that, in each case, at least 10 percent of the discharges were due to a secondary radiation associated with a decay period of the order of 1/2 second. The aluminum counter, when exposed to x-rays, showed a random distribution of the impulses in time. No attempt was made to determine whether the effect is a manifestation of induced radioactivity or whether the disturbed nuclei return to their original state.

**5. The Construction and Use of Geiger-Müller Counters.** G. L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—A discussion of the construction and use of Geiger-Müller counters for cosmic rays, gamma-rays, ultraviolet light, and for charged particles is given, based on experiences had in constructing about 600 counters for various purposes. The majority of these were cosmic-ray counters with tungsten filaments and copper-oxide cathodes, filled with a mixture of argon and oxygen. Technique for making reliable counters is described, especially in regard to the treatment of the electrode surfaces and the choice of a suitable gas. It has been found that smoothness of the cylinder-electrode is of little importance, but that the wire must be very free from conducting points, including dust precipitated on it electrostatically while the tube is in use. Criteria and tests of the correct behavior of a counter are given. Some amplifying and recording circuits for counter arrangements are described. These include circuits for single and coincidence counters, the circuits used in the two recent stratosphere flights, a triple-double-double coincidence circuit used by C. L. Haines and the author for a special beta-ray spectrograph, and a triple-multiple coincidence circuit for investigating cosmic-ray showers.

**6. Measurements of the Angular Distribution of Cosmic-Ray Intensities in the Stratosphere with Geiger-Müller Counters.** W. F. G. SWANN AND G. L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—The results of preliminary examination of the records obtained during the recent flight of Dr. and Mrs. Piccard, and in the National Geographic Society-U. S. Army flight are presented. The records were made as follows: (a) Natl. Geog.-U. S. Army flight, 40,000 ft., 46 min. (b) Piccard flight, 53,000 ft., 2 hrs. 30 min. The apparatus consisted, in each case, of 16 triple-coincidence cosmic-ray telescopes, arranged at 0°, 30°, 60° and 90° to the vertical, and employed 178 counting tubes. In the Piccard flight, a double-coincidence "intensity-meter," using 13 counters, was also carried for measuring the un-directed cosmic-ray intensity. A continuous time-compass record provides a means of examining the azimuthal variation of intensity. Some significant results are as follows: (1) The vertical intensity at 40,000 ft. (Natl. Geog.-Army flight) is about 39 times the value at sea level. At 53,000 ft. (Piccard flight), it is about 60 times the sea-level value. (2) Whereas the horizontal intensity is negligible in comparison to the vertical, at sea level, it is about 20 percent of the vertical intensity at 40,000 ft., and about 50 percent at 53,000 ft. We believe this result shows a significant effect of the earth's magnetic field on the secondary charged particles which are responsible for at least part of the operation of the counters. (3) The integrated intensity-function, which would determine the ionization per cc in an ionization chamber, by rays that actuate the counters, increases with altitude several times less rapidly than does the actual ionization. We believe this result to be significant of the participation of nuclear entities of high specific ionization in the ionization produced in a closed vessel. (4) The counting rate in the horizontal direction is particularly free from the contribution of simultaneous non-collinear rays.

**7. North-South Asymmetry of the Cosmic Radiation.** THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—During a recent survey of the directional distributions of the cosmic radiation a series of observations was made at an elevation of 14,000 ft. in Mexico at latitude (geomagnetic) 29°N, which compared the northern and southern intensities in the plane of the meridian from six different zenith angles. The ratios of the difference of southern and northern intensities to the average of southern and northern intensities together with their probable errors are given in Table I and give definite evidence of greater southern intensities particularly at angles close to the horizon. A north-south effect of this general character finds a natural interpretation in the theory of the orbits of charged particles, particularly as developed by Lemaitre and Vallarta. The curvatures of the orbits are such that the earth casts a partial shadow above the horizon on the pole side of the observer.

TABLE I.

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| Zenith angle | 6.4° | 19.2° | 32° |
| $2(I_s-I_n)/(I_s+I_n)$ | .011±.0096 | .030±.0092 | .050±.0096 |
| Zenith angle | 45° | 57.8° | 70.7° |
| $2(I_s-I_n)/(I_s+I_n)$ | .012±.015 | .049±.019 | .085±.024 |

**8. An Electrical Method for the Non-Destructive Testing of Sodium-Filled Valves.** W. R. KOCH, *Materiel Division, U. S. Army Air Corps, Wright Field.*—The exhaust valves of aircraft engines are made with hollow stems which are partially filled with metallic sodium to promote cooling. Since the alloy steels used have electrical resistivities of the order of ten times that of sodium the presence of the sodium within the stem cavity greatly influences the electrical properties of the valve. The resistance gradient along the valve stem is much lower at those portions which contain sodium than at the portions which are hollow or which are solid steel. By connecting the valve in an electrical circuit so that a current of fifty amperes flows along the length of the stem the potential distribution along the stem may be determined potentiometrically. The location and amount of the sodium is indicated by the position and extent of the low slope portion of the potential curve. On the basis of the internal diameter of the valve stem and the resistance gradient along the stem the cooling medium may be identified. The results obtained were verified by

actually opening rejected valves as well as by examining radiographs in those cases in which detectable shadows were cast by the sodium column.

**9. The Failure of Ohm's Law at High Current Densities.** ERNST WEBER, *Polytechnic Institute of Brooklyn.*—The concept of compressibility of the electron gas (Phys. Rev. **43**, 781 (1933)) is introduced into the equation of metallic conduction and leads to an explanation of the observed deviations from Ohm's law at extremely high current densities (P. W. Bridgman, Proc. Am. Acad. Sci. **57**, 131 (1922)). From the theory a value for the number of free electrons per unit volume can be deduced which is considerably (about $10^3$) smaller than the number of atoms per unit volume. This theory may constitute the first access to this number. The result is the same if one uses the classical distribution law or Fermi's law of distribution-in-energy. It is interesting to note that the expression for the compressibility as derived from Fermi's statistics has as minimum almost the same value and exactly the same dependence on temperature as the classical statistics would show.

**10. Measurement of the Dielectric Constant of Air at Radiofrequencies.** L. G. HECTOR AND H. L. SCHULTZ, *The University of Buffalo.*—In the course of preliminary work on the effects of large electric fields on the dielectric constants of gases, the heterodyne beat frequency method of measurement has been developed and applied to the absolute measurement of the dielectric constant of air at 900,000 cycles per second. Application of modern high frequency technique in coupling the variable and constant frequency oscillators to the detector completely eliminates the tendency of the two oscillators to synchronize. Improvement in the stability of the variable frequency oscillator allows time for temperature equilibrium of the gas to take place and facilitates recording the beat note by means of a string oscillograph. The results indicate that the dielectric constant of air at 900,000 cycles per second is in close agreement with values taken at low frequencies and with direct current measurements. In 26 determinations of the quantity $(\epsilon-1)$ the maximum deviation from the mean is 0.019 percent and the average deviation is only 0.007 percent. Constant sources of probable error reduce the reliability of the result to about 0.1 percent on the quantity $(\epsilon-1)$. This appears to be superior to previously reported results by more than one power of ten.

**11. On the Use of Radio Broadcast Carriers for Constant High Frequency Currents.** H. L. SCHULTZ AND L. G. HECTOR, *The University of Buffalo.*—Many broadcast stations are now equipped with excellent temperature controlled crystal oscillators so that the constancy of frequency compares favorably with that attainable with laboratory equipment. Moreover, the better stations are equipped with continuously operating frequency deviation meters and in addition the frequencies are periodically checked against monitoring stations. The particular difficulty arising in the use of broadcast signals for measurement purposes resides in the presence of modulation on the carrier. A method for effectively removing modulation and delivering the carrier frequency or multiples of this frequency is described. Removal of the modulation is effected through a special type of amplifying circuit which delivers essentially equal pulses of power to a low loss resonant circuit regardless of the percentage of modulation through wide limits.

**12. Space Charge in a Conducting Electrolyte.** WILLIAM SCHRIEVER, *University of Oklahoma.*—A constant difference of potential of 9 volts was maintained between two copper electrodes at the ends of an 8 cm square 40 cm long column of 0.0024 N copper sulphate solution. The difference of potential between a small movable copper electrode and the cathode was measured for positions between 0.1 and 39.9 cm from cathode. For each such position a curve, showing the potential difference as a function of the time, was obtained, for times up to 15 minutes. From these curves another set of curves was made showing the potential of a point in the electrolyte as a function of its distance from cathode, time being constant. And from each such curve the space-charge at any desired point was calculated. Within the region investigated, the space-charge in the cathode-end of the column was *negative*, and that in the anode-end was *positive*. However, further consideration showed that *very close* to the cathode the space charge must have been positive and that *very close* to the anode it must have been negative. At 0.6, 1.9 and 4.0 cm from the cathode the space-charges at the end of 15 minutes were, respectively, $-60$, $-5.5$ and $-1.8$ all $\times 10^{-5}$ statcoulombs/cm$^3$. These space-charges require, respectively, an excess of one $SO_4$ ion in every $0.75\times10^{13}$ such ions normally present, one in $7.8\times10^{13}$ and one in $23\times10^{13}$.

**13. Multiple Space Charge in Double and Triple Grid Tubes.** EVERETT W. THATCHER, *Union College.*—The study of the effect of space charge on thermionic currents has been restricted mainly to those cases in which maximum density of electrons occurs in close proximity to the emitter. An investigation has been made of certain phenomena associated with space charge external to a grid which surrounds the cathode. One case in which this situation was used has been treated briefly in connection with studies of shot-effect (E. W. Thatcher and N. H. Williams, Phys. Rev. **39**, 486 (1932)). This paper reports a new effect, the essential feature of which is a negative plate current-emission characteristic. The conditions under which this phenomenon is observed are outlined. Results of experiments with double and triple grid tubes are summarized. In general, two points on the characteristic may be found for which the plate current is independent of small variations in emission, whether of a statistical or "functional" nature. An explanation is presented based on the interaction of multiple space charge. An application to the problem of high gain amplification is suggested.

**14. Shot Effect and Thermal Agitation in an Electron Current Limited by Space Charge.** G. L. PEARSON, *Bell Telephone Laboratories, Inc.*—The theories of both shot effect and thermal agitation in an electron current limited

by space charge have been worked out for some time (F. B. Llewellyn, Proc. I. R. E. **18**, 243 (1930)). Experimental verification, however, is difficult because of the presence of other disturbing effects and inability to determine accurately the amount of space charge. Such measurements have now been made and they support the theory in each instance. (1) Shot voltage is reduced by space charge, the reduction being proportional to $J(\partial I/\partial J)^2$ where $J$ is the total electron emission and $I$ is the space current. This reduction is in addition to that caused by a decrease in the internal impedance of the tube. (2) A thermal agitation voltage is produced in the internal impedance of the tube which is dependent upon the temperature of the cathode. Although this effect is in qualitative agreement with theory the measured value is even less than that predicted.

**15. Effect of Electrostatic Field upon Rate of Vaporization.** E. HUTCHISSON, *University of Pittsburgh.*—Worthing and his associates have found that an electrostatic field directed away from a solid metallic surface lowers its rate of vaporization. A field of approximately $2\times10^6$ volts/cm decreases the rate of vaporization of molybdenum at 1462°K to 1 percent of its value without the field. The return of vaporized atoms polarized by the field as calculated by Greibach from the kinetic theory of gases does not explain the effect. In this paper an approximate calculation is made of the rate of vaporization on the basis of a change in the binding forces of surface atoms of molybdenum in the presence of an electric field. It is assumed that the balance between the attractions and repulsions of the atoms may be roughly represented by a Morse function. In the presence of the field, ions tend to move out, thus decreasing the repulsion while the electron cloud moves in, increasing the attraction. Both effects tend to increase the binding of the surface atoms. Assuming the measured compressibility, heat of vaporization and a polarizability equal to the atomic volume determined by crystal structure measurements, a computed change in binding is obtained which is of the right order of magnitude to explain the above change in the rate of vaporization.

**16. Contact Potential of Thoriated Tungsten.** DAVID B. LANGMUIR, *Massachusetts Institute of Technology.*—The contact potential of thoriated tungsten has been measured for different values of surface coverage and temperature. The experimental tube consisted of three coaxial cylinders inside which were two filaments, one of tantalum and one of thoriated tungsten. High vacuum conditions were obtained by evaporating tantalum from the first filament to the walls during exhaust. The metallic coating so formed on the glass constituted the cylindrical electrodes, and except for the filaments and leads there were no other metal parts within the tube. With the tantalum filament as cathode, with the tungsten cold, the volt-ampere characteristic to the tungsten was obtained for different states of activation, other conditions being kept constant. The curves so obtained could be made to coincide by shifting parallel to the voltage axis, and the amount of this shift was taken as the contact potential. The logarithm of the emission from the filament at zero field is a linear function of the contact potential, but the slope is less than the theoretical value $e/kT$. This discrepancy can be in large part explained by the temperature coefficient, which was observed to be of the order of magnitude of $5k$.

**17. The Relation Between Field Emission and Work Function of Liquid Mercury.** L. R. QUARLES, *University of Virginia. (Introduced by J. W. Beams.)*—The dependence on the cathode work function of the breakdown field between a liquid mercury cathode and a spherical molybdenum anode has been investigated. The general method of determining the breakdown potential is that of Beams (Phys. Rev. **44**, 803 (1934)). The contact potential difference between the mercury and a hot platinum filament is measured by two methods. In the first the mercury is connected to an electrometer and the system charged to a definite voltage. It is then isolated and allowed to come to equilibrium by the passage of electrons from the filament, which gives a measure of the mercury-platinum contact potential difference. The other method consists in charging the system to different voltages and letting it discharge for a fixed time, thus obtaining thermionic characteristics of the platinum-mercury circuit. The displacement of these characteristics gives the variation of the contact potential difference. If the work function of the platinum is assumed constant these measurements give the variation of the mercury work function. Results have been obtained over a work function range of one volt, and, while the trend is that forecast by the Fowler-Nordheim equation, the fields, calculated on the assumption of a smooth surface, are much less than predicted.

**18. Optical Properties of Sputtered Metal Films.** J. B. NATHANSON AND H. S. SEIFERT, *Carnegie Institute of Technology.*—Semi-transparent copper films, each of variable thickness, were produced by sputtering in hydrogen. From the location of the observed interference fringes, and the assumed density and optical constants of copper in the bulk, the masses of the films were computed as previously reported for manganese and platinum (J. O. S. A. **23**, 388 (1933)). The computed masses of copper were several times greater than those determined by weighing, as previously found for platinum. A higher refractive index, or lower density (or both), are thus indicated for the films as compared with these constants found for the metal in the bulk. A higher refractive index for copper was found (1) from independent observations of the film thickness by means of the Michelson interferometer; (2) from polarimetric observations following the method of K. Försterling (Göttingen Nachrichten, p. 58 (1911)). The physical state of the platinum films seems to vary somewhat with aging, since the location of the interference fringes was found to vary slightly over a period of about twenty months.

**19. Christiansen Light Filters.** E. D. MCALISTER, *Division of Radiation and Organisms, Smithsonian Institution.*—The Christiansen filter is unique in that by a proper choice of liquid and glass (or fused quartz) it yields a narrow band of high transmission in any region of the visible, near ultraviolet, and near infrared. Previous publications have shown

the necessity of temperature control, have given the various combinations of suitable liquids and glasses, and have shown the advantages of a good optical arrangement. The purpose of the present paper is to point out a further precaution that is necessary for any exacting use of the filter. Some radiation is absorbed and warms the filter even when it is water-cooled. Due to poor heat conductivity a temperature gradient is soon established and the band of transmitted light widens. In sunlight the filters are entirely unsatisfactory unless metal vanes (aluminum) are placed through the body of the filter to carry off the absorbed heat. Transmission measurements of a six-inch diameter filter equipped with vanes show 83 percent of the transmitted energy (solar) is in a 250A band, 4 percent of shorter wavelength, and 13 percent longer. The transmission is 55 percent at the peak. The possibility of making these filters of two glasses is discussed.

**20. A New Method of Making Extremely Thin Films.*** J. D. HOWE AND E. M. PURCELL, *Purdue University. (Introduced by K. Lark-Horovitz.)*—The method mentioned recently (K. Lark-Horovitz, H. J. Yearian and E. M. Purcell, Phys. Rev. **45**, 123 (1934)) has been developed for general use. A hole in a metal plate is filled with a volatile solid and the surface polished. This slit is clamped to the bottom of a liquid air container in a high vacuum. The material to be deposited is evaporated and covers slit and opening with a continuous film of desired thickness. The slit is then placed into the apparatus for the investigation and on evacuating the volatile material evaporates leaving the thin film freely supported on the slit. As volatile material camphor and naphthalene have been used. Since camphor produces in some cases oxidation (copper is deposited as cuprous oxide), purest naphthalene is now being used only. To avoid contact of the film with the air a small container with naphthalene is placed, after depositing of the film, under the slit, slightly heated from the furnace below and another layer of naphthalene is deposited so that the film is protected from both sides. In this way, also, materials which oxidize easily can be investigated in thin layers.

* Grateful acknowledgment is made to the American Philosophical Society for a grant-in-aid of this research. K. L. H.

**21. Fluorescence of the Chlorophyll Series: Fluorescence and Photodecomposition in Solutions of Pheophorbide *b* and Methyl Pheophorbide *b*.** H. V. KNORR AND V. M. ALBERS, *Kettering Foundation, Antioch College.*—The fluorescence spectra of pheophorbide *b* and methyl pheophorbide *b* in solution in anhydrous acetone have been photographed by a method previously described (Phys. Rev. **43**, 379 (1933)). The fluorescence spectrum of pheophorbide *b* consists of an intense band with its maximum at 650 m$\mu$ and a weaker band with its maximum at 678 m$\mu$. As photodecomposition proceeds, the relative intensities of the individual bands vary considerably. The intensity of the longer wavelength band decreases to almost zero after one hour of irradiation. The appearance of an additional band was observed after fifteen minutes of irradiation. Its intensity increases during the first two hours and then decreases slowly. Its maximum is at 654 m$\mu$. Three bands of almost equal intensity were observed in the fluorescence of methyl pheophorbide *b*, with maxima at 686, 651 and 640 m$\mu$, respectively. The intensity of the 686 m$\mu$ and 640 m$\mu$ bands decreases to almost zero, after eight hours of irradiation. An additional band, with its maximum at 654 m$\mu$, was observed. Its intensity increases during the first eight hours exposure to the radiation and then decreases. The band located at 654 m$\mu$ is also observed in the fluorescence of chlorophyll *b*.

**22. The Luminescence of Frozen Solutions of Certain Dyes.** FRANCES G. WICK AND CHARLOTTE G. THROOP, *Vassar College and Cornell University.*—Aqueous solutions of fluorescin are known to lose their luminescence suddenly when the water freezes. Frozen solutions of the uranyl salts are strongly fluorescent. Experiments described in this paper show the effect upon luminescent solutions of certain DuPont dyes of freezing the solutions and lowering the temperature to that of liquid air. Water, alcohol, acetone and glycerine were used as solvents. Ultraviolet light from a Westinghouse "black bulb" lamp was focused upon a glass tube containing the specimen. This tube was placed in a metal holder with a window in it and lowered by steps into an unsilvered Dewar flask containing liquid air. The intensities of luminescence at definite temperatures were measured by a Leeds and Northrup optical pyrometer with different color filters in the eyepiece to get the variation in intensity of definite wavelengths as the temperature was lowered. Marked changes take place in the intensity and color of the fluorescence and, in some cases, the frozen solutions are strongly phosphorescent. The abrupt variations which take place at certain temperatures may throw some light upon changes in the solvent at low temperature or upon the effect upon luminescence of the state of crystallization.

**23. Interpretation of Anomalous Stark Intensities.** J. S. FOSTER, *McGill University, Montreal.*—It is well known that the observed intensities of Stark components in the Balmer series are in many cases quite different from the relative probabilities of transition calculated by Schrödinger. Striking illustrations of such variations are afforded by the original experiments of Stark, the Lo Surdo analysis of $\overline{H_\alpha}$ by McRae, the extensive work by Mark and Wierl, the transition from typical canal-ray intensities to typical Lo Surdo intensities realized by Thornton, and the recent examination of Stark effects in the hydrogen isotopes by Foster and Snell. The present paper starts with the selective loss of initial states in collisions, as explained by Bohr. Appreciable development of this asymmetry in final states may be expected only under the most favorable circumstances, owing to their small size and low polarization. From the photographs (see Abstract, Foster and Snell) it is learned that dipole collisions are important, and it is assumed that the asymmetry is so transferred to the final states. Selective absorption follows as the simplest explanation of the experiments. If the field is not constant, one must not overlook the absorption of a photon by atoms up or down stream in a field different from that at the origin of the photon, but nevertheless capable of absorbing light of the wavelength and polarization characteristic of the light quantum. It appears, however, that this feature plays a

secondary role in the determination of observed relative intensities of Stark components in the majority of the experiments cited.

**24. The Spectra of Lead IV and Bismuth V.** G. K. SCHOEPFLE, *Cornell University.*—Early investigations in the spectra of Pb IV by Rao and Narayan, Smith, and Kishen have been extended to include 34 terms arising from the configurations $5d^{10}ns$, $5d^{10}np$, $5d^{10}nd$, $5d^{10}5f$, $5d^96s^2$, $5d^96s6p$ and $5d^96s6d$. With data by Arvidsson, Smith and the author, the region reported extends from 198 to 5005A, and 79 lines have been classified. In the extension to Bi V, values have been assigned to 14 terms involving 18 lines in the region below 1487A. By a Hick's formula the value of the $5d^{10}6s\ ^2S_{0\frac{1}{2}}$ term has been computed to be 340,885 $cm^{-1}$ for Pb IV and 451,700 $cm^{-1}$ for Bi V, giving ionization potentials of 42.0 volts and 55.7 volts, respectively.

**25. Relative Transition Probabilities of Almost Closed Shells.** C. W. UFFORD, *Allegheny College.*—The method of calculating the relative transition probabilities of different multiplets in Russell-Saunders coupling from spectroscopic stability has been simplified for configurations involving almost closed shells, so that transition probabilities for these configurations may be calculated as easily as those for the configurations containing the electrons missing from the almost closed shells. First it has been shown that the transition probabilities are the same for two pairs of configurations which are the complements of one another. The complementary configuration is the one obtained when all electrons outside closed shells are replaced by the electrons missing from the closed shell of which they are a part. Thus the transition probabilities for the configurations $d^8p^5-d^7p^6$ are equal to those for $d^2p-d^3$. To calculate the transition probabilities for configurations containing almost closed shells, it is necessary to write the zero order states of but one configuration, choosing from the $LSM_LM_S$ states the one with the fewest terms. In writing the zero order states the almost closed shells are represented by the quantum numbers of the electrons missing from the shell. By this method the relative transition probabilities of different multiplets have been calculated for the transitions $d^9p-d^8p^2$, $d^9p^2-d^8p^3$, $d^8p-d^7p^2$, and $d^7p-d^6p^2$.

**26. The Fundamental Band of $H^2CN$ at 17.5 $\mu$.** PAUL F. BARTUNEK AND E. F. BARKER, *University of Michigan.*—The fundamental band of heavy hydrogen cyanide $H^2CN$ has been measured with a spectrometer having a grating with 1200 lines per inch and a KBr fore prism. There is a strong zero branch at 570 $cm^{-1}$ and the fine structure lines on each side are well separated. From the line spacing the moment of inertia of the molecule may be computed, neglecting interactions. Its value is approximately 23.1 $\times 10^{-40}$ g $cm^2$. A comparison of the number with the corresponding value for ordinary hydrogen cyanide permits the calculation of the internuclear distances.

**27. The Structure of Rhombic Sulphur.** B. E. WARREN AND J. T. BURWELL, *Massachusetts Institute of Technology.*—From rotation and oscillation photographs with Mo $K\alpha$, rhombic sulphur is found to have the following cell and space group: $a=10.48$A, $b=12.92$A, $c=24.55$A, $Z=128$, space group $V_h^{24}$ (*Fddd*). The structure contains $S_8$ molecules which are symmetrical puckered rings with S–S distance 2.12A and bond angle $\alpha=105°$. The atomic coordinates are determined by comparison of calculated amplitudes with visual intensity estimates from oscillation photographs. The relation of rhombic sulphur to the high temperature forms is discussed briefly.

**28. The Determination of the Components of Interatomic Distances in Crystals.** A. L. PATTERSON, *Massachusetts Institute of Technology.*—In a previous communication (Patterson, Phys. Rev. **46**, 372 (1934)) it has been shown that a Fourier series can be set up which represents the weighted average electron distribution about any point in a crystal. The coefficients in this series are the quantities $F^2(hkl)$ obtained from absolute measurements of intensity. The coordinates of its maxima then represent in direction and magnitude the atomic distances in the crystal. A new series has now been derived which represents approximately a similar average distribution of atom centers. The coefficients of this series are $F^2/\bar{f}^2$ where $\bar{f}=\Sigma f_i/\Sigma Z_i$; the summations extending over all atoms of the cell. $f_i$ is the atomic scattering factor at absolute zero for the $i$-th atom whose atomic number is $Z_i$. The $f_i$'s and $\bar{f}$ are functions of $\sin\theta/\lambda$, $\theta$ being the Bragg reflection angle of the plane $(hkl)$ for radiation of wavelength $\lambda$. The peaks of the new series are much sharper than before and greater resolution can therefore be obtained. There is some distortion owing to the incompleteness of the new series and the compromise involved in the use of the factor $\bar{f}$; but this is apparently small. Copper sulphate pentahydrate is used as an example; the calculations being based on part of the data recently published by Beevers and Lipson.

**29. A Glassy State of Arsenic.** W. E. MCCORMICK AND WHEELER P. DAVEY, *Pennsylvania State College.*—It is found that below 100°C arsenic vapor condenses in pure hydrogen to give an amorphous (to the x-rays) powder of very small particle size. When the vapor is condensed between 100°C and 130°C a mixture of powder and coherent sheet is obtained. Between 130°C and 250°C only the coherent sheet is obtained. The metallic luster of the sheet increases with the temperature of condensation. X-ray examination shows the deposit to be non-crystalline. It might be described as a metallic glass. Above 250°C the deposit has slightly less luster and is distinctly crystalline to the x-rays. It is believed that this is the first report on the existence of three types of solid (amorphous flour, glass, crystal) for a single metal. References for related work: Strumanis (Zeits. f. physik. Chemie **B13**, 316 (1931)) on *rate* of crystal growth of Zn and Cd; Ingersoll and DeVinney (Phys. Rev. **26**, 86 (1925)) on amorphous nickel films; Bettendorf (Ann. d. Chemie **144**, 110 (1867)) on what he called (without experimental evidence) "amorphous arsenic" (probably the flour).

**30. Electron Diffraction by Transmission Through Thin Silica Glass Films.** LOUIS R. MAXWELL AND V. M.

MOSLEY, *Bureau of Chemistry and Soils.*—Electron diffraction has been obtained by the transmission of electrons (25 to 38 kv) through thin films of silica glass. The films were obtained from the glass after blowing out into a thin walled bubble. Further reduction in the thickness of the film was made by treatment with hydrofluoric acid. The interference pattern recorded on a photographic plate can be described as follows: (1) at small angles the electron scattering was strong in contrast to the known x-ray photographs which show small scattering in this region, (2) the prominent ring at $(1/\lambda)\sin\theta/2=0.12$ commonly observed by x-rays was present, (3) at $(1/\lambda)\sin\theta/2$ equal to about 0.20 a prominent halo was observed, (4) a strong diffuse ring appeared at $(1/\lambda)\sin\theta/2=0.40$. These results can be discussed from the standpoint of scattering from amorphous $SiO_2$ previously treated by Warren (Phys. Rev. **45**, 657 (1934)). Frequently sharp interference spots or partially completed circles characteristic of crystal formation were found in addition to the above pattern. The most prominent ones give Bragg spacings of 4.2A (strong), 3.7A (strong) and 2.52A (weak). The origin of this pattern has not been definitely established and it is possible that it may arise from impurities.

**31. Depth of Penetration of Electrons Diffracted by Single Crystals.** H. E. FARNSWORTH, *Brown University.*—A known number of atom layers of one metal were deposited on the surface of a single crystal of another metal by evaporation in a high vacuum. Direct results on depth of penetration were obtained from measurements on electron diffraction as a function of the thickness of the surface layer. A silver film deposited on a copper crystal is amorphous. A layer one atom deep reduces the maxima of the beams from the copper lattice by at least 70 percent for energies up to 300 e. volts. A number of foreign silver atoms equal to a few hundredths of that contained in one atomic layer can be detected by this method. A silver film deposited on a gold crystal is crystalline. The surface atomic layer of silver contributes at least 50 percent to the maxima of beams from a thick crystal for energies up to 300 e. volts, while a surface layer two atoms deep contributes at least 90 percent. This predominating effect of the surface atomic layer for primary energies as high as 300 e. volts is not in accord with theoretical predictions of v. Laue.

**32. Intensity Distribution in Electron Diffraction Patterns.** K. LARK-HOROVITZ, H. J. YEARIAN AND J. D. HOWE, *Purdue University.*—With the method described above* electron diffraction patterns of thin layers of bismuth, cadmium, calcium hydroxide, copper, cuprous oxide, gold, sodium nitride, nickel, tungsten oxide, zinc, zinc oxide and zinc sulfide have been obtained using cathode rays from a gas discharge of 50–80 kv. The intensity distribution is discussed as a function of (a) surface condition of the crystallites, (b) refraction of the electron waves, (c) orientation, (d) atom factor. In all cases mentioned "forbidden" orders have been found which in some cases exhibit an extremely sharp diffraction pattern. Their relation to refraction, inner potential and surface layers is being discussed. *The values of sin $\vartheta/\lambda$ for the forbidden inner rings are the same for Au, Ag, Cu, $Cu_2O$, Ni, Cd.*†

* See Abstract 20. † See reference to Abstract 20.

**33. Triatomic Ions in Mixtures of the Hydrogen Isotopes.** OVERTON LUHR, *Union College.**—A mass-spectrograph analysis has been made of aged ions in mixtures of hydrogen and deuterium. The concentration of deuterium varied from more than 80 percent to less than one percent. After drifting through 5 cm of gas at about 0.5 mm pressure, the ions were found to be over 95 percent triatomic; that is, $H_3^+$, $H_2D^+$, $HD_2^+$ and $D_3^+$. Measurement of the relative intensities of the triatomic ion peaks indicates a slightly greater number of $H_3^+$ and $D_3^+$ ions compared to $H_2D^+$ and $HD_2^+$ than would be expected from probability considerations if the H and D atoms behaved exactly alike. This apparent tendency for like atoms to group together would be expected from the equilibrium constants for the different types of molecules in the gas mixtures employed. Consideration of the probabilities of formation of the various triatomic ions, combined with measurement of the relative intensities of the peaks, furnishes a convenient method for analyzing a given sample of gas to determine the abundance of the isotopes. Certain precautions must be observed in the application of the method.

* Experimental work performed at Massachusetts Institute of Technology.

**34. A New Ion Source for Mass Spectroscopy.** A. J. DEMPSTER, *University of Chicago.*—Spectrum analysis has shown that multiply-ionized atoms of a great many elements are formed in "hot-sparks" and in high frequency electrodeless discharges. It has been found that a small spark at a pressure of $10^{-5}$ mm excited by high frequency alternating current from a Tesla coil is a source of multiply-charged ions which may be detected by the methods of positive ray analysis. In preliminary experiments the ions were accelerated by a potential of 20,000 volts and analyzed by the parabola method with electric and magnetic deflections at right angles to each other. With a spark between steel and tungsten, sixteen different ions were found including hydrogen, tungsten, carbon with one to three charges, and iron with one up to six charges. Exact atomic weight comparisons of these ions are planned with a new mass spectrograph of large resolving power.

**35. A Proposed Mass Spectrograph.** W. B. PIETENPOL, *University of Colorado.*—A new type of mass spectrograph is described, embodying two energy selectors of the cylindrical-condenser type employed by Aston, and a velocity selector of the balanced field type used by Bainbridge. The advantages claimed for the proposed instrument are 180 degree deflection giving large dispersion, both direction and velocity focusing, normal incidence, and a linear mass scale. The instrument is so designed that the energy of the ions selected by the first energy selector varies automatically with the initial energy imparted to the ions, so that a maximum effect may be obtained for all masses. The relative effect is therefore proportional to the relative abundance. Since the design of the instrument places rather nar-

row limits on the range of spectrum which can be photographed at a given setting, it is proposed to employ an electrometer alternatively with a photographic plate for general use. Because of its large dispersion, and the linear relation between the electric field employed and the specific charge of the ion selected, the proposed instrument seems particularly well adapted to bracketing methods of determining isotopic weights.

**36. Some Unusual Optical Problems.*** R. W. WOOD, *Johns Hopkins University*, Vice President of the American Physical Society.

**37. Electron Optics.*** C. J. DAVISSON, *Bell Telephone Laboratories, Inc.* Address of the Retiring Vice President of Section B—A.A.A.S.

**38. Interferometric Studies of Alpha Lines of Hydrogen and Deuterium.*** R. C. GIBBS, *Cornell University.*

**39. The Use of Deuterium in Spectroscopic Investigations of Molecules.*** G. H. DIEKE, *Johns Hopkins University.*

**40. Magnetic Moment of the Deuton.*** OTTO STERN, *Carnegie Institute of Technology.*

**41. Nuclear Reactions Produced by High-Speed Deutons.*** M. A. TUVE, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*

**42. Chemical Separation of the Isotopes of Hydrogen.*** H. L. JOHNSTON, *Ohio State University.*

**43. Deuterium and Reaction Kinetics.*** H. S. TAYLOR, *Princeton University.*

**44. A Study of the Deuterium Exchange Reaction Involving Acetone.*** JOHN R. BATES, J. O. HALFORD, L. C. ANDERSON AND R. D. SWISHER, *University of Michigan.*

**45. Ortho- and Para-Deuterium.*** F. G. BRICKWEDDE, *Bureau of Standards.*

**46. X-Ray Spectra and Chemical Combination.** JOSEPH VALASEK, *University of Minnesota.*—The x-ray target described by the writer (Phys. Rev. **43**, 612 (1933)) has been modified by cutting away its surface so that the primary x-rays from the face of the target do not enter the spectrograph. This removes the principal source of contamination of the spectra. Compounds not readily available as single crystals are pressed into a "pill" of semi-circular form which is used as the source of secondary x-rays. The $K\beta$ lines of the sulphides and chlorides of some of the elements in columns one and two of the periodic table have been measured. No regularities were apparent. In the cases of S, $FeS_2$ and ZnS, it was found that different crystal modifications of the same compound give the same spectrum as far as could be observed. The form of tube described lends itself readily to chemical analysis.

**47. The Crystal Structure of Beta-Manganese.** THOMAS A. WILSON, *Union College.*—Extension of previous work in applications of mathematical crystallographic methods to powder x-ray data of the manganese system has resulted in the complete solution of the beta-manganese structure. The structure is cubic; the space group is $O_h^6$; the cube edge length is 12.58A; the cube content is 160 atoms, arranged in the following groups of equivalent positions according to the Wyckoff tabulation: 8*a*, 8*b*, 48*e*, and 96*i*, with $u=0.11$ in 48*e*, and $u=0.10$, $v=0.33$ in 96*i*. These parameters have been checked by intensity calculations using structure factor values based on the Thomas atomic model. The x-ray density of beta-manganese is calculated to be 7.29.

**48. Comparison by X-Ray Diffraction of *p*-Azoxyanisol in Liquid and Liquid Crystalline Phases.** H. R. LETNER AND G. W. STEWART, *University of Iowa.*—It is found that the intensity at the peak of the diffraction curve is five percent greater for the liquid crystalline phase than for the liquid and is displaced about 0.2° with Mo $K\alpha$ radiation. Observations require precautions against convection currents which may lessen the intensity in the former phase. The diffraction curves for the two are otherwise strikingly alike from 0° to 40°. The differences may be in liquid structure as well as in stability, which is certainly greater in at least two dimensions for the liquid crystal. Observations were compared at 125° and 150°C. The change of peak intensity is contrary to the findings of Katz but the change in diffraction angle agrees.

**49. Shapes and Wavelengths of *K* Series X-Ray Lines.** C. H. SHAW AND J. A. BEARDEN, *National Research Fellow, Cornell University; Johns Hopkins University.*—The shapes and wavelengths of the principal lines of the *K* series of elements Ti 22 to Ge 32 were determined by means of a Societe Genevoise double crystal spectrometer. The calcite crystals used showed resolving power close to the theoretical value throughout the range of wavelengths studied. The targets were of electroplated metal wherever possible to insure a high degree of purity. The widths at half maximum and the index of asymmetry were measured in the $(1-2)$, $(1+1)$ and $(1+2)$ positions. In general it was found that the measurements in the various orders were different. In the case of the widths a calculation of the resolving power explains the difference. Curves of the variation of width and asymmetry with atomic numbers are given. Attention is called to the fact that even though gallium was in the liquid state the points lie on the curves. Thus the shape of the line may be said to be independent of the state. Diffraction angle measurements were made in both the first and second orders. The precision circle on which the second crystal was mounted was calibrated every five degrees to 0.2″ of arc by means of the four microscope method. The two determinations of wavelength always agreed to about 0.001 percent, which somewhat exceeds previous photographic results in

* Invited papers.

accuracy. The wavelength, width and relative intensities of certain satellites accompanying the $\beta_1$ and $\beta_5$ lines were also measured.

**50. On X-Ray Line Shapes and the Double Crystal Spectrometer.** LLOYD P. SMITH, *Cornell University.*—In a previously reported analysis of the double crystal spectrometer, a method for determining the x-ray line shapes for any pair of crystals was given. This required rocking curves in the (1, +1), (1, +2), (2, +1) and (2, +2) orders. A criterion based upon information supplied by the (1, −1) and (1, +1) rocking curves has been deduced which allows one to ascertain beforehand whether the method mentioned above has to be applied to obtain the true line shape or whether the (1, +1) rocking curve is itself the line shape within experimental error.

**51. X-Ray Intensity Measurements with a Geiger-Müller Counter, and the Determination of the Structure Factor for KCl.** DONALD P. LEGALLEY, *The Pennsylvania State College.*—A special Geiger-Müller counter has been developed which responds reliably to x-rays from a molybdenum target. The amplified impulses from this counter are recorded mechanically with the aid of a thyratron circuit. Oscillograph records taken by discharging the counter very rapidly with radon show a time of recovery of less than 0.001 sec. Therefore for counting rates up to 600 per minute there is less than a 1 percent correction due to random impulses. The counter and the circuit have been used to measure the intensity of the Mo $K$-alpha beam diffracted by the planes of finely powdered KCl, as well as the intensity of the undiffracted beam. (Balanced filters were used.) In this way the ratio of the intensity of the diffracted beam to the intensity of the main beam $P_S/P$ is measured, and when used in the well-known equations

$$F^2=\frac{2Qm^2c^4\sin 2\theta}{n^2\lambda^3e^4(1+\cos^2 2\theta)}; \qquad \frac{P_S}{P}=\frac{Qfl\rho' h}{4\pi r\rho\sin 2\theta}$$

gives a value for the structure factor $F$. The structure factor for the (100) planes of KCl has been determined to be $33.4\pm 2.2$. Further work on NaCl, Fe and W is in progress.

**52. X-Ray Diffraction and the Fatigue of Metals.** CHARLES S. BARRETT, *Carnegie Institute of Technology.*—Some preliminary results of an extended x-ray diffraction study of the fatigue process in various alloys are as follows: The radial widening of Debye lines is relatively insensitive to changes in the metal brought about by fatigue; in fact, an aluminum alloy (25 ST) shows no detectable widening of this type and a silicon steel shows only a minute amount although both had received more than $10^7$ reversals of stress just below the endurance limit. On the other hand a sensitive detector of changes during fatigue is the peripheral widening of spots in Debye rings, or the equivalent asterism. With the unbroken steel specimen mentioned above, the spots from highly stressed areas are much broader than those from slightly stressed areas, while areas at a given stress level give similar spots. Photograms of various areas on broken surfaces of fatigue specimens vary somewhat but always exhibit extreme widening.

**53. The Connecting Link between Classical Electromagnetic Theory and Wave Mechanics *via* a Derivation of the Schrödinger Equations as a Boundary Value Problem on the Atom.** LLOYD T. DEVORE, *Pennsylvania State College. (Introduced by W. R. Ham.)*—Arguments are presented to show that the atom may be visualized as having a finite shell for an outer boundary and no external field (neutral). It is also argued that if a Coulomb field exists between the charges within the atom, the picture necessarily represents a dynamic model (Earnshaw's theorem) and in particular the charges must be accelerated. With this picture as a basis, the following assumptions are fundamental to the derivations: (1) The vector potential of the field set up by the accelerated charges vanishes at the nucleus and at the outer boundary of the atom. (2a) The field set up within the atom may be quantized by an application of the quantization rule $\int pdq=nh$. (2b) An alternative assumption to that expressed in (2a) is the familiar relation $E=h\nu$, where $E$ is the energy associated with the standing electromagnetic waves within the atom and $\nu$ their frequency. (3) The law of the conservation of momentum may be applied to obtain relationships between the electromagnetic field and mechanical motions within the atom. With the above assumptions, the Schrödinger equations:

$$\Delta\psi+(8\pi^2m/h^2)(E-V)\psi=0, \qquad (1)$$
$$\Delta\psi-(8\pi^2m/h^2)V\psi+(4\pi im/h)(\partial\psi/\partial t)=0, \qquad (2a)$$
$$\Delta\bar{\psi}-(8\pi^2m/h^2)V\bar{\psi}-(4\pi im/h)(\partial\bar{\psi}/\partial t)=0 \qquad (2b)$$

are derived by starting with the equation satisfied by the vector potential within the atom.

**54. Equation of Waves in Media with Velocity Varying with Time.** P. I. WOLD, *Union College.*—The equation of a wave in a medium in which the velocity is a function of time has been obtained. The most convenient time function to handle appears to be $c=c_0e^{-\alpha t}$ and the equation obtained is $y=a\sin 2\pi\nu_0(t-(1/\alpha)\ln\zeta)$, where $\nu_0$ is the frequency at the source and $\zeta=1+(\alpha x/c_0)e^{\alpha t}$. This equation gives a redward shift in light frequency proportional to the distance of the observer from the source. The differential equation which is satisfied by this is

$$(\partial^2y/\partial t^2)+\alpha(\partial y/\partial t)=c_0^2e^{-2\alpha t}(\partial^2y/\partial x^2).$$

**55. A Theoretical Discussion of Professor Miller's Paper[1] on the Ether Drift Experiments.** W. B. CARTMEL, *Westmount, Quebec, Canada.*—This investigation led to a redevelopment of the equations of Lorentz,[2] and on taking into account the mirror angle $\omega$ which Lorentz did not do, these equations gave for the fringe shift:

$$\delta F=\frac{l}{\lambda}\left[2\sqrt{2}\omega\frac{v}{c}\cos\left(\theta-\frac{\pi}{4}\right)+\frac{v^2}{c^2}\cos 2\theta\right], \qquad (1)$$

which is similar to an equation given by Hicks.[3] From Eq. (1) curves have been drawn which fit remarkably well with Miller's results, but the value it gives for the earth's

velocity $v$ is wrong. Further consideration from the viewpoint of standing waves led to the equation:

$$\delta F=\frac{l}{\lambda}\left[\omega\frac{v^2}{c^2}+\frac{1}{2}\frac{v^3}{c^3}\cos\theta+\omega\frac{v^2}{c^2}\cos 2\theta+\frac{1}{2}\frac{v^3}{c^3}\cos 3\theta+\omega\frac{v^2}{c^2}\sin 2\theta\right]. \quad (2)$$

Eq. (2) shows (1) From Miller's results or from the Michelson-Morley results,[4] a value for the orbital component of the earth's velocity of roughly 30 km per second. (2) Since the terms in $2\theta$ are functions of the mirror angle $\omega$, no $v^2/c^2$ effect can be expected with a flat field instead of fringes, which explains the negative result of Kennedy[5] and Illingworth,[6] who only looked for the $v^2/c^2$ effect. (3) Fourier components identical with those given on page 227 of Miller's paper.[1] (4) A curve which fits Miller's results within a hundredth of a fringe.

Most important of all, the considerations that led to Eq. (2) also gave the Lorentz transformation without having to assume a contraction of the interferometer arm, but Miller's results are not found to be in agreement with principle I of the special theory of relativity. Curves will be presented that show clearly that Eq. (2) fits Miller's results much better than Eq. (1), and a complete derivation of the formulas will be given.

[1] Dayton C. Miller, Rev. Mod. Phys. **5**, 203 (1933).
[2] H. A. Lorentz, *The Theory of Electrons*, 178 (1916).
[3] W. M. Hicks, Phil. Mag. **6**, 3, 32, 555 (1902).
[4] A. A. Michelson and E. W. Morley, Phil. Mag. **5**, 24, 449 (1887).
[5] R. J. Kennedy, Astrophys J. **68**, 367 (1928).
[6] K. K. Illingworth, Phys. Rev. **30**, 692 (1927).

**56. A Modification of the Heitler and London Method.** CLARENCE ZENER, *The Institute for Advanced Study, Princeton, N. J. (Introduced by W. L. Severinghaus.)*—The customary Heitler and London method starts out from atomic wave functions for the electrons. The orbital method of Hund and Mulliken uses solutions of a two center field in first approximation. A combination of the two is proposed in which atomic wave functions are used modified by the neighboring atom. Such wave functions are obtained by starting the Hartree self-consistent field with atomic in place of molecular orbital wave functions. In this way the gradual transition, as the interatomic distance decreases, from the atomic to the molecular functions is followed through. When this method is carried out it may be possible to avoid the large repulsive interactions between the valence electron of one atom and the inner shell of the other atom, which have recently been found by James.

**57. The Theoretical Binding Properties of Metallic Lithium.** FREDERICK SEITZ, *Princeton University.*—On the basis of previous theoretical developments concerning the binding properties of metals, and applied in detail to sodium, an investigation of the constitution of lithium is undertaken. In the previous work the process of solution was divided into two parts, namely, the solving of the best one-electron approximation on the one hand, and the investigation of more general statistical correlations of electron-positrons than those afforded by the first part, on the other. In the case of Na, the first part yielded about one-fifth of the observed binding energy while the second, for which the most satisfactory treatment has been given by E. P. Wigner in a very recent paper, removes about 80 percent of the remaining discrepancy. In the case of Li, it is found that the one-electron picture is appreciably changed, the individual wave functions being less similar to free-electron wave functions than in the case of Na. This has as its consequence that almost half of the observed energy is included in the one-electron solution. At the present stage of calculation, the result of Wigner on the nature of additional correlations is taken over directly and yields a binding energy of 34 kg Cal. as compared with the observed value of 38.9.

**58. Magnetic Moments of the Deuton and Other Nuclei.** D. R. INGLIS, *University of Pittsburgh.*—It is shown that the magnetic and mechanical moments of nuclei (except the deuton) can be correlated in terms of the moments of the particles (protons with gyromagnetic ratio $g=-5$, neutrons with $g=-1.1$) in excess of the number giving (empirically) no moment: that is, one proton or neutron with a possible "orbital" moment and perhaps two more neutrons with only spin moment. The approach is somewhat similar to that of Landé-Tamm-Altschuler, but is simpler in number of vectors, introduces the importance of the proton-neutron bond, finds that states of lowest proton spin-orbit coupling energy fit the data best, and explains the accurately known data (ratios) without contradiction. The deuton is taken to be a simple rotator, proton and neutron. It should be stable in its zero-rotation state, but then the spins with the above $g$'s would give a much larger value than the deflection value $|g|=0.7$ for the deuton. If we assume an unexplained stability of the first rotational state (a similar suggestion has been made in comparing the mass defects of the deuton and alpha-particle), solution of a secular problem leads to a sufficiently small value of $g$ for the deuton. With only a dipole spin-spin coupling, the value is $\frac{1}{2}$. Assuming magnetic spin-spin and rotation-spin coupling (including the Thomas relativistic correction, the factor being $\frac{3}{4}$ in this case) we get $g=-0.6$.

**59. Nuclear Spin in Isotopic Mixtures.** I. I. RABI, *Columbia University.*—It is pointed out that nuclear spins and magnetic moments of the different isotopes of a mixture can in some important cases be measured by means of atomic beams. The method utilizes the fact that the different isotopes when they have different magnetic moments or spins have some magnetic levels which have zero moments at definite values of the external magnetic field. This method also offers an independent measure of the relative abundance of the isotopes which possess nuclear magnetic moments. The case of $i=\frac{1}{2}$ however requires separate discussion.

**60. The Shoal Fathometer.** HERBERT GROVE DORSEY, *U. S. Coast & Geodetic Survey.*—The Shoal Fathometer, a special case of the fathometer described in the J.O.S.A. and R.S.I., Sept. 1924, was recently developed at the U. S. Coast & Geodetic Survey as a precision instrument for measuring shallow depths. A 1025 cycle tuning fork drives

a synchronous motor at 20.5 revolutions per second and the scale is graduated to 20 fathoms making the velocity of calibration 820 fathoms per second. Instead of using the flash in a rotating neon tube for visual indication, a thin aluminum disk with a narrow slot is rotated in front of a large neon tube bent in a circle. The echo flashes the entire tube by condenser discharge through a thyratron and the slot appears to stand still, indicating the depth. A magnetostriction transceiver is actuated from a 17,000 cycle thermionic generator, by light reflected on a photoelectric tube each revolution, causing a condenser to discharge through a thyratron, keying the tubes to produce a short signal in the water. There are no moving contacts in any part of the system. In actual use the indications seem more reliable than the standard method of measuring depths by a line and lead sinker. A complete description will appear in the *Review of Scientific Instruments*.

**61. Optical Observations of Sound Waves in Arcs.** C. G. SUITS, *General Electric Company*.—Sound waves passing through atmospheric pressure arcs are photographed with a rotating mirror camera of $\frac{1}{2}$ microsecond time resolution. The method is analogous to that employed in studying exploded wires by Anderson and Smith (Astrophys. J. **64**, 359 (1926)). The sound source employed is a condensed discharge through a 0.003″ iron wire placed 5 cm from and parallel to the axis of the 40 ampere white flaming arc between cored carbons. A preliminary value for the sound velocity in this arc is $1.85\times10^5$ cm sec.$^{-1}$, from which the temperature is calculated (by a method described in a separate paper) to be 5300°K.

**62. Sound Velocity in Gas Mixtures at High Temperatures.** H. PORITSKY AND C. G. SUITS, *General Electric Company*.—Experimentally determined values of the velocity $C$ of sound in atmospheric pressure arcs in air are interpreted in terms of the temperature of the gas. The velocity may be expressed in general in the form: $C=[(RT/M)(1+R/C_v)]^{\frac{1}{2}}$, which applies to pure gases or mixtures of gases that obey the perfect gas laws. In this relation $T$ is the absolute temperature; $M$ is the mean molecular weight defined as: $M=\Sigma M_i p_i/\Sigma p_i$, $C_v$ is the specific heat (per gram molecule) defined as: $C_v=\Sigma(C_v)_i p_i/\Sigma p_i$, where the summation is taken for all the gas components present. In the case of the arc in air, the components considered are the undissociated and dissociated oxygen and nitrogen. The values for the specific heat and degree of dissociation, taken from the equilibrium calculations of H. L. Johnston and associates (J. Am. Chem. Soc. **55**, 153 (1933)), are used, care being taken to apply the correct partial pressures. Possible sources of error due to thermal diffusion and other causes are considered.

**63. The Rotational Dispersion of Sound in Hydrogen.** ANGUS S. ROY AND MORRIS E. ROSE, *University of Michigan*.—The problem of the dispersion of sound in hydrogen due to rotational energy lag is investigated. From the result of an order of magnitude calculation of the cross section for the excitation of rotation it is to be expected that such a dispersion would exist only at frequencies greater than $10^6$ cycles per second. This prediction is entirely consistent with the result of the experimental work, which is that no dispersion is found in hydrogen up to a frequency of 1465 kilocycles per second at atmospheric pressure. In the dispersion region the sound velocity depends on the ratio of the pressure and the frequency; therefore, in order to avoid the use of many crystals, measurements were made at 388 kc and 1465 kc and at various pressures ranging from 424 to 772 mm Hg. The results showed a variation of less than one percent from the low frequency velocity of sound in hydrogen.

**64. The Change in Thermal Energy Accompanying Change in Magnetization of Nickel.** AGNES TOWNSEND, *Columbia University*.—The specimen, in the form of a wire 1 mm in diameter and 30 cm long, is placed axially in a cylindrical calorimeter about which a solenoid is wound. An array of thermocouples in thermal contact with the specimen permit changes in its temperature to be detected. The change in thermal energy which accompanies any change in magnetization is measured by comparing the concurrent change in temperature with that which appears when a known electric current passes through the specimen for a known time interval. As a specimen of nickel is carried through a half cycle of magnetization, commencing with maximum magnetization, the thermal energy decreases until (approximately) the knee of the hysteresis curve is reached. This is followed by a large increase as the steep part of the curve is traversed, and then by a much smaller increase as the half cycle is completed. The behavior of nickel is in contrast with that of carbon steel, for which Ellwood found an *increase* in thermal energy over the initial stage and a *decrease* over the final stage of this process.

**65. A Magnetic Study of the Metallic State and the Fermi-Dirac Statistics.** SIMON FREED AND HARRY G. THODE, *University of Chicago*. (*Introduced by A. J. Dempster*.)—The application of the Fermi-Dirac statistics to metals leads to a distribution of the spin of the electrons which does not vary much until about 40,000°C, the so-called critical temperature, is reached. Hence, magnetic measurements of metals which register the magnetism associated with the spin could scarcely serve as a test of the statistics since the variations in magnetism expected from the statistics would set in at such temperatures. However, on diluting a metal with a non-metal, a lowering of the critical temperature would be anticipated. When the metal in the diluted state occupies a volume of say 20,000 times as great as in the pure state, the distribution at room temperature is practically the same on the Fermi-Dirac statistics as on the classical statistics; the elementary magnets would be almost independent of each other. We have measured the magnetic susceptibilities of sodium dissolved in liquid ammonia at various concentrations, the dissolved metal occupying from 100 times to 20,000 times the volume of pure metal. The atomic susceptibility of sodium varied from that of the pure metal to about 100 times as much. In the most dilute solution measured, the atomic susceptibility was about two-thirds the para-

magnetic susceptibility which would arise from independent magnets having one-half unit of spin. The temperature coefficients of the susceptibilities will also be discussed.

**66. Magnetoresistance in Sodium-Potassium Alloy.** C. W. HEAPS AND J. E. ARMSTRONG, *The Rice Institute.*—It has been found by Fakidow and Kikoin (Phys. Zeits. d. Sow. **3**, 381 (1933)) that the liquid alloy NaK increases its resistance when subjected to a transverse magnetic field. This discovery has been further investigated using longitudinal fields and specimens of very fine diameter. Contrary to expectations it has been found that with tubes considerably finer than those used by Fakidow and Kikoin there appears to be a larger effect of tube diameter on magnetoresistance. A spurious effect due to motions in the liquid is thus shown to be present. However, a genuine, intrinsic effect is believed to exist. In a longitudinal field the magnetoresistance is larger than in a transverse field. To explain longitudinal magnetoresistance it is assumed that the field produces structural changes in atomic systems. For the liquid alloy, therefore, a magnetic field would seem to induce a pseudo-crystalline state. One point of view would be that the field is able to produce alterations in G. W. Stewart's cybotactic state. X-ray experiments are being performed to test this theory.

**67. The Hall Effect in Sodium, Potassium and Caesium.** F. J. STUDER AND W. D. WILLIAMS, *Union College.*—The Hall effect has been studied in carefully purified samples of sodium, potassium, and caesium obtained by distilling the metals in vacuum, into thin flat molds of Pyrex, with sealed-in electrical leads. The Hall constants determined are as follows: Sodium $-0.0021$, potassium $-0.0042$, and caesium $-0.0078$. The Hall effect in each case was found to be independent of the current density in the specimen, and of the magnetic field intensity. The effect of temperature was studied for potassium, and no variation in the Hall constant was noted over the range $-15$°C to 60°C. Attempts were made to follow the Hall e.m.f. from the solid to the liquid state, but the readings were always unsteady as the melting point was reached, so that no consistent data were obtained. The change in resistance due to the magnetic field was too small to observe, up to a field of 20,000 cgs units. The theory of Sommerfeld and Frank has been considered in connection with the alkali metals lithium and sodium, insufficient data being available for the others.

**68. A New Balanced Circuit for Resistance Thermometers, Combustible Gas Indicators, etc.** M. G. JACOBSON, *Mine Safety Appliances Company. (Introduced by A. G. Worthing.)*—A circuit is developed which is a cross between a potentiometer circuit and a Wheatstone bridge circuit: it can be regarded as a potentiometer circuit in which a part of the power source itself (one or more cells of a battery) instead of an independent e.m.f. is used to compensate the voltage drop through a part of the circuit fed by the power source; or it may be regarded as a Wheatstone bridge, in which the 2 parallel branches are replaced by 2 or more cells of the feeding battery. It is shown that this circuit is particularly advantageous for portable instruments, because it gives the same or even more sensitivity than a Wheatstone bridge with a much smaller current consumption. This circuit is successfully used in several instruments manufactured by the Mine Safety Appliances Company in Pittsburgh, in whose laboratories it was developed. For applications to hot wire combustible gas indicators, etc., it is important to maintain the temperature of the wire which is in one of the branches of the above circuit at a very constant value—against changes in e.m.f. and the wire itself. A simple circuit for this purpose is described. The mathematical proofs and details of both circuits are given in an appendix.

**69. Rubber Deformations Caused by Uniformly Repeated Stresses.** MILTON L. BRAUN, *Catawba College.*—If a rubber band of length $l$ is stretched by a given force to $l+e$ its length when the stretching force is removed becomes $l+\Delta l$. If the same stress is applied a second time the elongation becomes $e+\Delta e$, and the first net stretch $s\ (=e)$ becomes $l+(e+\Delta e)-(l+\Delta l)=s+\Delta s$ for the second stretch, the relation between the increments being $\Delta s=\Delta e-\Delta l$. The effect of $n$ isothermal applications of a given gravity load to an ordinary vulcanized rubber band was found to be:

$$(1)\ E=an^{\alpha},\quad (2)\ S=bn^{\beta},$$
$$(3)\ L=l+E-S=l+an^{\beta}(n^{\alpha-\beta}-b/a)=l+cn^{+}$$

(empirically), where $E$ is the elongation beyond the original length when the load has acted for one minute, $S$ is the actual stretch produced by an individual application of the load, $L$ is the length of the band measured one minute after the removal of the load, $n$ is an integer representing the number of the consecutively repeated force, $a$, $b$, $c$, $\alpha$, $\beta$, $\gamma$, and $l$ are positive constants, $l$ being the original length of the band. These equations have been established as a first approximation for several rubber compositions, for various loads and temperatures, and for values of $n$ beyond a hundred. Further work is contemplated.

**70. High Rotational Speeds in Vacuum.** E. G. PICKELS AND J. W. BEAMS, *University of Virginia.*—The rotating member consists of three main parts: a small, conical, air driven, air supported turbine (see Beams, Weed and Pickels, Science **78**, 338 (1933)); a much larger and heavier rotor of any desired shape, which spins in the vacuum chamber; a steel piano wire extending vertically downward along the axis of rotation from the apex of the turbine above the vacuum chamber to the larger rotor which it supports and drives. The wire enters the chamber through a small hole that leaves a very slight clearance. Viscous oil slowly fed into this clearance both lubricates the bearing and serves to make it vacuum tight. The vacuum obtainable is apparently limited only by the slight vapor pressure of the oil. The rotational speed is limited only by the strength of the rotor—e.g.,—a solid duralumin rotor (450 grams, 9 cm diam.) exploded when the maximum centrifugal force reached approximately 900,000 times gravity. This larger rotor, even when considerably unbalanced, spins smoothly. Since friction losses in both the wire and the vacuum rotor are negligible, and since the vacuum pro-

vides a high degree of thermal insulation, the apparatus affords not only a most efficient centrifuge, but a means of investigating many different phenomena.

**71. High Speed Electrical Motors.** R. C. COLWELL AND N. I. HALL, *West Virginia University.*—Within the last two years, very high speeds approximating one million r.p.m. have been obtained with air turbines and gas driven centrifuges, but no electric motor heretofore has ever rotated faster than 32,000 r.p.m. Two types of high speed electric motors have been built which have actually rotated at 45,000 r.p.m. and are capable of withstanding the centrifugal force at 100,000 r.p.m. The first of these is a synchronous motor with a laminated rotor on a steel shaft rotating in ball bearings. This rotor has no d.c. winding and the laminations must be of a special shape. This motor is not self-starting but is synchronized at low speed and then brought up to full speed by raising the frequency of the applied current. The second type is an eddy current motor which consists of an aluminum disk mounted on a vertical shaft; it is pulled around by a rapidly rotating magnetic field. The rotating field is produced by a 500 cycle two phase generator which is run fifty percent over normal speed. By using vacuum tubes or a specially designed high frequency alternator it should be possible to attain much higher angular velocities.

**72. Current-Voltage Relations in Blocking Layer Photo-Cells.** LAWRENCE A. WOOD, *Cornell University.*—Observations have been made of current (0.1 to 10,000 $\mu a$) in a Weston photronic blocking-layer photo-cell, as a function of illumination (1 to 100,000 lux) and of potential difference across the cell. The use of a graph of current against voltage is discussed, with particular reference to the choice of an external resistance for maximum power output. The leakage current through the blocking layer has been calculated, and from it the d.c. conductance in the low-resistance direction is obtained. This consists of a constant conductance of the order of 80 micromhos, as well as two other terms, one varying approximately as the 0.8-power of the leakage current and the other as the 0.4-power of the illumination. In the dark a conductance as high as 20,000 micromhos may be obtained; this reaches about 30,000 micromhos with maximum illumination. Similar studies of the Westinghouse Photox cell indicate a much smaller variation of conductance with leakage current and a larger variation with illumination.

**73. Temperature Effects on Photo-Voltaic Current and e.m.f. of a Selenium Mono-Crystal Platinum Film Combination.** R. M. HOLMES AND L. C. WHITMAN, *University of Vermont.*—Lamellar crystals of selenium were grown in an evacuated tube by condensation of the vapor. Platinum films covering approximately half of each surface were deposited by sputtering. The combination was placed in a uniform temperature enclosure. Light transmitted through one of the films causes an electron flow from selenium to the illuminated film, then through an outside circuit returning to the non-illuminated film. The magnitude of the current depends upon temperature. From −20°C to 50°C there is a reversible and nearly linear decrease, the rate at 50°C being −4 percent per degree. Between 50°C and 100°C the decrease is smaller, reversible and non-linear while exposure to higher temperatures results in a permanent decrease caused by baking of the platinum films. By e.m.f. is meant the opposing *p.d.* introduced into the outside circuit to stop the current. This decreases linearly and reversibly from −20°C to 20°C at approximately 0.5 millivolt per degree. The decrease is reversible but smaller and non-linear up to 100°C. Baking of the films during exposure to higher temperatures causes a permanent decrease. These effects are described by a theory which relates the current and e.m.f. to resistances in the combination either reversibly or permanently changed by heating.

**74. Loss and Restoration of Photo-Conductivity in Red Mercuric Iodide.** FOSTER C. NIX, *Bell Telephone Laboratories, Inc.*—Single crystals of red mercuric iodide, which normally display photo-sensitivity when precipitated, lose their photo-sensitivity on aging. This loss is accompanied by a change from the mono- to the polycrystalline fibrous state with considerable randomness of orientation of the individual crystallites. The non-sensitive crystals can be resensitized by subjecting them to an electric field for a time of the order of a few minutes. The rate of resensitization and the magnitude of the attained photo-sensitivity are found to increase with (a) increase in applied field strength and (b) decrease in temperature. When the light is turned on the photoelectric current is found, under certain circumstances, to rise briefly to a maximum and then descend to a permanent value at which the total current is equal to the value of the dark current prevailing when the voltage was first applied.

**75. Diffusion of Hydrogen through Iron and Palladium.** W. R. HAM AND J. D. SAUTER, *The Pennsylvania State College.*—As previously reported* the diffusion rate of hydrogen through palladium may be greatly modified by heat treatment of the palladium in various atmospheres. This is also true of iron. In general the apparent mass action law for diffusion of hydrogen through these two metals depends on rate alone; i.e., a sample of fresh palladium may be degassed until at 300°C and 760 mm pressure the rate is a certain amount, another sample may require heating to 600°C at 760 mm pressure to obtain same rate. The flow equations of both will be identical insofar as pressure changes at these temperatures are concerned. Iron exposed to nitrogen may have its diffusion rate for hydrogen increased 10 to 15 times, but after baking out at higher temperatures the diffusion curve comes back to its original position. Diffusion isotherms for Fe and Pd and very slow rates always approach $R_1 = A_1 p^{1.0}$; for very high rates, $R_2 = A_2 p^{.5}$. There is an apparently continuous variation from one exponent to the other.

* Phys. Rev. **45**, 741 (1934).

**76. The Expansion of Copper from Absolute Zero to Its Melting Point.** W. J. HARING AND WHEELER P. DAVEY, *Pennsylvania State College.*—The total expansion of copper was measured from 75°K to 1356°K and the curve was

extrapolated to 0°K. The total expansion from 0°K to the melting point was thus found to be 3.01 percent of the length at 0°K. This is consistent with the theory of melting of face-centered cubic materials (Davey, Phys. Rev. **27**, 319 (1926)) and with the spherical "shape" attributed to the atomic domain of such materials. The expansion over the whole range from 0°K to 1356°K is given by $L=L_0(1+\alpha t)$ where $\alpha$ lies between $2.24\times10^{-5}$ and $2.35\times10^{-5}$. It is given still more accurately between 200°K and 1200°K by $L=L_0(1+\alpha t+\beta t^2)$ in which $\alpha$ and $\beta$ are $2.26\times10^{-5}$ and $-2.44\times10^{-9}$ respectively between 200°K and 500°K and $2.08\times10^{-5}$ and $1.66\times10^{-9}$ respectively between 700°K and 1200°K.

**77. Technique for Making Sound Ingots for Density Determinations.** P. G. WALDO AND WHEELER P. DAVEY, *Pennsylvania State College.*—Pure copper was melted by means of a gas flame in alundum crucibles inside an evacuated ("satin") quartz tube. At room temperature the pressure inside the tube was 0.004 mm. At 1080°C the pressure rose to 1 mm in spite of continuous pumping by means of a Cenco Hyvac pump. Surprisingly this low pressure of gas was enough to give visible gas pockets in the copper and the lattice parameter was different from that of pure copper. When the quartz tube was surrounded by a second quartz tube evacuated by a second Cenco Hyvac pump, the pressure in the inner tube only rose to 0.02 mm and copper of normal density (8.994±0.004) was obtained. It is thought that, if the above technique had been observed by Phelps and Davey (A.I.M.E. Tech. Pub. 443), their results would have been different.

**78. Representations and Ray Representations in Quantum Mechanics.*** J. VON NEUMANN, *Institute for Advanced Study, Princeton, N. J.*

**79. Symmetry Relations in Various Physical Problems.*** E. WIGNER, *Princeton University.*

**80. Some Applications of Group Theory to Non-Relativistic Problems.*** J. H. VAN VLECK, *Harvard University.*

**81. Some Applications of Group Theory to Dirac's Relativistic Theory.*** G. BREIT, *University of Wisconsin.*

**82. The Electrical Phenomena of the Cochlea and the Auditory Nerve.*** HALLOWELL DAVIS, *Harvard Medical School.*

**83. The Absorption of Sound in Gases.*** VERN O. KNUDSEN, *University of California.*

**84. Some New Instruments of Acoustical Research.*** E. C. WENTE, *Bell Telephone Laboratories, Inc.*

**85. The Stark Effect in the Hydrogen Isotopes.** J. S. FOSTER AND A. H. SNELL, *McGill University, Montreal.*—The Stark effects for the first four members of each Balmer series have been photographed from a Lo Surdo source containing a mixture of the isotopes. Each observed asymmetric Stark intensity pattern for deuterium is nearly the mirror image of the corresponding hydrogen pattern. Similar results are obtained with a canal-ray tube which operates at unusually high pressures. The observed low total intensity of each Balmer line at the point corresponding to the first application of the external field in a Lo Surdo source is thought to be due to additional collisions arising from the dipole forces which are abruptly and completely developed at this point. Variations from the regular Epstein spacing of deuterium components are found to be in fair agreement with the Schlapp theory of the fine structure of the Stark effect.

*(To be called for immediately following paper No. 26)*

**86. X-Ray Measurement of Depth of Cold Work.** CHARLES S. BARRETT, *Carnegie Institute of Technology.*—Spots on Debye rings from a metal lose distinctness when the metal is cold worked. The depth of a cold worked layer on the surface of a metal may be determined by a series of photograms using non-penetrating x-rays. Each photogram is made with a different thickness of metal removed from the surface by etching. The method is direct and sensitive. It finds a practical application in the recently developed technique of surface cold-rolling of shafts to increase their endurance to alternating stresses. A fatigue specimen of axle steel (0.42 percent C), whose surface was cold worked by rollers of 2″ diameter and 1½″ contour radius which were pressed against the specimen by a 400 lb. radial force, was studied by this method. The specimen proved to have been cold worked to a depth of 0.055″±0.005. X-ray penetration into the specimen was negligible; reflections from (310) planes with cobalt radiation were used in a back reflection camera. R. E. Peterson, who furnished the specimen, predicted about 0.067″ for the depth in this instance, on the basis of a stress distribution under the rolls as calculated by Thomas and Hoersch.

*(To be called for immediately following paper No. 52)*

**87. Determination of the Sign of Nuclear Magnetic Moments by the Method of Atomic Beams.** I. I. RABI, *Columbia University.*—The sign of the nuclear magnetic moment with respect to its angular momentum can be inferred from the hyperfine structure by observing whether the hyperfine structure multiplet is normal or inverted. In molecular beam experiments there is no such criterion due to the symmetry in the magnetic moments of the different magnetic levels. Since such information would be of interest with regard to the proton and deuton moments a method is proposed in which a single magnetic level is sorted out of the beam and sent through a very weak inhomogeneous field in such a manner that non-adiabatic transitions occur to other magnetic levels. When the beam is analyzed subsequently in another magnetic field the sign of the nuclear magnetic moment may be deduced from the resultant states of the atoms.

*(To be called for immediately following paper No. 59)*

* Invited papers.

**88. Frequency and Magnitude of Cosmic-Ray Showers as a Function of Altitude.** RALPH D. BENNETT, GORDON S. BROWN AND HENRY A. RAHMEL, *Massachusetts Institute of Technology.*—Preliminary measurements of the magnitude and frequency of cosmic-ray showers have been made at each of four elevations: 170 meters, 1620 meters, 3100 meters and 4300 meters, for periods of time extending from 189 to 336 hours. One of the new cosmic-ray intensity meters of the Carnegie Institution was used in making the measurements, and only showers involving more than about 100 particles passing through the ionization chamber have been considered. Analysis of the frequency of arrival of showers as a function of their magnitude indicates that there are at least three classifications of showers at each location. The observations at the lowest level were made indoors under a slate, steel and concrete roof while the others were made in a tent. The observations made indoors indicate a deficiency in showers corresponding to less than about 500 particles passing through the chamber. The frequency of arrival of showers, taking all sizes above about 100 particles into account, increases somewhat faster with increase in elevation than does the absolute value of cosmic-ray intensity. The shower frequency curve extrapolated to single-ray showers and integrated to give the total ionization due to showers indicates that showers obeying the frequency laws derived contribute only a small fraction of the total ionization. A few showers of very great magnitude were observed at each level, their magnitude increasing rapidly with altitude. At the 4300 meter level three showers were observed which threw the instrument off scale, the largest of which produced not less than $10^9$ ion pairs, indicating not less than 5000 particles passing through the chamber and an energy release in the chamber (probably a small fraction of the total) of not less than $3\times10^{10}$ electron volts. The relationships derived for the time intervals between showers indicate that they arrive in a random manner.

*(To be called for immediately following paper No. 7)*

**89. On the Principle of Uncertainty in Sound.** WINSTON E. KOCK, *University of Cincinnati. (Introduced by L. T. More.)*—Following Stewart, a discussion of the applicability of the principle of uncertainty ($\Delta\nu\Delta t\approx 1$) to sound phenomena is given. Various sound phenomena are thereby explained and certain related experiments with frequency vibrato are reported. The phenomena explained are: the chromatic glissando imitation of a portamento, analysis of a formant into a Fourier series, the relation between vibrato wideness and pitch range, and the pleasing effect of a frequency vibrato.

*(To be called for immediately following paper No. 68)*

**90. The Inductive Glow Discharge Oscillator.** WINSTON E. KOCK, *University of Cincinnati. (Introduced by L. T. More.)*—An analysis of the intermittent glow discharge oscillator with inductance inserted in the condenser arm and operating in the neighborhood of resonance frequency is presented. The production of oscillations of the first and second kinds and the application of an overdamped oscillator in producing formants is discussed.

*(To be called for immediately following paper No. 89)*

**91. Wave Mechanical Treatment of the LiH Molecule.** JULIAN K. KNIPP, *Harvard University.*—A variational treatment of the LiH molecule has been carried out in which the two electrons of the inner shell of the Li atom are represented by Slater wave functions and the orbitals of the two valence electrons are treated after the method of James and Coolidge (but without the internuclear distance as one of the coordinates). In this treatment elliptical coordinates are used for the expression of the outer electron function, which takes the form of an exponential times a power series. A calculation made at the experimental equilibrium internuclear distance of the ground state, a distance of three Bohr radii, gives with eleven terms in the series a binding energy of 1.77 e.v., to be compared with the experimental value of 2.56 e.v. The addition of two terms containing the cosine of the difference of the azimuthal angles of the two outer electrons brings the binding energy to 1.90 e.v. An examination of the contributions to the energy of individual terms seems to indicate that several more terms of both sorts might give further reduction of approximately 0.2 e.v. A parallel treatment of the LiH ion carried out at an internuclear distance of three Bohr radii gives for the lowest state a repulsion of 0.19 e.v. with excellent convergence.

**92. The Production of Cosmic-Ray Showers by Lead at Different Elevations.** D. D. MONTGOMERY AND C. G. MONTGOMERY, *Bartol Research Foundation of the Franklin Institute.*—The rate of occurrence of bursts of ionization in a fifty liter Dow metal ionization chamber filled with nitrogen at 200 lbs. pressure, produced by 140 lbs. of lead shot placed over it has been measured at the summit of Pike's Peak (14,109 ft.), Glen Cove (11,425 ft.) and Colorado Springs (6098 ft.). From Colorado Springs to Pike's Peak the number of bursts greater than 1.5 million ions due to the lead increases by a factor of about nine. This increase corresponds to an absorption coefficient of $0.9\pm0.1$ per meter of water if it is assumed that the absorption may be represented by the Gold integral. The production of bursts must then either be due to a very soft component of the cosmic radiation or else some mechanism for their production similar to that proposed by W. F. G. Swann (Phys. Rev. **46**, 828 (1934)) must be supposed.

**93. The Longitudinal Motion of a Long Coil Spring Suspended Vertically from a Rigid Support.** D. A. WELLS, *University of Cincinnati. (Introduced by L. T. More.)*—A general solution for the longitudinal motion of a long coil spring suspended vertically from a rigid support has been obtained. The variation in mass per unit length has been taken into account and displacements as a function of time are determined from the stretched equilibrium position. It was found that the differential equation involving displacement from the equilibrium position could be thrown into the usual wave equation by a proper change of variables. Particular solutions for typical boundary conditions (lower end free, lower end loaded and lower end fixed) are given.

**94. Transverse Vibrations of Long Rods.** ISAY A. BALINKIN, *University of Cincinnati. (Introduced by S. J. M. Allen.)*—An expression is derived by the use of calculus only giving the fundamental frequencies for long rods fixed at one end and vibrating alone or with a concentrated load at the free end.

$$\nu=(1/2\pi)\{3EIg/(W+0.236W_1)l^3\pm 3g/2l\}^{\frac{1}{2}}.$$

When the axis of the blade is horizontal, the term $3g/2l=0$. When the free end of the blade is below the support—"elastic pendulum," the term $3g/2l$ is added and it is subtracted when the free end is above the support. For this position $\nu=0$ when the two terms under the radical become equal. The maximum concentrated load that a long rod can carry is then $W=2EI/l^2$ which is 20 percent below the value given by the classical Euler's formula for columns, $W=2.5EI/l^2$. Experimental curves are shown to compare favorably with the theoretical deductions for all cases considered.

**95. The Magnetic Moment of the Potassium $K^{39}$ Nucleus.** J. J. GIBBONS AND J. H. BARTLETT, *University of Illinois.*—Starting with the $K^+$ field given by Hartree, a $4s$ wave function has been found by numerical integration. The orthogonality correction diminishes the value of the wave function at the origin by about one-third. The experimental value of the hyperfine structure separation of the $^2S$ normal state is 0.015 $cm^{-1}$. This results in a nuclear magnetic moment of 0.10 nuclear magneton, as compared with the value of 0.38 nuclear magneton calculated by Millman, Fox and Rabi (Phys. Rev. **46**, 320 (1934)) on the basis of the modified Goudsmit formula.

**96. The Energy Levels of the Asymmetrical Rotator in the New Quantum Theory.** ENOS E. WITMER, *University of Pennsylvania.*—The Hamiltonian for the asymmetrical rotator can be written in the form:

$$H=\tfrac{1}{2}ap^2+\tfrac{1}{2}(c-a)H'(s;\,\theta,\,\phi,\,\psi,\,p_\theta,\,p_\phi,\,p_\psi),$$

where $a$, $b$ and $c$ are the reciprocals of the principal moments of inertia, $p$ is the total angular momentum, $\theta$, $\phi$, $\psi$, $p_\theta$, $p_\phi$, $p_\psi$ are Euler's angles and the conjugate momenta, and

$$s=(b-c)/(a-c).$$

The $a$, $b$ and $c$ do not appear either in $p$ or $H'$. For convenience take $a>b>c$. Then it can be demonstrated that the energy levels $E$ can be written in the form:

$$E=(h^2/8\pi^2)j(j+1)\{a+(c-a)\tau(s;\,n,j)\}.$$

This formula is analogous to a similar formula in the old quantum theory. Here $n$ is the second quantum number. Since $\tau$ depends merely on one parameter $s$ besides $n$ and $j$, it becomes feasible to tabulate $\tau$, and this has been done in part by the author. Furthermore,

$$\tau(1-s;\,-n,j)=1-\tau(s;\,n,j).$$

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