# PROCEEDINGS
## of the
# AMERICAN PHYSICAL SOCIETY

### MINUTES OF ATLANTIC CITY MEETING, DECEMBER 28–30, 1932

The 34th Annual Meeting (the 182nd regular meeting) of the American Physical Society was held in Atlantic City on Wednesday, Thursday and Friday, December 28, 29 and 30, 1932, in affiliation with Section B—Physics—of the American Association for the Advancement of Science. The presiding officers were Dr. W. F. G. Swann, President of the Society, Dr. Paul D. Foote, Vice-President, Dr. Karl K. Darrow and Professor R. C. Gibbs. There were more than two hundred physicists in attendance at the meetings.

The annual joint session with Section B was held on Thursday morning. The presiding officer was Professor David L. Webster, Vice-President of Section B. The Retiring Vice-President, Professor Bergen Davis, delivered an address on *Conquest of the Physical World* and he was followed by Dr. A. W. Hull of the General Electric Company and Dr. Thomas H. Johnson of the Bartol Research Foundation. Dr. Hull spoke on *Characteristics and Functions of Thyratrons*, and Dr. Johnson on *The Cosmic-Ray Hodoscope and a Circuit for Recording Multiply Coincident Discharges of Geiger-Mueller Counters.*

On Thursday afternoon Professor Richard C. Tolman of the California Institute of Technology delivered the annual Josiah Willard Gibbs Lecture. His subject was *Thermodynamics and Relativity.*

On Friday morning there was a symposium of invited papers on *Cosmic Rays.* The speakers at this symposium were (1) Dr. Gordon L. Locher of the Bartol Research Foundation on *Expansion Chamber Data on Cosmic-Ray Ionization;* (2) Professor R. A. Millikan and Dr. H. Victor Neher of the California Institute of Technology on *New Technique in the Cosmic-Ray Field and Some of the Results Obtained from It,*—Dr. Neher spoke on the new recording cosmic-ray electroscopes which he had developed with Professor Millikan; and (3) Professor Arthur H. Compton of the University of Chicago on *Some Evidence Regarding the Nature of Cosmic Rays.*

The annual dinner of the Society was held on Thursday evening at seven o'clock at the Ambassador Hotel. There were two hundred and nine present. Dr. W. F. G. Swann presided, and introduced the new President, Dr. Paul D. Foote. The after-dinner speakers were Professors Arthur H. Compton, Karl T. Compton, Robert A. Millikan and David L. Webster.

*Annual Business Meeting.* The regular annual business meeting of the American Physical Society was held on Thursday afternoon, December 29, 1932, in Room 12 of the Municipal Auditorium. The meeting was presided over by President Swann. The President had appointed Messrs. Barton and Breit to canvass the ballots for officers of the Society. They reported the following election for the year 1933:

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|---|---|
| President | Paul D. Foote |
| Vice-President | Arthur H. Compton |
| Secretary | W. L. Severinghaus |
| Treasurer | George B. Pegram |
| Members of the Council —four year term | L. O. Grondahl<br>E. C. Kemble |
| Members of the Board of the Physical Review—three year term | K. K. Darrow<br>J. C. Hubbard<br>A. E. Ruark |

The ballots also showed an almost unanimous approval of the following modifications of the constitution which had been recommended by the Council:

Change Article VI, Paragraph 1, to read as follows:

"The President, Vice-President, Secretary, Treasurer, Managing Editor, the three Past-Presidents most recently retired from office, eight other members elected in the manner specified in Article VII, and all Past-Presidents first elected to the office of President prior to December 1932 shall constitute a Council which shall have general charge of the affairs of the Society."

Change Article VII, Paragraph 3, to read as follows:

"No officer of the Society, except the Secretary, Treasurer and Managing Editor, shall be eligible for reelection to the same office until at least one year after the completion of his term of office."

Change Article VII, Paragraph 1, line 6* to read as follows:

"printed on the official ballot. The ballot shall also contain the names of one or more candidates. . . ."

Change Article VII, Paragraph 1, line 9* to read as follows:

"than three weeks before the Annual Meeting. Such a ballot, if marked by a qualified. . . ."

Change Article X†, line 4† to read as follows:

"to all fellows of the Society at least three weeks in advance of the meeting at which such. . . ."

The Secretary reported that during the year there had been 168 elections to membership. The deaths of 20 members have been reported during the year; 50 have resigned. The membership of the Society as of December 28, 1932 is as follows: Members: 1931, Fellows: 667; Honorary Members: 6; Total Membership: 2604.

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 Meeting because of the fact that the fiscal year had been changed from ending on November 30th to end on December 31st. The Treasurer's financial report will be audited, presented and distributed.

The Managing Editor made a statement of the condition of the journals of the Society, reporting a deficit of about $3000 as of May 1, 1932 increased at the rate of $750 a month since then. He stated that a thorough study of printing costs and new contracts through the Institute of Physics will make considerable reduction in the cost of publications for 1933. In this connection he referred to the changed format of the journals which would not only result in important economies but will give a double column page which is more easily read and is more adaptable as to set-up than the former single column and rather wide page of the Physical Review. But he stated that the saving will not be enough to enable the Physical Review to continue publishing the same number of pages without incurring a large deficit.

The Editor reported briefly an analysis of the results of the questionnaire which had been sent to members of the Society. Two-thirds of the ten hundred and fifty members replying indicated that they would consider it advisable to discontinue supplying the Physical Review in return for present dues rather than to increase dues, and although a large number of members indicated that they would be willing to pay $2 in addition to dues for membership subscription to the Physical Review the Council had decided that it would be unwise to place any more charges on the members at the present time. The Editor stated that he had therefore only one recourse by which to avoid increasing the deficit on the publications, namely, to reduce the number of pages. He stated that with the cooperation of the contributors he believed that this could be done without materially impairing the publications.

*Meeting of the Council.* At the meeting of the Council held on Wednesday, December 28, 1932, one candidate was elected to fellowship, three candidates were transferred from membership to fellowship and eighteen were elected to membership. *Elected to Fellowship:* John von Neumann. *Transferred from Membership to Fellowship:* J. E. Lennard-Jones, Gordon L. Locher and Eugen P. Wigner. *Elected to Membership:* Carl O. G. Borelius, L. T. Bourland, S. J. Broadwell, Otis R. Carpenter, Alex de Bretteville, Jr., H. W. Gillett, Helen Staff Hopfield, John J. Hopfield, William Hume II, Charles Lukens, A. M. J. F. Michels, John A. Sanderson, A. F. C. Stevenson, A. Maurice Taylor, John G. Thews, Ancil R.

* Lines are numbered as in Bulletin, Vol. 5, No. 5, Part 2, November 15, 1930.

† As renumbered by action at New Orleans meeting; was formerly Article VIII.

Thomas, Ralph N. Traxler, Glenn M. Webb, Philip S. Williams and R. D. Wyckoff.

The regular scientific program of the Society consisted of 65 papers. Numbers 1, 5, 26, 27, 52 and 60 were read by title. The abstracts of these papers are given in the following pages. An *Author Index* will be found at the end.

W. L. SEVERINGHAUS, *Secretary*

## ABSTRACTS

**1. Motion of an air-segment in a water-filled capillary tube.** WILLIAM SCHRIEVER AND J. F. EVANS, *University of Oklahoma.*—Known pressures were applied to a water column containing an air-segment in a horizontal capillary tube (0.2 mm diameter) and the resulting velocities of the air-segment were measured. A linear relation was found to exist between pressure and velocity, but the experimental curves when extrapolated made small intercepts on the pressure axis. The smallest measurable pressures, however, always produced motion of the bubble. For air-segments longer than a certain length, resistance proved to be independent of the length, but for very short air-segments, the resistance was measurably less. The resistance of an air-segment was shown to be approximately equal to the sum of the resistances offered by its two menisci. The resistance of an air-segment three days old was found to be of the order of ten times as great as that of the same air-segment when fresh. No adequate explanation has been devised for this curious "aging" phenomenon. It was further found that a moving bubble, if suddenly relieved of all pressure, would reverse direction and travel about two-thirds of its own length before stopping. A plausible explanation has been given for this last effect.

**2. Physico-mathematical aspects of the conduction of nervous impulse.** N. RASHEVSKY, *Westinghouse Research Laboratories, East Pittsburgh, Pa.*—Making the generally accepted assumption, that the propagation of a nervous impulse consists of a continued excitation of adjacent regions by the bio-electric currents produced in the already excited parts of the nerve, we find that the process of propagation is described by an integral equation. As has been shown in a previous publication, the velocity of propagation of such a disturbance is in general not uniform. In the present paper cases are studied, in which this velocity is uniform. Formulae are derived for two different cases. In one it is assumed, that the nerve is electrically homogeneous along its length. In the other, it is assumed that the myelin sheath is a perfect insulator, and that the bio-electric currents can pass only through the Ranvier nodes, where the continuity of that sheath is broken. The theory applies not only to nerve conduction, but formally holds also for the spread of activation in passive metals, such as studied by R. S. Lillie.

**3. On a thermodynamic relation in the theory of electrophoresis.** O. HALPERN, *New York University.*—The electrokinetic potential cannot in general be subjected to thermodynamic treatment. It is possible however to treat the special case of a particle migrating in a liquid by virtue of adsorbed charged molecules the ionization of which lends itself to thermodynamic discussion. In this way one may explain certain striking regularities connected with electric mobility of dissolved ions and that of surfaces covered with a film of the same ionic material. The same method proves useful in the treatment of colloid stability.

**4. Variation with height of convective heat flux from parallel vertical plates.** R. B. KENNARD, *Bureau of Standards.*—The temperature distribution between heated parallel vertical plates in air was measured by an optical interference method. Heat loss from the interior surfaces of the plates was calculated from the temperature gradients next to the surfaces, assuming that heat leaves the surfaces by pure conduction in the ambient air. Curves are obtained showing the variation in heat flux from the bottom to the top of the plates. The total convective heat transfer, obtained by integrating these curves, is compared with that obtained directly by electric power measurement, after correcting for radiation. The heat transfer as measured directly is found to be from twenty to thirty percent greater than that calculated from the observed temperature gradients and the accepted value of the conductivity of air. Since no sources of systematic error of this magnitude are suspected, the discrepancy suggests that the effective conductivity of the air near the surfaces may be somewhat greater than that determined under static conditions. The possibility of considerable departure from straight laminar flow in the region very near the plate is considered. An application of the studies to the design of fin type radiators is made.

**5. The electrical potential of amorphous and crystalline amphoteric surfaces in liquids.** O. WINTERSTEINER AND H. A. ABRAMSON, *Columbia University.*—It has been shown that the ionization of protein molecules adsorbed onto quartz surfaces is not changed appreciably by the adsorption process. That is, the electric mobility of the dissolved protein ions and that of microscopically visible quartz particles covered with an adsorbed film of the protein are practically identical. Insulin is a readily crystallizable protein which is highly insoluble near and at its isoelectric point. The electric mobility of the crystals of this protein has been studied simultaneously with the electric mobility of the amorphous protein (adsorbed or in particle form). The crystal surfaces were negatively charged at the isoelectric point of the amorphous surface. This is interpreted (in harmony with previous data on amino-acid crystals) as evidence for the point of view that at the

extreme limits of the crystal lattice of these amphoteric crystals the polar groups are oriented in such a way as not to be available for ionization in the simple sense found for the adsorbed protein. It is possible to choose conditions so that adsorption of a film of amorphous insulin onto the surface of the crystal itself can be effected, giving the crystalline surface the electrokinetic properties of the surfaces of the dissolved or amorphous, adsorbed material.

**6. A potential problem for a semi-infinite medium of variable conductivity.** L. B. SLICHTER, *Department of Geology, Mass. Inst. of Technology.*—In determining electrically the depth to bed rock in foundation problems, and in larger scale studies of the upper crust of the earth by electrical means, the problem arises of interpreting a potential field observed at the surface due to a point electrode in terms of the conductivity of the sub-soil. The simplest case is that in which the structure is essentially horizontal, so that the conductivity varies only in the vertical direction. The direct problem is not uniquely solvable, but results of sufficient reliability may be obtained by comparing the observed data with corresponding results computed for assumed structures. The postulated structures have always consisted of a number (usually two or three) of discrete layers, each of constant conductivity. The labor of computation is very great when this number exceeds three. This problem is here examined when the conductivity is permitted to vary continuously with depth. Particularly simple solutions exist when the conductivity function consists of a number of straight line segments. Some comparisons between solutions for the layered type of medium and those for the continuously varying type are given.

**7. An experimental study of the motion of particles in systems of complex potential distribution.** R. D. WYCKOFF AND H. G. BOTSET, *Gulf Research Laboratory, Pittsburgh. (Introduced by P. D. Foote).*—Certain practical problems in the flow of liquids through porous media involve the tracing of the motion of a given line of particles through the flow system. Because of the equivalence of the pressure in a liquid bearing sand to a velocity potential the motion of a liquid particle in a sand is exactly analogous to that of an ion in an electrolytic system. This analogy suggests the use of electrolytic models for tracing the motion of a line of particles in systems of complex potential distribution where the analysis would be difficult or even impossible. By the use of such models solutions have been obtained for systems involving various configurations and shapes of the sources and sinks. The distortions produced in the system by the presence of impermeable barriers located between the sources and sinks may also be observed. In these models the motion of the particles is indicated by a sharp trace representing the line of advance.

**8. Interatomic distance calculations for ionic crystals.** M. L. HUGGINS AND J. E. MAYER, *Department of Chemistry, Johns Hopkins University.*—By using the Born and Mayer expression (Zeits. f. Physik **75**, 1 (1932)) for the potential energy of an ionic crystal a set of basic ionic "radii" has been calculated. Interatomic distances computed from these radii agree with the experimental values within the probable experimental error, or nearly so, deviations from additivity due to differences in the relative ionic sizes and in the structure type being calculated quantitatively.

**9. A new method for calculating molecular vibration frequencies.** DONALD H. ANDREWS, V. DEITZ AND S. GOLDHEIM, *Chemistry Department of the Johns Hopkins University.*—When a polyatomic molecule vibrates freely in a single mode of motion it is necessary that each atom in the molecule vibrate with the frequency characteristic of that mode of motion. As a first approximation it may be assumed that each of the atoms vibrates along a straight line in the manner of an ideal harmonic oscillator. One can then calculate the virtual elastic force which would be necessary to produce the oscillation in question. This force must equal the vector sum of the various forces acting on the atom. In solving for the equation of the motion, one can estimate the directions of motion of the atoms from a knowledge of the shape of the molecule and the forces involved. In this step mechanical models are a considerable aid. The vector diagram of the forces on each atom is next set up and solved for the resultant force. The directions of lines of motion are then altered until the resultant forces on the various atoms are just sufficient to give them all the same frequency. It is possible in this way to obtain the modes of motion for a number of molecules too complex to be treated by the ordinary methods. Using the generally accepted values for the force constants it is possible to calculate values of the frequencies which are in good agreement with the observed data.

**10. The index of refraction of carbon dioxide as a function of the density.** FREDERICK L. BROWN, *University of Va.*—Our present data on the optical properties of gases at high pressures are meager and the theories are conflicting. The method here described is similar to that of Phillips (Proc. Roy. Soc. London, **A97**, 225–240 (1920)). A Fabry-Perot interferometer is completely enclosed in a steel bomb, with heavy glass windows, immersed in a constant temperature bath at 34.1°C. The bomb is connected through a drying tube to a calibrated burette by means of which the total amount of gas is measured by a "bailing out" process. The accompanying fringe shift is obtained by actual count. It was found that the Lorenz-Lorentz function $(\mu^2-1)/[(\mu^2+2)\rho]$ does not remain constant. The inverse of the Lorenz-Lorentz function when plotted against density shows a marked increase at the higher densities. The data included densities in excess of 0.8 g/cc and refractive indices in excess of 1.19.

**11. The Raman spectra of five higher alcohols.** P. L. BAYLEY, *Lehigh University.*—The Raman spectra of five normal alcohols (amyl to nonyl) have been determined. In the series from methyl through hexyl alcohol the number of Raman lines increases with the length of the carbon chain and the position of the lines show a regular progression. In heptyl, octyl, and nonyl alcohol, however, only those lines corresponding to the spectrum of ethyl alcohol

could be found. Spectra taken of hexyl and heptyl alcohols with equal intensity of both the main lines and the scattered background show the change clearly. This change may be due to the tendency of high boiling point liquids to produce faint and diffuse lines but it is nevertheless surprising that it should occur so sharply. A comparison of spectra of the series of normal alcohols with those of the corresponding iso-compounds shows that the number and relative positions of lines are determined almost entirely by the number of carbon atoms in the chain,—*n*-butyl and iso-amyl alcohols having almost identical spectra and likewise far lower members of the series. The broad line at $\Delta\nu = 1450$ is definitely double in iso-amyl and hexyl alcohols. Hexyl alcohol alone has a line beyond 1450, at 1657A.

**12. Attempts to observe an electron affinity spectrum.** O. OLDENBERG, *Harvard University.*—The failure of previous attempts to observe an electron affinity spectrum (due to the combination of neutral, electronegative atoms and electrons) is explained by inadequate experimental methods. Based on recent results regarding combination spectra of positive ions and electrons, new attempts have been made to observe the electron affinity spectrum of atomic iodine by using three methods (hollow cathode, positive column with addition of a rare gas, glowing filament). No new spectrum was observed. This failure is discussed theoretically. It seems that the capture of electrons by halogen atoms is an improbable process as compared with the combination of positive ions and electrons.

**13. Recombination spectra in the positive column of a caesium discharge.** F. L. MOHLER, *Bureau of Standards, Washington.*—Mohler and Boeckner (Bur. Standards J. Research **2**, 489 (1929)), found that the intensity of the caesium recombination spectrum increased with vapor pressure and varied less rapidly with electron concentration than was to be expected on the hypothesis of spontaneous recombination. It has been possible to measure the intensity over a much wider range of conditions by sighting along the axis of a columnar discharge. The intensity distribution between continuous bands and higher series lines remains nearly the same. The intensity at equal electron concentrations is nearly proportional to the vapor pressure. Curves of intensity *versus* electron concentration increase as the square of the concentration with low concentration and become linear at higher concentration. The form of the curves can be explained by assuming that recombination takes place at a rate proportional to the square of the electron concentration and that the radiation is quenched by electron collisions in a process which is the converse of ionization by collision. A similar process has been assumed by Webb and Sinclair (Phys. Rev. **37**, 182 (1931)) to explain the afterglow in mercury though they found that only the electrons with energy exceeding about one volt were effective in quenching mercury radiation.

**14. The effect of a small admixture of a foreign gas on the conductivity of a rare gas irradiated by its own resonance radiation.** O. S. DUFFENDACK AND R. W. SMITH, *University of Michigan.*—An investigation is made of the effect of impurities on the conductivity produced in Ne and in He at pressures from 1 to 10 mm by irradiation with their own resonance radiation. The conductivity is deduced from the volt-ampere characteristic of neighboring parallel plane collectors placed in the unionized gas between two low-voltage arcs ten tube diameters apart. The characteristic is linear on both sides of the voltage axis and obeys the mobility equation. It is found that for carefully purified gas the conductivity becomes relatively small. It thus appears that under the conditions of these experiments electron emission by impact of metastable atoms with the collector surfaces and tube walls is a negligible factor. Addition of a trace (0.001%) of A or Kr causes a marked increase in conductivity while addition of Ne to He causes a decrease. The explanation is proposed that metastable atoms which are probably formed indirectly through absorption of resonance radiation suffer either ionizing collisions (increased conductivity) or dissipative collisions (decreased conductivity) depending on the ionization potential of the added foreign gas. The work is being extended to permit estimation of collision probabilities and action cross sections.

**15. An extension of the Pt I-like isoelectronic sequence to tellurium IV, lead V, and bismuth VI.** G. K. SCHOEPFLE, *Cornell University.* (*Introduced by R. C. Gibbs*).—By using a vacuum spectrograph in the region of 657A to 1965A some of the lines arising from the transition $d^9p$ to $d^9s$ electronic configurations of Tl IV, Pb V, and Bi VI have been found. Except for the $^3P_0$ term, the values of the $^3PDF$, $^1PDF$ ($5d^96p$) and $^3D$, $^1D$ ($5d^96s$) are determined with respect to $^3D_3$. These data are compared with those for the ($4d^95p$) to ($4d^95s$) transition of the Pd I-like sequence. Note is taken of the work by Mack, Carroll, Rao and Arvidsson.

**16. Pressure broadening of spectral lines.** HENRY MARGENAU, *Yale University.*—Pressure broadening by foreign gases has been treated in a previous paper (Phys. Rev. **40**, 387 (1932)) on the basis of a statistical analysis of the van der Waals interaction curves. It is now shown that this statistical analysis must necessarily lead to the same result as the more common, but less perspicuous, procedure of expanding the modulated frequencies in a Fourier integral. There is no collision broadening which is not included in the effect previously discussed. Extending the former results, we have calculated the distribution of frequencies within a spectral line broadened by very high pressures, obtaining an approximate closed expression, and an accurate function which can be evaluated graphically. Agreement with experiment is good, but not entirely unambiguous because of lack of certainty of the molecular constants of attraction. More significant, perhaps, is the fact that it is possible now to determine the latter from an analysis of the line contour.

**17. A new band in the spectrum of the OH molecule.** HERRICK L. JOHNSTON, DAVID H. DAWSON AND MARGERY

K. WALKER, *Department of Chemistry, The Ohio State University.*—Although the ultraviolet "water vapor" bands were among the earliest molecular spectra to undergo extensive investigation, heretofore only six bands have been reported. These involve transitions between the (0, 1, 2) vibrational levels of an excited $^2\Sigma$ state and the (0, 1) vibrational levels of the normal $^2\Pi$ state. With improved conditions for exciting the spectrum we have obtained 91 lines, heretofore unreported, in the neighborhood of the (0′, 1″) band at λ3428. 44 of these lines prove to be extensions of λ3428; 54 lines (including 11 in common with λ3428) form a new band with a head at λ3484; and 4 lines remain unidentified. Analysis of the new band identifies it as the (1′, 2″) band of the "water vapor" system. A preliminary calculation of the moment of inertia of the new ($V''=2$) level yields $1.625\times10^{-40}$ g cm$^2$ as compared with $1.496\times10^{-40}$ and $1.558\times10^{-40}$ for the respective ($V''=0$) and ($V''=1$) levels. The identification of the new band permits the formulation of the vibrational energy equation for the normal $^2\Pi$ electronic state of OH, as $G=3735.0(V+\frac{1}{2})-82.8(V+\frac{1}{2})^2$.

**18. The infrared rotation vibration spectrum of hydrogen sulphide.** A. D. SPRAGUE AND H. H. NIELSEN, *Ohio State University.*—The fine structure of the hydrogen sulphide band at 1.9μ, first reported by Mischke (Zeits. f. Physik **67**, 106 (1931)), has been explored in absorption with a prism-grating spectrometer by using a grating of 3600 lines per inch and slit widths of 0.2 mm. The absorption cell, thirteen inches long, gave a maximum absorption of about 20% of the incident energy. It was found that the general contour of the band had two maxima which lay at 1.93μ and 1.97μ, respectively. The wave-length at which this band occurs suggested that it might be a harmonic of the band at 3.73μ investigated by Nielsen and Barker (Phys. Rev. **37** (1931)), but this band showed only one maximum. It therefore seemed of interest to reexamine the 3.73μ band with the view of definitely establishing the 1.9μ band as its overtone or not. This examination disclosed that the band reported at 3.73μ was actually only half the whole band, and that the second maximum occurred at about 3.88μ. The spacings between adjacent prominent lines are apparently of the same order as those for the harmonic.

**19. Barium hydride band spectra in the near infrared.** WILLIAM W. WATSON, *Yale University.*—Two new band systems of the molecule BaH have been found, one in the region of 9000A, the other beyond 10,052A. The first with principal heads at 8924A and 9017A degraded to the red is $^2\Sigma\rightarrow{}^2\Sigma$ with the same lower $^2\Sigma$ as for the $^2\Pi\rightarrow{}^2\Sigma$ bands in the visible red. A quantum analysis gives for the upper $^2\Sigma$ state $B_0=3.232$, $D_0=-1.323\times10^{-4}$ and $\gamma_0=-4.84$. This very large spin doubling indicates strong interaction with a near-lying, lower $^2\Pi$ state. Computation gives 1700 cm$^{-1}$ for the interval $\nu(\Pi, \Sigma)$, and thus this $^2\Pi$ is undoubtedly the upper state for the bands observed beyond 10,052A. The nature of the electron configurations for these four BaH states is discussed. Experience in the use of infrared sensitive plates in photographing emission band spectra is detailed.

**20. The production of specified wave forms with the photoelectric siren.** HAROLD P. KNAUSS, *Ohio State University.*—If a siren disk is used to interrupt a beam of light falling on a photoelectric cell, the amplified output produces a complex tone similar to that of the familiar air siren. Milne and Fowler (Proc. Roy. Soc. **A98**, 414 (1922)) made a study of the wave form of the Seebeck air siren, and found that they could design orifices for the disk to produce a practically pure tone. In the photoelectric siren, it is easier to make the disk openings of some simple shape, and modify the stationary aperture to produce desired wave forms. The disk used in the present experiments has radial slots 5 degrees wide, spaced at 30 degree intervals. It is placed near a lens which throws an image of a small source of light on the photoelectric cell, and interchangeable stationary apertures are placed between the disk and the lens. Assuming a stationary aperture bounded by an arc of radius $r_0$, and a curve expressed as $f(\theta)=r-r_0$, the area exposed at any instant will be $A=\int_\theta^{\theta+\pi/36} f(\theta)d\theta$ and the photoelectric current will vary as this integral varies with the time. The function $f(\theta)$ may thus be determined for a given wave form, or *vice versa.*

**21. Measurements on contact potential difference between different faces of copper single crystals.** H. E. FARNSWORTH AND B. A. ROSE, *Brown University.*—Measurements on contact potential difference between the (111) and (100) faces of single crystals of copper, as a function of the time of outgassing in a high vacuum, were made by the standard Kelvin null method. Care was first taken to obtain smooth surfaces etched parallel to the desired planes with practically no etching parallel to other planes. Two sets of observations with different experimental tubes show that the (111) face assumes a positive potential with respect to the (100) face. This value increases rapidly from near zero to about 0.4 volt during the first few hours of outgassing at dull red heat, and then more slowly to a limiting value of $0.463\pm.002$ at 70 hours and remains constant to at least 150 hours. In one case the value decreased by further heating at temperatures which exposed other faces by evaporation. Observations were taken at a pressure of about $10^{-7}$ mm Hg as measured on an ionization gauge. Although the present outgassing is not complete it is more than that required to reduce the surface gas layer to such a thickness that it possesses a definite crystal structure related to that of the underlying copper, as shown by Farnsworth. Hence the above result should be characteristic of surface gas crystals on copper.

**22. Equivalent circuit of a blocking-layer photo-cell.** LAWRENCE A. WOOD, *Cornell University.*—Observations by Schottky and Deutschmann on the cuprous oxide rectifier indicate a circuit consisting of a capacitance and two resistances, probably arranged with one shunting the capacitance and the other in series with the combination.

Capacitance bridge measurements at audiofrequencies with a Weston Photronic Cell indicate that for this a second capacitance element must be added to the previously mentioned circuit. The graph of observed values of effective reactance against effective resistance is a circle with its center displaced from both axes. Displacement of the center from the resistance axis seems to arise only from the addition of a second reactance element. Upon illumination of the cell the radius of the circle decreases and the displacements are diminished. The new values are reached quickly upon illumination, but after illumination require almost ten minutes to return to their original values. Measurements of the varying component of the voltage produced by the cell when illuminated with light of sinusoidally-varying intensity show a rapid decrease with frequency. Resonance may be obtained by placing an inductance across the cell. The relation of these observations to the equivalent circuit of the photo-cell is discussed.

**23. Interpretation of x-ray satellites.** HUGH C. WOLFE, *Heckscher Research Assistant, Cornell University.*—Druyvestyn's explanation of the $K\alpha$ satellites has been put to the test of numerical calculation by using the Hartree field in the case of potassium ($Z=19$). The $K\alpha$ satellites are attributed to transitions from states with one $K$ and one $L$ electron missing to states with two $L$ electrons missing. By treating $e^2/r_{12}$ as a perturbation and using the wave functions of the unperturbed Hartree wave equation, the energies belonging to the configurations $1s\,2s$, $1s\,2p$, $2s\,2p$, and $(2p)^2$ were calculated according to Slater's theory of complex spectra. The symbols describing the configurations refer to electrons missing from closed shells. The assumption of Russell-Saunders coupling is a justifiable approximation since the interchange energies turn out to be large compared with the spin-orbit interaction, which is measured by the $K\alpha$ doublet separation. There are five allowed transitions which may be correlated with five characteristic $K\alpha$ satellites

| Line | $\nu/R$ obs. | Transition | | $\nu/R$ calc. |
|---|---|---|---|---|
| $K\alpha'$ | 245.05 | $1s\,2p\,{}^1P\rightarrow(2p)^2$ | $'S$ | 245.05 |
| $K\alpha_3$ | 245.56 | $1s\,2s\,{}^3S\rightarrow 2s\,2p$ | $^3P$ | 245.63 |
| $K\alpha_4$ | 245.69 | $1s\,2s\,{}^1S\rightarrow 2s\,2p$ | $^1P$ | 245.53 |
| $K\alpha_5$ | —— | $1s\,2p\,{}^3P\rightarrow(2p)^2$ | $^3P$ | 246.38 |
| $K\alpha_6$ | —— | $1s\,2p\,{}^1P\rightarrow(2p)^2$ | $^1D$ | 246.15 |

$K\alpha_{5,\,6}$ are not observed in potassium but appear in other elements as a doublet at higher frequency than $K\alpha_{3,\,4}$. A small change in the interchange integrals would reverse the sequence of the frequencies calculated for $K\alpha_3$ and $K\alpha_4$ and likewise for $K\alpha_5$ and $K\alpha_6$. The reason for choosing the transitions assigned here is to make $K\alpha_3$ and $K\alpha_5$ appear as triplet-triplet transitions, since these lines have fine structure. The strong lines, $K\alpha_{3,\,4}$, which persist from $Z=11$ to $Z=30$, are due to an initial $KL(2_1)$ ionization. The weak lines, $K\alpha'$ and $K\alpha_{5,\,6}$, which appear from $Z=11$ only to $Z=19$ and $Z=16$, are due to an initial $KL(2_2)$ ionization.

**24. A critical study of the intensity formula for the powder method of crystal analysis.** F. C. BLAKE, *Ohio State University.*—By combining the Thomson and Lorentz factors into a single factor, and the usual structure factor and the atomic form factor into another single factor, the intensity formula consists of the product of these two together with the form or multiplicity factor, the Debye temperature factor and the absorption factor, treated by Claassen and Rusterholz. It is possible from a knowledge of these five factors to study intensity as a function of the wave-length for metals of different atomic numbers. Calculated results can be compared with experiments by means of densitometer experiments properly interpreted. The comparison has been made for aluminum using molybdenum and copper rays and agreement found for molybdenum rays. The reasons for disagreement when copper rays are used are discussed. There are other factors not properly handled in the intensity formula. These are discussed.

**25. $\alpha$-particles from ionization chamber materials.** J. A. BEARDEN, *Johns Hopkins University.*—The troublesome effect of $\alpha$-particles in the measurement of small ionization currents is well known. The number of $\alpha$-particles emitted by various materials usually used in ionization chambers has been determined by using an F P 54 vacuum tube and photographic recording over long time intervals. It was found that cold rolled steel was the best material for the walls and electrodes of chamber. Brass and copper were the next best materials. Careful cleaning of the metal surfaces with sandpaper reduced the number of particles usually observed by about 75 percent. Such a cleaned surface when exposed to air for a few hours returned almost to its original condition. Iron under the best conditions gave less than 3 $\alpha$-particles of range greater than 4 mm per 100 sq. cm per hour. Attempts were made to purify copper and use plated surfaces, but this was not successful. Thin celluloid, painted with india ink or thin iron foil was found satisfactory for windows. However some samples of india ink were not satisfactory. Well cleaned amber was very good for an insulator, while glass was poor. Methyl bromide, good quality $CO_2$, and $N_2$ were found to be suitable gases.

**26. New electron diffraction rings in zinc oxide and their interpretation.** K. LARK-HOROVITZ AND H. J. YEARIAN, *Purdue University.*—The diffraction of zinc oxide powder deposited from an electric arc between zinc electrodes has been investigated with electrons from 6 to 20 kv velocity. Besides the ordinary diffraction rings corresponding to the x-ray pattern, diffraction rings have been observed corresponding to 1/2 of 100 and 1/2 of 002.

| | | |
|---|---|---|
| Voltage | 19500 | 16700 |
| Ratio of diameters | $D_1/D_{100}$ 0.482 | |
| | $D_2/D_{002}$ 0.498 | 0.501 |

These rings are of much smaller intensity than the ordinary diffraction rings. The diameter of these rings as obtained for different voltages agrees with the value calculated for the different wave-lengths. Assuming that besides the diffraction from solidly packed crystallites ($n\lambda=2d\sin\theta$) diffraction also occurs from loosely arranged crystallites, in

which case refraction at the surface of each crystallite takes place $n\lambda(1-(4d^2/150n^2)V_0)^{1/2}=2d\sin\theta$ where $d$ is the spacing, $n$ the order of diffraction and $V_0$ the inner potential of the crystal these rings can be interpreted using an inner potential of 4 volts for zinc oxide. The rings appear strongly if the powder shows a mesh of loosely arranged fibers under the microscope, and while these fibers break after continued electron bombardment, the rings become weaker in agreement with the explanation given above.

**27. The problem of the intrinsic magnetic field by P. Weiss.** JAKOB KUNZ, *University of Illinois.*—A large number of magnetic phenomena have been coordinated by P. Weiss by the assumption of an intramolecular magnetic field. On the other hand arguments have been advanced by Akulow and Honda against the existence of such a field of 6 to 14,000,000 gauss. The strongest argument of Weiss consisted in the calculation of the increase of the specific heat of the ferromagnetic materials in the neighborhood of the Curie point. But the phenomena of the specific heat above the Curie point are not accounted for in Weiss' theory. Moreover it has recently been found that there exists in magnetite a sharp increase of the specific heat and a sudden change in the magnetic properties far away from the Curie point, and other substances such as paramagnetic MnO also show a very abrupt change of the specific heat at a low temperature. The magnetocaloric effect determined by $dT=-(T/C_4)(dJ/dT)dH$ is given by thermodynamics alone. The transition of ferromagnetic into paramagnetic properties is, especially in Weiss theory, obscure, as the number of magnetons is very different below and above the Curie point.

**28. The dynamic aspect of ferromagnetism.** F. BITTER, *Research Laboratories, Westinghouse Elec. & Mfg. Co., East Pittsburgh.*—During the last few years a static theory of ferromagnetism has been achieving considerable success. In its latest form this theory expresses the energy of a crystal as a function of the direction of magnetization as follows:

$$E_\theta=c\Sigma^1\alpha_i^2\alpha_j^2+k_1\Sigma A_{ii}\alpha_i^2+k_2\Sigma^1A_{ij}\alpha_i\alpha_j-I_w\Sigma H_i\alpha_i+\text{const}$$

and claims that the actual direction of magnetization is given by the direction in which $E_\theta$ has a minimum. $A_{ij}$ are the components of the strain tensor describing the distortion of the crystal, and $\alpha_i$ etc. are the direction cosines of $I_w$. The summations are with respect to $i$, $j$, $k$. In order to apply such a static theory consistently we should seek the minima of $E_\theta$ not under constant strain, but under constant stress. The stress tensor components are given by $F_{ii}=\partial W/\partial A_{ii}$ etc. We assume this differentiation to be carried out with $\alpha_i$ etc. constant.

$$W=\frac{c_{11}}{2}\Sigma A_{ii}^2+\frac{c_{12}}{2}\Sigma^1A_{ii}A_{jj}+c_{44}\Sigma^1A_{ij}^2+E_\theta$$

$c_{11}$, $c_{12}$ and $c_{44}$ are elastic constants. With the help of these expressions we may write $A_{ij}$ as a linear function of the quantities $F_{ij}$. Substituting in the expression for $W$ we obtain

$$E_\theta{}^1=c^1\Sigma^1\alpha_i^2\alpha_j^2+k_1{}^1\Sigma F_{ii}\alpha_i^2+k_2{}^1\Sigma^1F_{ij}\alpha_i\alpha_j-I_w\Sigma H_i\alpha_i+\text{const.}$$

All terms not involving $\alpha$ are lumped in the final constant. The new coefficients have the values

$$c^1=\frac{k_1{}^2}{2(c_{11}-c_{12})}-\frac{k_2{}^2}{4c_{44}}+c;\qquad k_1{}^1=0;\qquad k_2{}^1=0.$$

Accordingly, all terms involving products of $F$ and $\alpha$ drop out of $W$. This static theory of ferromagnetism predicts that magnetization is unaffected by externally applied stresses, in contradiction to experimental facts. The correct theory is probably a dynamic one in which $I_w$ oscillates so rapidly that the quantities $A_{ij}$ remain constant because of the large inertial forces acting on the heavy nuclei.

**29. The temperature dependence of Young's modulus for nickel.** JERROLD ZACHARIAS, *Columbia University.*—Young's modulus is calculated from the free period of longitudinal vibration of a thin rod. The latter is found experimentally for temperatures between 30°C and 400°C by a method previously described (S. L. Quimby, Phys. Rev. 39, 345 (1932)). Observations are here reported upon single crystals grown from especially pure nickel and upon hard drawn, polycrystalline rods of commercial nickel which contained copper, carbon, iron, manganese, silicon and cobalt to the amount of 1.1 percent. The variation of Young's modulus with temperature depends on the previous thermal history of the sample. Between 30°C and 200°C Young's modulus for *annealed* specimens decreases about 13 percent. This is followed by an increase to the Curie point of about 6 percent and above the Curie point by a linear decrease. For single crystals the maximum at the Curie point is so sharp as to indicate a discontinuity in the temperature coefficient. For *hard drawn* specimens and specimens *quenched* at 1100°C the minimum is wholly absent. Young's modulus decreases continuously to the Curie point, where, however, the temperature coefficient suffers an abrupt change.

**30. A magnetic velocity selector for molecular beams.** I. I. RABI AND V. W. COHEN, *Columbia University.*—In experiments on the direct measurement of nuclear spin by magnetic deflection of molecular beams it was found convenient to use a magnetic velocity selector. A portion of a beam of neutral sodium atoms, spread out in a velocity spectrum by an inhomogeneous magnetic field, is selected by a movable selector slit for further analysis. Beams 53 cm long and velocities 1/2 the average for the corresponding temperature have been used. For a given width of selector slit resolution varies inversely as the selected velocity. The beam was detected with the Langmuir-Taylor surface ionization detector. An original beam intensity of 30 cm, galvanometer sensitivity 1 mm = $10^{-12}$ amperes is reduced to 1/300 by the selector with a resolution $dv/v=1/10$. Detector fluctuations are of this order. However, we found it possible to accumulate sodium for 8 minutes on the cold detector wire. By sudden heating we obtain 15 cm ballistic throws corresponding to complete ionization of the accumulated sodium. Residual gases and impurities give no appreciable effect. With the accumu-

lation method it was relatively simple to perform further experiments with the very feeble monochromatic beam.

**31. Direct measurement of the scattering of potassium atoms by other atoms and molecules.** W. H. MAIS AND I. I. RABI, *Columbia University.*—A narrow beam of neutral potassium atoms (angular width 20′) was scattered by hydrogen, helium, nitrogen and carbon dioxide under low pressure. The scattering was investigated by means of a surface ionization detector, as a function of angle with the original beam from 0° to 60°, as a function of pressure of the scattering gas, and of the temperature of the potassium beam. The results allow a determination of the scattering function or $f$ curve within these limits. The small angle scattering expressed in terms of collision radii gives much larger collision radii than either kinetic theory radii or radii obtained from lattice distances. However, if one defines as a collision a change of direction of the potassium atoms of one-half degree, then the computed radii approach more closely the values to be expected. For the temperature of the potassium atoms the de Broglie wave-length is of the order of $2\times10^{-9}$ cm and we consequently would hardly expect any contribution to the scattering of the potassium atoms due to diffraction by the scattering gas atoms. The results may therefore allow of an evaluation of the mutual interaction between the potassium atoms and the atoms of the scattering gas.

**32. Orthogonality of scattered-wave functions.** E. H. KENNARD, *Cornell University.*—Solutions of the equation, $\Delta\psi+a^2(W-V)\psi=0$ are sometimes needed which at infinity take on the form $\psi=e^{i\mu\cdot x}+\Phi$, $\Phi\sim Ce^{i\mu r}/r$; cf. the functions used in treating x-ray emission by Sommerfeld, who proved their orthogonality in that case by a special argument. A general proof that such solutions are always orthogonal when $V$ is suitably restricted to the neighborhood of a point $P$ can be arrived at by paraphrasing mathematically the following argument. Let two wave packets with almost-definite energies approach $P$ in different directions from infinity. In the beginning they do not overlap ($\Phi=0$) and so are obviously orthogonal; in consequence of the Schrödinger time equation they preserve this orthogonality; then as they flow over $P$ the diverging $\Phi$ waves develop and $\psi$ becomes in each packet approximately a characteristic solution of the type in question. For a convenient mathematical statement one writes down

$$I=\int e^{-i\beta\mu_1^2}(e^{-i\mu_1\cdot x}+\Phi^*(\mu_1))d\tau\int_{\delta\pi}e^{i\beta\mu^2}(e^{i\mu\cdot x+\Phi(\mu)})d\pi,$$

$\delta\pi$ = any region in the $\mu$ space; one then shows that $dI/d\beta=0$, and that as $\beta\to\infty$ the contributions from $\Phi$ to $I$ vanish and by Fourier integral theory $I=0$ unless $\mu_1$ lies in $\delta\pi$. It follows that $I=0$ when $\beta=0$, which expresses the desired orthogonality.

**33. The probability function for the production of $He^{++}$ by single electron impact.** WALKER BLEAKNEY, *Princeton University.*—With a mass-spectrograph previously described (Phys. Rev. 40, 496 (1932)) the $He^{++}$ ion was found as a result of single electron impact. The ionization potential turned out to be 79 volts as expected. Above this point the effective cross section for such a collision increases rapidly with increasing electron velocity and passes through a maximum in the neighborhood of 330 volts. At this point the effective cross section is of the order of $2\times10^{-19}$ cm². It is concluded therefore that of all the helium ions produced by 330-volt electrons about one percent are originally doubly charged. At higher electron velocities the relative number increases slightly but the actual number decreases.

**34. Measurement of the masses of He and $H^1$, $Ne^{20}$, $Ne^{22}$, $B^{11}$, $Cl^{35}$ and $Cl^{37}$ with a mass-spectrograph.** K. T. BAINBRIDGE, *Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.*—The ratio of the masses of He and $H^1$ was measured by comparison of $He^{++}$ and $H_2^{1+}$ on fourteen spectra. Referred to $H^1=1.00778$, $He=4.00218\pm0.00004$. All of the succeeding masses are referred to $O^{16}$. $Ne^{20}=19.9967\pm0.0009$ from ten spectra by measurement of the $Ne^{20}$ line with respect to the known masses of C and O hydrides, and $C_2$ and its hydrides. $Ne^{22}=21.99473\pm0.00088$ from five spectra by measurement of $Ne^{++}$ in relation to $C^+$ and its hydrides over the linear part of the mass scale. Both neon values are outside Aston's limit of error and an explanation for his extraordinarily high mass values will be suggested. Within the limits of error of the $Ne^{22}$ and $F^{19}$ masses, the mass of $Ne^{22}$ is in agreement with the mass calculated from the disintegration experiments on $F^{19}$. $B^{11}=11.01073$ from two spectra as determined by the same method used for doubly ionized $Ne^{22}$. $Cl^{35}$ and $Cl^{37}$ were measured in the second order (doubly ionized) by comparison with OH, $OH_2$, $OH_3$ ions. $Cl^{35}=34.9796\pm0.0012$ from seven spectra, and $Cl^{37}=36.9777\pm0.0019$ from five spectra. Sample spectra will be shown.

**35. Decay of luminescence and light absorption in phosphorescent materials.** D. H. KABAKJIAN, *University of Pennsylvania.*—A number of substances were exposed to alpha, beta and gamma-rays from radium or polonium and the variation in their light absorption coefficient, $\mu$, was determined. The substances were either in the form of transparent plates or of deposits of crystalline powder on thin glass. The rate of variation of $\mu$ for all the substances investigated, whether phosphorescent or non-phosphorescent, can be represented by curves of the same type. It is found that for a constant source of radiation $\mu$ does not increase exponentially with time but tends to reach a saturation value. The saturation value for each material depends upon the intensity of the irradiation but is independent of the total amount of energy absorbed by it. It also depends upon the temperature at which irradiation takes place. The increase in the value of $\mu$ does not seem to be directly related to the light emissivity of the material. With the data obtained from the absorption curves it is possible to plot luminous flux-time curves of irradiated phosphorescent materials instead of brightness-decay curves. The curves show a decay of flux that can not be represented by a simple exponential.

**36. Fluorescence of solutions of chlorophyll *a*.** H. V. KNORR AND V. M. ALBERS, *Kettering Foundation, Antioch College.*—The fluorescence of chlorophyll *a* in solution in anhydrous ether, benzene, acetone and methanol has been photographed by means of a Hilger $E_3$ spectrograph. The fluorescence was excited by radiation from four Pyrex mercury arcs. The solutions were maintained at a temperature of 6° centigrade. One minute exposures on Ilford hypersensitive panchromatic plates were used to obtain the spectrograms. The concentrations used were 1 mg per 100 cc of solution. The fluoresence consists of a main band, the wave-lengths of its maximum being 6718A for ether, 6767A for benzene, 6720A for acetone and 6745A for methanol; a second band the wave-length of its maximum being 6330A for ether, 6358A for benzene and 6392A for acetone. A shift in the position of the main band toward the violet and the second band toward the red is observed when the solutions are irradiated continuously. This shift is attributed to additional bands of the new fluorescent compounds which are formed photochemically. The initial positions of these bands do not agree with those observed by earlier investigators. Two additional bands at 7335A and 6792A have been observed for chlorophyll *a* in ether, by using longer exposures on Eastman extreme red plates.

**37. The fluorescence of some substances containing vitamin A.** JAY W. WOODROW AND A. R. SCHMIDT, *Iowa State College.*—One of us has previously reported the observation of a fluorescence band at about 550 mμ for cod-liver oil when irradiated by ultraviolet light. With improved equipment, we have obtained two distinct fluorescent bands for cod-liver oil, one a narrow band extending from about 530 to 570 mμ and the other much wider and extending from about 410 to 510 mμ. The same two bands were obtained with butter fat, but they were not so intense. This broad band from 410 to 510 mμ was also obtained with spinach and tomato juice, both of which contain vitamin A. The broad fluorescence band in cod-liver oil is very much reduced in intensity for cod-liver oil which has lost most of its vitamin A potency is due to bubbling air through it at a high temperature. Apparently, the fluorescence is connected with either the vitamin A or the carotin present.

**38. "Conquest of the Physical World."*** Address of the Retiring Vice President of Section B—A.A.A.S.,

BERGEN DAVIS

*Columbia University*

The natural impulse of mankind is to obey the command to "Subdue the Earth and have dominion over it." The scientist subdues the forces of nature to beneficent uses. The great mass of mankind has overrun the surface of the earth with irreversible destruction. The conquests of science are a ceaseless adventure, more thrilling than the prosaic adventures of exploration or adventures in the political life. A rapid survey is made of the conquests of physical science, such as the conquests of the heavens, the discovery of the laws of motion by Galileo and Newton, the conservation of mass and the conservation of energy, the establishment of the atomic hypothesis and the electromagnetic theory of light. Two major discoveries at the close of the last century were the Roentgen rays and radioactivity. These initiated the study of the structure of matter and the nuclear atom of Rutherford and Bohr. The quantum theory of radiation, and its absorption and emission rapidly followed. The special relativity theory of Einstein was a major conquest, containing the broad generalization of the identity of matter and energy. Studies in radioactivity and the photoelectric effect definitely established that matter and energy are atomistic. There is no continuum in nature. The discovery of isotopes, together with the identification of matter and energy led to processes of atomic disintegration and atom building. Recent experiments show that the proton has great chemical affinity for certain atomic nuclei. We are at the beginning of a new chemistry, the chemistry of the nucleus. The way is open that will lead to the conquest of the internal energy of atoms to our uses. The oasis of knowledge has been greatly enlarged, but the surrounding desert of the unknown is still without limit.

* Invited papers.

**39. "Characteristics and Functions of Thyratrons."***

A. W. HULL

*Research Laboratory, General Electric Company, Schenectady, New York*

The fundamental properties of Thyratrons are described and illustrated. Present models are discussed from the standpoint of grid control characteristics, power amplification, starting time, deionization time, current and voltage limits, and efficiency. Typical applications are described to illustrate the different functions which the Thyratron is adapted to serve. These functions include on-and-off control operations, continuous variation of current by phase control, rectification, inversion, frequency changing and commutation of motors. Scientific applications are discussed, and future possibilities briefly forecast.

**40. "The Cosmic-Ray Hodoscope and a Circuit for Recording Multiply Coincident Discharges of Geiger-Mueller Counters."***

THOMAS H. JOHNSON

*The Bartol Research Foundation of the Franklin Institute*

The cosmic-ray hodoscope was designed to provide a continuously sensitive method for tracing the paths of the cosmic rays throughout an extended volume. The present model consists of a bank of 36 counter tubes each of which is connected to a neon flash lamp. The cosmic-ray tracks appear as a row of simultaneously flashing lamps. The method of eliminating flashes other than those due to cosmic rays and the method of recording the flashes are described and possible uses indicated. The circuit for recording coincident counter discharges, designed in collaboration with J. C. Street, is described

and discussed as regards its resolving time, sensitivity and constancy. The paper was illustrated by demonstrations.

**41. High-speed ions of stellar origin.** Ross Gunn, *Naval Research Laboratory, Bellevue, D. C.*—It is noted that the observed state of rest of numerous ionized calcium clouds guarantees that all interstellar space is substantially neutral. The presence in the solar atmosphere of strong electric fields suggests that negative ions might be accelerated and move off into space with energies of some millions of volts. The process of emission is studied. It is found that only within a sunspot are conditions such that a negative ion can traverse the solar atmosphere and acquire energy comparable to the potential difference between the sun proper and free space. An electron or negative ion which succeeds in traversing the layer emerges at high speed and attracts to itself, from the high atmosphere, a neutralizing positive ion by electrostatic attraction; and, finally, the two ions, forming a neutral pair, leave the sun at precisely the same velocity. The energy of the neutral stream is estimated to be a very small but appreciable fraction of the energy radiated by the sunspot. *Bearing on the penetrating radiation.* Neutral ion pairs of solar origin can have no relation to the penetrating radiation because of their low energy, but similar processes in early type stars will give rise to neutral ion pairs of approximately $10^{10}$ or $10^{11}$ electron-volt energies. It is suggested that these energetic neutral ion pairs which perhaps get separated by electromagnetic forces or by collisions in the earth's atmosphere are identical with the penetrating radiation. Reasons are given for believing that the distribution of such particles in space is nearly uniform.

**42. The disintegration of lithium by protons of high energy.** M. C. Henderson, *University of California.*—The results recently obtained by Lawrence, Livingston and White have been extended to protons having an energy up to 1,125,000 electron-volts. After the rapid increase found by Cockroft and Walton at lower voltages the number of disintegrations per proton increases above 400,000 electron-volts proportionally to the 3/2 power of the energy. The range of the proton is known to be proportional to the same power of the energy. These facts indicate that the probability of disintegration of the individual lithium nucleus is independent of the energy of the proton above 400,000 volts. The relative number of disintegrations over the whole range from zero to 1,125,000 electron-volts is given quite exactly by $N=k'Ve^{-a/V^{\frac{1}{2}}}$ where $V$ is the energy of the protons and $k'$ and $a$ are constants. From 400,000 to the upper limit reached this formula is practically indistinguishable from $N=k(V^{3/2}-V_0^{3/2})$ when the experimentally determined values of the constants are used. The more complex formula has theoretical justification and the radius of the lithium nucleus as calculated from the experimental value of $a$ is about $4\times10^{-13}$ cm. The cross section effective for disintegration seems to be much smaller, with a radius of $1.4\times10^{-14}$ cm. The actual number of disintegrations is half the number of alpha-particles emitted and is equal to 2.0 disintegrations per $10^9$ protons at 250,000 electron-volts; 10.2 disintegrations per $10^9$ protons at 500,000 electron-volts; 40 disintegrations per $10^9$ protons at 1,000,000 electron-volts. The results at 500,000 volts are in excellent agreement with those of Cockroft and Walton. The form of the curve differs slightly and the probable causes of this difference are discussed.

**43. The disintegration of lithium by protons.** J. R. Oppenheimer, *Berkeley, California.*—The disintegration of lithium by protons first observed by Cockroft and Walton was expected on theoretical grounds; but the disintegration of much heavier elements, which is also observed experimentally, appears irreconcilable with the usual nuclear model. To see whether the voltage dependence of the effect in lithium was in detail in accord with the theory, we have therefore made the calculations, using for model the Gamow model of a repulsive Coulomb potential broken off at a radius $r$, assuming that the number of capture-disintegrations is proportional to the probability of finding a proton inside $r$, and taking into account the stopping of the protons in the target. For the range in question the theoretical dependence of the yield on the proton voltage $V$ is given with sufficient accuracy by $V\exp(-aV^{-\frac{1}{2}})$ where $a=2.4\times10^3[1-6(10^{12}r)^3]$. With $a=1930$, this fits all the observations from $1.5\times10^5$ up to $1.16\times10^6$ volts within experimental error; in this range the yield varies by a factor of over a hundred. The experimental $a$ gives an $r=3.2\times10^{-13}$, which is small but not impossible. The observed yield is never more than a tenth of the theoretical upper limit, which we get by assuming that every proton which penetrates inside of $r$ causes a disintegration. Thus the present evidence confirms, in the case of lithium, the applicability of the Gamow model.

**44. Detection of corpuscular radiation by vacuum tube methods.** John R. Dunning, *Columbia University.*—The advantages of the direct detection of the ionization produced by alpha-particles or high-speed protons include linearity, high resolution, freedom from beta and gamma-disturbances, uniform response over large area, adaptability to differential methods, low "natural count," and full quantitative results. This paper is a study of the design of high gain resistance-capacity coupled amplifiers for this purpose. The magnitude and wave form of the initial pulse are functions of a number of factors, and to secure both high sensitivity and resolution, the initial circuits must have special characteristics involving certain compromises. The resistive and capacitative components of the input admittance are highly important, and the reduction of the effective input capacitance associated with the first tube and ionization chamber is discussed. Numerous sources contribute to the noise level which a high initial amplification and other practices minimize. Various types of input tubes have been tested, and the characteristics of an ideal tube are indicated. The complete set-up includes a linear amplifier with staggered time constants, peaked frequency response, isolation filter circuits, extreme shielding, and a balanced output circuit feeding a high-frequency moving light beam oscillograph. The apparatus has been used to obtain oscillograph records of alpha-particles and of protons, both from nuclear disintegration and from neutron impacts.

**45. The airplane method of obtaining cosmic-ray intensity data.** LYNN G. HOWELL, *Humble Oil Company, Houston, Texas and* LEWIS M. MOTT-SMITH, *The Rice Institute, Houston, Texas.*—In order to obtain new data on the intensity curve of the cosmic radiation at high elevations an airplane was used to carry an electroscope to the various altitudes up to about 27,000 feet. The advantages of this method are discussed. The construction of a high pressure Wulf-type electroscope for this purpose is described. The details of the calibration of the instrument and the technique for making reliable intensity measurements in an airplane are presented. In the course of this work measurements were made at various altitudes of the cosmic-ray absorption by lead shields of thickness 1.3, 2.5 and 4.7 cm. The results of these measurements indicate that there are difficulties in the way of making the corrections for local radiation by the use of shields.

**46. Airplane cosmic-ray intensity measurements.** LEWIS M. MOTT-SMITH, *The Rice Institute, Houston, Texas and* LYNN G. HOWELL, *The Humble Oil Company, Houston, Texas.*—With the help of the United States Air Corps and particularly of Captain A. W. Stevens of Wright Field the following cosmic-ray measurements have been made: (1) daytime intensity curve from 1000 to 27,000 feet, (2) night-time intensity curve up to 27,000 feet, (3) absorption in a few cm of lead at various elevations, (4) intensity measurement at 27,000 feet during the solar eclipse of August 31, 1932. Comparison with the earlier high altitude measurements, notably those of Kolhörster, indicates that the present curve is steeper at 27,000 feet, so that the marked decrease in the absorption coefficient above 20,000 feet is not observed. It is found, however, that the values at the highest altitudes are too small by a factor of about two to fall on Millikan and Cameron's synthetic cosmic-ray curve. No significant decrease in intensity was observed during the night-time observation even at the highest altitudes. In accord with all previous eclipse measurements, no change in intensity was observed during the solar eclipse.

**47. Energy-loss and scattering of cosmic-ray particles.** CARL D. ANDERSON, *California Institute of Technology.*—Cloud-chamber photographs of cosmic-ray particles traversing a lead diaphragm of 11 mm thickness taken in a uniform magnetic field of 15,000 gauss have yielded the following facts. Electrons of initial energy of 300 million volts were found to lose about about 35 million volts energy per cm of lead traversed. The mean change in direction due to scattering in the 11 mm lead plate for a group of 33 tracks of $Hr > 10^6$ gauss cm (measured both above and below the lead plate) was 0.7 degrees, the smallest angle being less than 0.2 degrees and the largest 3.1 degrees, the angle being measured in the plane of the front glass plate of the cloud-chamber. This group of tracks represents either (1) electrons of minimum energy 300 million volts, or (2) protons of minimum energy 150 million before traversing the lead plate. For protons the minimum energy based on curvature is 50 million volts, but allowing for the energy loss to be expected in traversing the lead, a lower limit of 150 million volts must be assigned. A second group of 14 tracks comprised of electrons of energies ranging from 100–300 million volts showed a mean change in direction due to scattering in the lead plate of 4.9 degrees, the smallest angle being less than 0.5 degrees and the largest 14 degrees. In general the change in direction in the lead diaphragm due to scattering is much greater than that due to the effect of the 15,000 gauss field.

**48. The variation of cosmic-ray intensities with azimuth on Mt. Washington, N. H.** THOMAS H. JOHNSON, *The Bartol Research Foundation of the Franklin Institute and* J. C. STREET, *Harvard University.*—The triple coincidence counting rates of three G.M. counters in line were recorded at the elevation 6288 ft. in the four azimuths, magnetic N, S, E, and W with the line of counters inclined 20°, 30°, and 40° from the vertical. For each inclination the lowest counting rate was found in the east, with the west and the north higher than the average. The magnitude of the variations are such that it is exceedingly improbable that they arise from statistical fluctuations. The variations observed in the data for each position are, however, within statistical expectation. An east minimum can be explained on the basis of Störmer's theory of the motion of a charged particle in the earth's field if a preponderance of the cosmic rays observed at that elevation are protons of energies of the order of $10^{10}$ volts. The absence of an east-west difference at lower elevations would find its interpretation in the idea that the rays which penetrate the atmosphere have energies so high that they are not excluded from the east by the earth's field. It may be also possible to explain the effect by the influence of the earth's field on secondary rays.

**49. "Expansion Chamber Data on Cosmic-Ray Ionization."***

GORDON L. LOCHER
*National Research Fellow, at the Bartol Research Foundation of The Franklin Institute*

Experimental evidence is presented for a new process of ionization by swiftly moving corpuscles. According to this theory, part of the ionization is produced by characteristic x-radiation generated in the gas by the passage of the particle through it. A discussion will be given of the amount of ionization along cloud tracks of cosmic-ray particles, as compared with that found in ionization chambers, also of the rate of influx of the particles, as found with a precision cloud machine and Geiger-Müller counters. An analysis is made of simultaneous groups of cloud tracks.

**50. "New Technique in the Cosmic-Ray Field and Some of the Results Obtained with It."***

R. A. MILLIKAN AND H. VICTOR NEHER
*California Institute of Technology*

There have been developed new types of cosmic-ray electroscopes which are at least ten times as sensitive as the most sensitive of those heretofore used by either of us, and which are in addition self-recording and independent of gravity as well as of the vibrations of the supporting platform. They

* Invited papers.

make a permanent record of cosmic-ray intensities in the localities through which they pass, and a record which is just as accurate and dependable whether the recording instrument is in a moving railway train, automobile, airplane, or steamship, or at rest in a laboratory, so that when a given area has once been surveyed with their aid subsequent students need only come and read their records, permanently preserved on films,—records which are of course entirely free from all personal equation and preconception. These electroscopes have thus far failed to reveal any variation in the cosmic-ray intensities in any of the localities through which they have been carried over the earth's surface so long as they have been kept at a uniform depth beneath the top of the atmosphere. This statement applies accurately to sea-level observations, which have now been carried from 49° north to 8° north. Readings at high altitudes are not yet complete. Also readings with these electroscopes both at low and at high levels (14,000 feet) reveal no direct effect of the sun or of any other celestial objects. Thus far, then, the new technique has brought no evidence that the incident cosmic-ray photons are mixed in appreciable amount with their secondary corpuscular radiations when they enter the atmosphere. The continuation of these readings in the higher atmospheric levels will reveal whether the softer components of the incoming cosmic rays are as free from such mixing as are the harder components.

**51. "Some Evidence Regarding the Nature of Cosmic Rays."***

ARTHUR H. COMPTON
*The University of Chicago*

Five methods of distinguishing between photons and electrons or other charged particles as the primary cosmic rays are discussed: (1) A study of cosmic-ray absorption, which indicates that if electrically charged the rays must have much higher energy than if they are neutral. (2) The intensity at high altitude, which is consistent with the view that charged particles enter the atmosphere from above. (3) The Bothe-Kohlhorster experiment, indicating that high-speed particles exist whose absorption is about that of cosmic rays. (4) Deflection by magnets, which shows electrically charged primary or secondary particles of very high energy. And (5) variations in cosmic-ray intensity with differences in magnetic latitude on the earth's surface. Evidence is presented to show that this difference cannot be due to magnetic effects on secondary electrons, but that it is the primary rays which are thus affected. This supports the view that cosmic rays are electrified particles, with energies (if electrons) of $10^{10}$ electron-volts and more.

**52. A portable high tension voltmeter.** H. T. CLARK, *Purdue University.*—A glass tube two inches in diameter and eight inches long is filled with oil and contains two disks and a very light aluminum vane suspended midway between the electrodes. This vane is fixed rigidly to a mirror which is mounted above the oil level (in a side tube) and the assembly suspended on a light gold wire under tension. A potential a.c., when applied to the electrodes, causes a deflection of the vane. The arrangement in oil permits the application of high voltages and furnishes a convenient method of damping. A laboratory model punctured at approximately 120,000 volts. This model has been calibrated up to 25,000 volts for an electrode separation of 6.5 cm. The sensitivity at low voltages is about 100 volts per cm and at high voltages it is about 250 volts per cm for a 1.5 meter scale distance.

**53. The electrostatic generation of high voltages for nuclear investigations.** R. J. VAN DE GRAAFF, K. T. COMPTON AND L. C. VAN ATTA, *Massachusetts Institute of Technology.*—A previous abstract (Phys. Rev. 38, 1919 (1931)) described an electrostatic generator consisting essentially of a pair of hollow spherical electrodes charged by belts. Both theoretical and experimental aspects of this type of electrostatic machine will be discussed. A description will be given of the design of a much larger generator now under construction at the M.I.T. experiment station on the Round Hill estate of Colonel E. H. R. Green. The electrodes of this machine are hollow aluminum spheres 15 feet in diameter, the interiors of which afford laboratory space for the operators. Each electrode is mounted on an insulating column of Textolite six feet in diameter and 24 feet high, within which the charging belts run in warm dry air. The machine is designed to develop a steady d.c. potential of the order of 10 million volts with a continuous power output of about 20 kilowatts. If desired this power can be greatly increased by the installation of additional belts. The construction of this machine is well advanced and its operation is expected within a few months. This development was made possible by a grant from the Research Corporation which has also aided effectively in preparing the engineering design.

**54. A 1,500,000 volt portable electrostatic generator of rugged design.** E. H. BRAMHALL AND R. J. VAN DE GRAAFF, *Massachusetts Institute of Technology.*—For many purposes a compact and portable source of high voltage is needed. To provide for such a demand an electrostatic generator has been constructed developing a constant potential of about 1.5 million volts and having a power output of approximately half a kilowatt. Ruggedness, simplicity, and economy have been important considerations in the design. The generator is of the belt type (see preceding abstract), the electrodes consisting of spun aluminum spheres two feet in diameter. Each sphere is supported on an insulating column three feet long and one foot in diameter. Maintenance of warm dry air within the columns insures independence of atmospheric conditions, while a helical india ink leak along the surface of each column insures a uniform potential gradient between sphere and ground. A rigid box-like structure of steel serves as a base, and the entire assembly, having an overall height of seven feet, is mounted on large rubber-tired casters.

**55. The initiation of discharges in high vacua.** J. W. BEAMS, *University of Virginia.*—Surge potentials (of about $10^{-6}$ sec. duration) were applied to point-plane or wire-cylinder electrodes in high vacua, and the conditions of

* Invited paper.

breakdown studied. (For method see Phys. Rev. **41**, 687 (1932)). The smaller electrode was of Pt, W, or steel; the larger of Ni or steel. When the point or wire was negative it was found that the discharge was started by the field electron current from the cold cathode. (See Wood, Phys. Rev. **5**, 1 (1897), Hull and Burger, Phys. Rev. **31**, 1121 (1928), Snoddy, Phys. Rev. **37**, 1678 (1931).) With point or wire positive, however, and plane or cylinder grounded, discharges were observed to occur when the maximum field at the cathode was much lower than usually believed to be necessary in order to produce sufficient field electron current to start the discharge. This discharge potential was raised by heating the anode, by baking out the complete tube or by allowing several discharges to pass. The evidence indicates that these discharges are initiated by positive ions pulled out of the point or wire anode by the electric field.

**56. The effect of high electrostatic fields upon the vaporization of molybdenum.** G. B. ESTABROOK, *University of Pittsburgh. (Introduced by A. G. Worthing.)*—It has been found for wires of varying diameters, (1) that, for field strengths of about $0.52\times10^6$ volts/cm or less at the wire surface, there was no change in the rate of change of resistance with time and hence the rate of vaporization upon application of the field; (2) that, for field strengths above approximately $0.52\times10^6$ volts/cm, as successively higher fields were applied, the rate of vaporization first decreased slowly, then more rapidly, and finally asymptotically toward zero at field strength over $1.8\times10^6$ volts/cm; (3) that, with increasing temperatures, the same field strength applied at the surface of a wire produced progressively smaller decreases in the rate of vaporization; (4) that, when there was an effect upon the rate of vaporization, sudden increases in resistance occurred when the field was applied, and sudden decreases when it was removed. A decrease in vaporization rates was found for platinum, along with a sudden increase in resistance upon applying the field, and a sudden decrease when the field was removed. Worthing has reported similar results for tungsten except that the sudden increases and decreases were opposite to those of platinum and molybdenum.

**57. On the effect of high electrostatic fields on the vaporization of metals.** A. G. WORTHING, *University of Pittsburgh.*—Work with tungsten and molybdenum (see preceding abstract) shows that their vaporization rates may be altered greatly by electrostatic fields. Obviously there may be involved either the recapture by the external field of material vaporized presumably as dipoles, the actual prevention of vaporization, or both. Recapture of material vaporized as atoms on the dipole assumption alone fails because of the huge polarizabilities required. Recapture of material vaporized as large aggregations of atoms fails because the effect actually becomes appreciable only at fields of the order of a million volts per cm, though the prevention of vaporization is almost complete at fields three or four times this value. Production of electrostatically oriented surface layers of dipoles with consequent strengthening of the external field, similar to the strengthening of an external magnetic field by ferromagnetic material, with consequent recapture of vaporized materials fails quantitatively. The foregoing seems to exhaust possibilities of classical explanations of this effect. Further consideration is being given on the basis of quantum mechanics.

**58. Interference of light in transparent films of manganese.** J. B. NATHANSON, *Carnegie Institute of Technology.*—Transparent films of manganese of variable thickness were obtained by sputtering manganese on Pyrex glass plates. The manganese cathode was totally enclosed in mica except for a circular opening 1.5 cm in diameter, facing the glass plate. When the films were examined in monochromatic light, a series of dark circular fringes were observed similar to Newton's rings. Examination showed no deposit of manganese in the small region directly opposite to the center of the opening in the mica. A section of the film taken perpendicular to its face would therefore be similar to that of a vertical section of a volcano. Employing the wavelength of monochromatic light in the metal as a means for thickness measurements, the average thickness of the film was evaluated graphically from the diameters of the interference rings. Measurements were made for light of wavelengths 5461A and 5893A. Two different films were measured, having maximum thicknesses of $7\times10^{-5}$ cm and $8\times10^{-5}$ cm respectively. The masses of the films were computed from the average thickness of the films and the density of manganese. A comparison of the computed masses with those obtained by weighing of the glass plates before and after sputtering, showed differences not exceeding 14%. The phenomenon described also suggests the possibility of evaluating the refractive indices of metals in thin films.

**59. Resistivity of expanded conductors.** P. I. WOLD, *Union College.*—In connection with certain work on the Hall effect it became important to know how the resistivity of a conductor is affected by the presence of a large number of gas bubbles or other insulating material. Measurements were taken on a form of Hg obtained from an ammonium amalgam. The Hg is expanded with numerous bubbles of gas of various sizes and in disorganized array. Lord Rayleigh has considered the case of a rectangular array of uniform insulating spheres in a conducting matrix and gives the approximate formula $\sigma=(1+\frac{1}{2}p)/(1-p)$ or $p_1=(2\sigma-2)/(2\sigma+1)$ where $\sigma=R_2/R_1$; $R_2$ and $R_1$ are the resistances with and without spheres and $p$ is the fractional volume occupied by the spheres. This is found to hold fairly well for $p<0.2$. Many measurements were taken on sand, of approximate sphericity, in $CuSO_4$ solution and for which $p=0.7$ about. For these values the simple formula breaks down. A modified formula bringing in the next term in a series has been derived which gives

$$p_2=p_1[1-0.196p_2^{10/3}],$$

where $p_2$ is the new or corrected value. A double application of this last relation gives (for $p$ as high as 0.75) values correct to 1/2%. For lower values of $p$ the accuracy is higher. Fricke has derived a formula which takes into consideration the nonsphericity of the particles and which, for spheres, reduces to Rayleigh's simple formula. The present

work indicates that, except possibly in extreme departure from sphericity, Fricke's correction is not so important as that given above.

**60. Absorption and reradiation of short electric waves.** C. R. FOUNTAIN, *George Peabody College for Teachers, Nashville, Tennessee.*—Radiations from a short wave transmitter (3.7 meters) are absorbed and reradiated by a resonance rod at various positions in the field. The quantity of energy reradiated is vastly greater than seems possible by classical wave theories, yet beautiful interference curves are obtained by moving the rod. The human body also reradiates such waves, requiring all energy observations to be read through a telescope 75 feet from the transmitter. The magnitude of the effect is shown by a "swinging curve," with receiver stationary at 12.6 meters from the transmitter while the resonance rod is swung around the transmitter in a circle of 12.6 meters radius. Maxima came at the following distances from the receiver: 2.44 meters (182%), 6.20 meters (137%) 10.00 meters (125%). Minima occurred at 4.50 meters (67%), 8.18 meters (83%). "Rod removed" was considered 100%. If the slender rod, 12.6 meters from the transmitter, is to supply 25% more energy to the receiver, 10 meters away, it must gather in and reradiate all the energy radiated from the transmitter through an angle of 72°, a path 4 waves wide. The bunching of energy, as in the photoelectric effect, seems to exist with waves 3.7 meters long.

**61. A search for a new gyromagnetic effect: Magnetization by the rotation of a magnetic field.** S. J. BARNETT, *University of California at Los Angeles and California Institute of Technology.*—In 1925 J. W. Fisher, in London, made experiments in which a magnetic rod at rest was crossed by a weak magnetic field produced and rotated by a two phase electrical system. He expected the magnetic elements to be rotated with the field, and the rod itself to become (gyrostatically) magnetized exactly as if itself were in rotation with the same frequency (Barnett effect). The null effect obtained led him to conclude that no mean rotation of the elements with the field occurred. I showed, however (Phys. Rev., 1925), that on the most favorable hypotheses Fisher's expectation should be greatly reduced by multiplication with a factor approximately 1.5 times the cross magnetization ÷ the saturation magnetization. Fisher's errors were of the same order as this reduced result. A new investigation of this subject, going much further than Fisher's, has now been made, with rods of iron and permalloy dust in impressed fields with intensity 15 gauss rotating at about 15,000 revolutions per second. The mean magnetometer deflection on double reversal of the rotation was about 0.2 mm (in the wrong direction), mean error about 1 mm; while the deflections predicted from the modified formula were about 4 cm and 1.5 cm for permalloy and iron, respectively. Fisher's formula, or the Barnett effect, would give about 10 meters and 7 meters, respectively. It is thus clear that either (1) no appreciable rotation of the elements occurs in weak fields, or (2) if such rotation occurs the molecular torques opposing axial alignment are much greater (as would be expected) when the field rotates than when the rod rotates.

**62. The gyromagnetic ratios for nickel and cobalt.** S. J. BARNETT, *University of California at Los Angeles and California Institute of Technology.*—In an elaborate investigation of the rotation of both iron and permalloy by magnetization (Proc. Amer. Acad. 66, No. 8) the gyromagnetic ratios for the two substances were found to be, respectively, $1.04\times m/e$ and $1.05\times m/e$, with errors probably less than one-half percent. Successful observations have now been made on the less tractable substances nickel and cobalt, but the results are somewhat less precise. The ratios obtained for those substances are about $1.06\times m/e$ and $1.07\times m/e$. The experimental method had to be modified to reduce the effects of certain sources of error, including magnetostriction, before any success was obtained with cobalt. Inasmuch as serious errors, not suspected by other investigators, have been eliminated in all of this work the results obtained are far more reliable than those obtained by others, who have always obtained $1\times m/e$ within the limits of their supposed experimental errors (except Einstein and de Haas, who, in 1915, thought they had found $2\times m/e$). The ratios obtained in this investigation agree, within the experimental error, with those published by L. J. H. Barnett and myself in 1925 (Proc. Amer. Acad. 60, No. 2) as the result of an elaborate investigation of the magnetization of many ferromagnetic substances by rotation. The mean then obtained was $1.06\times m/e$, with an error estimated as some two percent.

**63. Probabilities of *K*-electron ionization of silver by cathode rays.** D. L. WEBSTER, W. W. HANSEN, AND F. B. DUVENECK, *Stanford University.*—These probabilities are measured by $K$ line intensities from thin films. Preliminary data with Ag on a Be block (Phys. Rev. **42**, 141L (1932)) are confirmed, and a first approximation for the correction for fluorescence under Be continuous rays is replaced by more exact calculations. Since these increase the correction considerably, we have also taken data on Ag without Be, giving approximately the same results. Defining $U$ as $V/V_K$ and taking intensities at $U=2$ as unity, results to date indicate intensity 0.745 at $U=1.5$, 1.13 at 3, 1.12 at 5, 1.06 at 7. Available wave-mechanical theories depend on Born's approximation, invalid unless $U$ is large. Classical quantum theory appears best expressed by multiplying Thomas's formula by a factor for convergence of possible cathode-ray paths approaching a nucleus, giving

$$\text{Probability}=\frac{\text{constant}}{U}\left\{1-\frac{1}{U}+\frac{2K}{3}\left(1-\frac{1}{U^2}\right)\right\},$$

where $eV_KK=$orbital kinetic energy. This departs so far from experiment as to prove strictly classical postulates unsatisfactory even as temporary approximations. Heuristic theories can be formulated by modifying the law of repulsion (l.c.), but the trouble probably lies in the fundamental defect of any classical theory, in contradicting the indeterminacy principle.

**64. Relative intensity of the silver *K*-lines from a thick target as a function of voltage and emergence angle.** D. L. WEBSTER, W. W. HANSEN, AND F. B. DUVENECK, *Stanford University.*—The *K*-line intensity from a thick silver target has been measured in arbitrary units for voltages up to 180 kv with emergence angles from 1° to 25°. A practical use of these data is the determination of the voltage which will give the maximum line x-ray efficiency at any emergence angle. At 1°, the best voltage is 70 kv, but at 25° it is well above 180 kv. These data may also be used in conjunction with results on thin targets (preceding abstract) to get information as to the retardation of cathode rays in silver. For this purpose the data are corrected to eliminate the effects of target absorption (by Kulenkampff's method) and of rediffusion (Phys. Rev. **37**, 115 (1931)). We find that the cathode-ray retardation law can be represented by the formula $dT/ds = -\text{const.}/T^{0.5}$ where $T$ is the kinetic energy of the electron, and $s$ is distance along the cathode-ray path. The above result agrees within our rather large limits of error with more direct tests (as summarized by Williams). Reversing the logic it seems likely that thick target emission phenomena can be completely explained by the laws of thin target emission, cathode-ray retardation and rediffusion, and x-ray absorption.

**65. Comparison of the angular distributions of the cosmic radiation at elevations 6280 ft. and 620 ft.** THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—The ray intensity $j(\theta)$ of the cosmic radiation has been studied as a function of the angle $\theta$ from the vertical on Mt. Washington, N. H., elevation 6280 ft., and at a base station, elevation 620 ft. The results show a distribution less concentrated about the vertical at the higher elevation. Unless some *ad hoc* assumption is invoked this result is inconsistent with the intensities and absorption coefficients deduced by Millikan and Cameron as their results would lead to a considerably more concentrated distribution at the upper elevation. Integrating the ray intensities over all angles, the total numbers of rays per $cm^2$ per sec. have been computed at the two elevations. The increase in the number of rays with elevation is less than the known increase in the ionization (Millikan and Cameron). The ratio of numbers of rays per sec. is 1.46 against 1.87 for the ratio of ionizations at the two elevations. The average 6280 ft. ray, therefore, produces 1.28 as many ions per unit path as the 620 ft. ray. This change in ionizing efficiency may perhaps be explained by supposing that the rays of the softer components which predominate at the upper level occur more frequently in associated groups.

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