Proceedings of the American Physical Society

MINUTES OF THE ATLANTIC CITY MEETING, DECEMBER 28–30, 1936

THE 38th annual meeting (the 211th regular meeting) of the American Physical Society was held at Atlantic City, New Jersey, on Monday, Tuesday and Wednesday, December 28, 29 and 30, 1936, in affiliation with Section B-Physics of the American Association for the Advancement of Science. The presiding officers were Professor F. K. Richtmyer, President of the Society, Professor H. M. Randall, Vice President, Dr. Lyman J. Briggs, Professor H. A. Erikson, Dr. Lauriston S. Taylor, and Professor D. L. Webster. There were about four hundred physicists in attendance at the meeting. All sessions were held at the Hotel Chalfonte.

The joint session with Section B of the A. A. A. S. and the American Association of Physics Teachers was held on Tuesday morning at ten o'clock. The presiding officer was Professor D. L. Webster in the place of Dean George B. Pegram, vice president of Section B. The retiring vice president of Section B, Professor John T. Tate, presented a paper on "Electron Impacts in Gases." Professor F. K. Richtmyer, president of the American Physical Society, delivered an address on "Multiple Ionization of Atoms."

On Monday morning and afternoon there was a symposium of fifteen invited papers on "Some Problems in Radiological Physics." The program was arranged by Dr. Lauriston S. Taylor of the National Bureau of Standards.

On Tuesday evening the Physical Society and the American Association of Physics Teachers held a dinner at the Hotel Chalfonte. Professor F. K. Richtmyer, president of the Physical Society, presided. A brief speech was made by Professor H. M. Randall. Dr. A. G. McCall of the U. S. Department of Agriculture spoke on the subject of soil conservation and erosion. The award of the prize for excellence in teaching was given posthumously to Professor William S. Franklin by the American Association of Physics Teachers. This award consisted of two bronze plaques to be placed in the laboratories of the Massachusetts Institute of Technology and Lehigh University. A certificate was also presented to Professor Franklin's son. There were two hundred guests at the dinner.

Annual Business Meeting. The regular annual business meeting of the American Physical Society was held on Tuesday morning, December 29, 1936 at nine-thirty o'clock, President Richtmyer presiding. The president had appointed Messrs. Richard M. Bozorth and William H. Crew to canvass the ballots for the officers of the Society. They reported the following elections:

President, H. M. RANDALL
Vice President, LYMAN J. BRIGGS
Secretary, W. L. SEVERINGHAUS
Treasurer, GEORGE B. PEGRAM
Member of the Council, one year term, H. A. ERIKSON
Members of the Council, four year term, M. J. KELLY, J. C. SLATER
Members of the Board of Editors, three year term, KENNETH T. BAINBRIDGE, H. P. ROBERTSON, H. B. WAHLIN

Approval was voted of the following modification of the by-laws as recommended by the council:

Change Article V, Section 4, to read as follows:
"No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting."

The Secretary reported that during the year there have been 238 elections to membership. The deaths of 12 members have been recorded; 30 have resigned; 91 have been dropped; and 60 have been placed on the inactive list. The membership of the Society as of December 24, 1936 was as follows: 2160 members; 725 fellows; 6 honorary members; 2891 total membership. The membership at the present time shows a gain of 45 members, a rather small increase since last year but this is accounted for by the fact that a great many members who were carried on the rolls of the Society during the depression have either been dropped or placed on the inactive list.

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 the fiscal year ends on December 31. The Treasurer's financial report will be audited, printed and distributed to members.

The Managing Editor made an informal report.

Meeting of the Council. At the meeting of the Council held on Monday afternoon, December 28, 1936 two members were transferred from membership to fellowship and sixty-four were elected to membership. *Transferred from membership to fellowship:* N. Henry Black and Erich Hausmann. *Elected to membership:* Herbert L. Anderson, Kanetako Ariyama, Charles H. Bachman, Robert M. Besancon, Harold G. Beyer, Nautamlal B. Bhatt, C. B. Braestrup, Robert B. Burnham, C. W. Chapman, Peh-ping Cheo, Djen-yuen Chu, R. F. Clash, Jr., Arnold A. Cohen, William J. Culmer, C. W. Curtis, Lee Devol, Emmanuel Dubois, Charles K. Eckels, Charles H. Ehrhardt, Walter M. Elsasser, Einosuke Fukushima, Erwin R. Gaerttner, John E. Gorham, Horace J. Grover, Homer D. Hagstrum, Sally Harrison, Harry H. Hubbell, Jr., Richard W. Jones, David M. Kerns, Gilbert D. Kinzer, Solomon J. Klapman, Reginald G. Lacount, Andrew W. Lawson, Jr., Lawson M. McKenzie, Albert V. Masket, Bertrand J. Miller, Alexander M. Monnier, Joseph Morgan, Otto Morningstar, Philip Nolan, Thomas J. W. O'Neil, Chester H. Page, Hermon M. Parker, Wallace W. Perkins, John R. Pierce, W. G. Pollard, Philip N. Powers, Maurice H. L. Pryce, David L. Rich, A. Rostagni, Walter E. Sargeant, Klaus Schocken, Ross E. Shrader, R. K. Sharma, Keizo Sinma, Lynn H. Stauffer, Robert B. Taft, A. H. Taub, John Victoreen, E. R. Walker, Arthur C. Weid, Royal Weller, Victor J. Young, and Arthur A. Zuehlke.

The regular scientific program of the Society consisted of sixty-eight papers, of which numbers 2 and 16 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. Some Problems in Radiological Physics. LAURISTON S. TAYLOR, *National Bureau of Standards.*—This paper does not present any new experimental results but is intended to serve as an introduction to the succeeding papers on radiological physics. It appears that radiation dosage measurements are satisfactory up to 200 kv, although for higher voltages and gamma-rays there is not yet complete unanimity of opinion regarding what methods are best. Thimble ionization chambers are used in these voltage ranges but there is no adequate standard for calibrating them. With the possibility that neutrons may have biological application, further problems of dosage measurement are in the offing. The means for protection from super-voltage x-rays, gamma-rays, and neutrons are very uncertainly effective—some workers practically neglecting it entirely while others overdo it. Measurements of voltages above 300 kv are not entirely satisfactory, and in most medical installations no simple and adequate means is available at present. The measurement of radiation quality in the supervoltage range is still uncertain and of the several methods proposed none is as yet in general use. For neutrons the question of energy distribution or quality of radiation is essentially untouched.

2. The Measurement of Very Hard X-Rays in Roentgens. G. C. LAURENCE, *National Research Council of Canada.*—The standard x-ray ionization chamber is impracticable for very hard radiation and it is customary to use thimble chambers with thick walls composed of the light elements. In interpreting these measurements in roentgens, it has been assumed usually that the intensity of the ionization in the air space is equal to the value it would have in the center of a very large volume of air. This is approximately true, but it is shown that the intensity in the thimble chamber is greater by a factor B that differs generally from unity by a few percent. An expression for B is derived and curves are given to assist in calculating it for any quality of very hard radiation with different compositions of wall material. Using radium B+C radiation filtered through 0.5 mm platinum, B has the value 0.977 for a carbon chamber, and 1.082 for aluminum. B for carbon varies between 0.96 and 0.975 for x-rays excited at potentials between 400 kv and 1000 kv and filtered through 1 mm lead. Absorption corrections and other details that must be considered in thimble chamber measurements are discussed.

3. The Measurement of Backward Scattered X-Radiation. EDITH H. QUIMBY, *Memorial Hospital, New York, N. Y.*—In radiation therapy an important factor in determining the amount which can be delivered through a given field is the tolerance of the skin. The radiation which produces the skin reaction is a combination of the direct beam and that scattered backward by the underlying tissues; it varies among other things with the quality of the radiation and with the size of the field. The back scatter cannot be satisfactorily measured with small closed ionization chambers of the thimble type, because of potential errors introduced by the wall thickness, air volume, etc. The extrapolation type of chamber described by Failla is well adapted to making such measurements, since the wall effect can be eliminated; the volume can be varied between wide limits and the ionization for a vanishingly small

volume found by extrapolation. Data are presented for back scatter measurements with both types of chamber, from a volume of organic material comparable with the human body, for a wide range of qualities and of field sizes.

4. Dosage Determinations on Ten Different 400 kv Roentgen Ray Generators. OTTO GLASSER, *Cleveland Clinic, Cleveland, Ohio.*—Ten high voltage generators both of the pulsating and constant potential type were examined. The radiation quantity was measured for given conditions in roentgens by means of an "air wall" thimble chamber. Absorption curves in copper and tin were made. The values obtained were compared with those measured on 200 kv roentgen ray generators under otherwise identical conditions.

5. A Study of the Secondary Radiations Emitted by Filters Used in Roentgen Therapy. L. D. MARINELLI, *Biophysics Laboratory, Memorial Hospital, New York, N. Y.*—The secondary emission from aluminum, copper, tin and lead has been studied by shifting the relative position of the primary and additional filters with respect to an open ionization chamber of the mesh type. The softer part of the emission from Al, Cu and Su has been found to be satisfactorily eliminated by 0.16 mm celluloid in the case of Al primary filter; 0.18 mm Al plus 0.16 mm celluloid, or 0.40 mm celluloid in the case of Cu; and 0.17 mm Cu plus 0.4 mm celluloid in the case of Su. No conclusive figure could be reached in the case of lead with 200 kv x-rays. The harder portion of the emission cannot be controlled efficiently by the insertion of secondary filters, and data are presented for the calculation of the skin to filter distance in order to reduce the residual scatter to 1 percent of the available beam, when primary filters of Cu and Su are used. Experimental evidence points out that a Cu filter removed from the skin by more than 10 cm does not contribute any appreciable amount of soft radiation to the skin dose.

6. The Production of Very Thin Beryllium Flakes for a Po-Be Neutron Source. T. R. FOLSOM, *Physics Department, Memorial Hospital, New York, N. Y.*—A technique for producing extremely thin flakes of metallic beryllium by a vacuum-evaporation process is described. The use of these flakes to produce an intense Po-Be neutron source concentrated in a very small volume is discussed.

7. Physical Measurements Concerning the Biological Action of Neutrons. PAUL C. AEBERSOLD, *Radiation Laboratory, University of California.*—The large yield of neutrons produced by the bombardment of beryllium with the high voltage deuterons obtainable with a cyclotron allowed investigation of the biological actions of neutrons. With 20 microamperes of 5.8 Mev deuterons, the intensity of ionization in an x-ray r-meter thimble chamber at 15 cm from the beryllium target is the same as that due to 10 r/min. of x-rays. This neutron intensity was found to be biologically equivalent to 20 to 50 r/min. of x-rays, depending on the organism irradiated. To produce biologically equivalent intensities of gamma-rays would require 50 to 125 grams of radium. However, to obtain this yield of neutrons would require more than 10,000 grams of radium mixed with beryllium. The biological effectiveness per unit of ionization measured with a small Bakelite-walled thimble chamber was found for neutrons to be two to five times as great (depending on the organism) as for x-rays. Although the ionization due to neutrons varies with the hydrogen content of the chamber wall and its enclosed gas, the variation observed is not sufficient to indicate that neutrons cause two to five times as much ionization in tissue as x-rays when these radiations cause equal ionization in a Bakelite-walled chamber. Thus using other "tissue-like" chamber walls, there still appears to be a differential, as well as an increased biological effectiveness for neutrons; consequently until further knowledge is gained concerning "tissue" ionization, a small Bakelite-walled thimble chamber calibrated with x rays may serve as a standard ionization measure for neutrons.

8. The Mechanism of Delayed Killing of Maize Seedlings with X-Radiation. LOUIS R. MAXWELL, *Bureau of Chemistry and Soils.**—Dry seeds of maize after receiving heavy x-ray dosages (60,000 to 100,000 r units) show no reduction in germination; however, soon after the plumule has emerged growth ceases and the plant dies. This phenomenon has been called "delayed killing." An S-shaped survival ratio curve has now been obtained which shows that 50 percent delayed killing will occur at 35,000 r units. This result can be interpreted from the standpoint of the hit theory involving the conception of a certain number of required hits within a vital volume of the seed. On this basis the experimental results can be expressed in either of two ways: (1) that a single vital volume of 6×10^{-16} cm^3 must be hit 14 times by primary electrons to cause delayed killing or (2) that there may exist several vital volumes each of which must be hit a number of times in order to produce delayed killing. Since the seed embryo is multicellular the latter explanation is more tenable. When various restricted zones 0.5 to 2.8 mm wide taken across the seed are exposed it is found that no appreciable killing occurs until a slit width greater than 0.5 mm is used. This definitely proves that no single vital volume of the above small dimensions exists.

* In cooperation with the Bureau of Plant Industry.

9. Columnar Ion Concentration and the Biological Effectiveness of X-Rays, Neutrons and Alpha-Particles. RAYMOND E. ZIRKLE, *Johnson Foundation for Medical Physics, University of Pennsylvania.*—Biological effectiveness per ion depends to a marked extent upon the concentration of ions produced in the track of the ionizing particle. Four different columnar concentrations have been investigated: (*a*) that produced by electrons set in motion by x-rays; (*b*) that produced by recoil nuclei set in motion by neutrons; (*c*) that produced by the polonium alpha-particle at the beginning of the column; (*d*) the same at the end of the column. These concentrations are listed in increasing order. All four have been used on one type of biological object; (*a*) and (*b*) upon two others. In all cases, the higher the concentration of ions in the column, the greater is the biological effectiveness per ion. The magni-

tude of this effect varies markedly among the three different organisms. (The neutron experiments were carried out in the Radiation Laboratory, University of California, with the collaboration of P. C. Aebersold and E. R. Dempster.)

10. Neutron-Yield Curves for Light Elements. L. R. HAFSTAD AND M. A. TUVE, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—During a visit by E. Amaldi, measurements on neutron-yield curves for several light elements bombarded with deuterons were carried out in our laboratory. Observations were made from 200 to 1000 kv by using the Rome technique for determining the absolute number of neutrons produced. These observations show the values of current and voltage required for producing neutrons in large quantities in this voltage range, and determine the amounts of artificial radioactive substances which can be produced.

11. The Absorption of Ultra-Short X-Rays. F. K. RICHTMYER, *Cornell University.*—Accurate data giving absorption coefficients of monochromatic ultra-short x-rays (i.e. $\lambda < 100$ X.U.) are desirable: (1) to check and extend current theories of the interaction between high frequency radiation and matter; (2) to place in the hands of the roentgenologist and the industrial technician pertinent information with regard to the uses of high voltage x-rays in radiology and in industry. Recent developments in the technique of producing high voltage x-rays and in the design of spectrometers for work in this x-ray region have made it possible to obtain acceptably correct values of monochromatic absorption coefficients for x-rays of wavelength as short as $\lambda = 30$ X.U. These data have been reported by Cuykendall[1] and Jones.[2] From these and similar data by other authors, "half-value" thicknesses for representative materials are computed. Also, the filtering action of representative materials on high voltage x-rays is presented.

[1] Cuykendall, Phys. Rev. **50**, 105 (1936).
[2] Jones, Phys. Rev. **50**, 110 (1936).

12. The Chemical Activity of X-Ray Activated Water Molecules. HUGO FRICKE AND HOMER P. SMITH, *Walter B. James Laboratory for Biophysics, The Biological Laboratory, Cold Spring Harbor, N. Y.*—An important fact in the biological effects produced by x-rays (as compared, for example, with those of light) is that the initial chemical reactions result from the activation of all molecular species present in the irradiated medium. In view of the large content of water in living cells, the reactions resulting from the activation of the water molecule are of particular importance. The present report is a summary of our studies in this field, including investigations of solutions of a number of organic, and certain biologically important inorganic, molecules. Particular attention is given to the influence of certain general factors, particularly the oxygen molecule and the hydrogen ion.

13. The Effect of Irradiation on Oil Drops. WILHELM STENSTROM AND IRWIN VIGNESS, *University of Minnesota Hospital, Minneapolis, Minn.*

14. The Measurement of Scattered Radiation in Roentgenography of the Chest. R. B. WILSEY, *Kodak Research Laboratories, Rochester, N. Y.*—Scattered radiation was recorded photographically in the shadows of lead shot placed on the tube side of the patient. The evaluation of the ratio of scattered radiation to the total of scattered and primary radiation just outside the shot shadow was determined with the aid of time-scale sensitometric exposures placed at the corners of the film. The correction for the difference in time-scale and intensity-scale sensitometric exposures was found by a separate experiment. In a series of adult chests of medium size, the proportion of scattered radiation recorded in the roentgenogram averaged 55 percent, while values as high as 65 percent occurred in some portions of the chest. In larger patients, the proportion of scattered radiation averaged as high as 65 percent over the lung fields with some areas recording values over 80 percent. These data indicate the necessity of applying the Potter-Bucky diaphragm to the roentgenography of the larger sizes of chest.

15. Secondary Radiation Intensity as a Function of Certain Geometrical Variables. HERMAN E. SEEMANN, *Kodak Research Laboratories, Rochester, N. Y.*—X-ray intensity measurements of a beam passing through filters or diaphragms may be affected by the secondary radiation produced. Definite means for estimating the secondary radiation intensity must therefore be used if this quantity is to introduce no error in the final results. Making certain assumptions, it is possible to treat the problem geometrically and, with source and receiver fixed, obtain simple relations between the secondary intensity and the distance between scatterer and receiver. Several cases are considered: (1) the position of a filter of fixed size is varied, (2) the filter size is varied so as to always fill a fixed cone of radiation, (3) the edge of the diaphragm furnishes secondary radiation due to partial transmission of the primary beam, or (4) due to the incidence of the primary beam directly upon the faces of the hole. The results apply to other forms of radiation, since the treatment is geometrical. There is satisfactory experimental verification of the formulas developed for cases (1) and (2), but (3) and (4) will require great constancy of radiation intensity and sensitivity of measuring apparatus.

16. Thermal Diffusivity of Nickel. CHAUNCEY STARR, *Harvard University.**—The dynamic method of determining thermal diffusivities devised by King has been improved. A sinusoidal temperature is impressed on one end of a wire specimen, and the thermal diffusivity is determined from the characteristics of the temperature wave traveling along the specimen. In King's method the velocity of the wave is measured. In the present method the amplitude decrement is determined. The unknown surface heat loss from the specimen can be eliminated from the calculations by measurement with heat waves of two different periods. Greater precision is possible with this method than with previous methods. The thermal diffusivity of nickel, measured at 25°C, was 0.15885 cm²/sec., with a probable error of 0.06 percent. The specimen had been annealed in

hydrogen at 870°C, and had a total nickel content greater than 99.98 percent, a density of 8.79 g/cm³, and an electrical resistivity of 7.21 microhm-cm at 22°C. The thermal conductivity of nickel corresponding to this determination is 0.618 watt/cm °C.

* To be read by title.

17. Biophysical Methods in Studies of Mammalian Temperature Regulation. ALLAN HEMINGWAY, *Yale University and the University of Minnesota.*—Electrical conductivity measurements of the tissues of warm blooded animals have been made using alternating currents of frequencies ranging from 1000 to 1,000,000 cycles per second. At the higher frequencies the phase angle of the tissues becomes zero. This makes possible the measurement of the heat received by an animal which is heated by a high frequency current, the power consumption of the animal being simply the product of high frequency voltage and current, these values being obtained from suitable high frequency instruments. By placing metallic electrodes in contact with the skin of an animal and placing these electrodes in a high frequency circuit the current passing through the animal generates heat which can be accurately measured. This provides the physiologist with a tool for giving to animals a known amount of heat produced by physical means and with a minimum amount of discomfort to the animal. Such a method is especially useful in studies of heat tolerance. Dogs have been heated by a diathermy current (one million cycles per second) which does not produce electrical stimulation of the neuromuscular system. The heat received by the animal has been measured together with changes in the physiological mechanisms for heat dissipation which include (1) increased skin and rectal temperatures and (2) changes in respiratory activities.

18. Characteristics of Shock-Wave Propagation Near an Explosive Source. L. THOMPSON AND N. RIFFOLT, *Naval Proving Ground, Dahlgren, Va.*—Continuing an experimental study[1] of the condensation pulse generated by a detonating high explosive, the following results have been obtained. (*a*) Cathode oscillograms of the pressure pulse taken at similar points of the field for charges of different magnitudes show the conditions actually to be similar, at least with respect to maximum pressure. A shape factor is identified by the slightly greater values of reduced times obtained for spherical sources, comparing data for cylindrical charges. (*b*) The shock-wave is shown to be definitely diverging from the gas bubble at x values less than 15 (half-diameters). (*c*) The formulas therefore represent a "free" sound field (as distinguished, for example, from the permanent regime at the nose of a high-speed bullet in flight) with velocities extending to several times the normal velocity. The characteristics are those which would develop in fact if there were free propagation in accordance with the formulas all the way from the boundary of the charge, at which point the pulse velocity is sometimes as much as 5000 meters per second.

[1] *The Propagation of a Shock-Wave in Air*, L. Thompson and N. Riffolt, abstracts 64, 65, Phys. Rev. **49**, 421 (1936).

19. High-Speed Multi-Jet Oil Diffusion Pumps of Metal Construction. C. M. VAN ATTA AND L. C. VAN ATTA, *Massachusetts Institute of Technology.*—Several models of a new design of all-metal, multi-jet oil diffusion pump have been constructed, tested and used at this laboratory during the past two years. Some of the distinctive features of the design are a compact boiler and jet system, direct heating of jets by conduction through metal parts of low thermal resistance, cooling of all surfaces exposed to the high vacuum space, low power requirements and small over-all dimensions for resulting pumping speeds, and ease of dismantling and servicing without disconnecting high-vacuum or fore-vacuum lines. The performance characteristics of this design may be judged from the following data taken on three pumps all with jet clearances of approximately 4.5 mm. As the gas leak into the system

Diam. of Pump Jacket (in.)	Power Required (watts)	Pumping Speed for Air (liters/second)
$3\frac{1}{2}$	240	40
$4\frac{1}{4}$	260	75
7	480	200

is increased, the pumping speed remains constant up to a fore-pressure of about 1.5×10^{-2} mm Hg and is still appreciable at a fore-pressure of 3×10^{-2} mm Hg, so that mechanical pumps are adequate for backing purposes. Curves showing pumping speed as a function of fore-pressure and of oil temperature will be shown, the influence of jet clearances discussed and the methods used for measuring pumping speeds described.

20. A Cold Cathode Rectifier. CHARLES. T. KNIPP, *University of Illinois.*—The cold cathode rectifier exhibited at the Science Exhibit sponsored by the A.A.A.S. at St. Louis last holidays has been very much improved as an efficient device for the rectification of comparatively high alternating voltages. The rectifier as first made, with comparatively small electrode surfaces (about 10 sq. cm area each), transmits 30 ma on half wave rectification, and about 50 ma on full wave rectification. This is for 25,000 alternating volts. Rectifiers having electrodes of larger area and spaced differently are in the process of construction. Photographs of wave-forms for both half and full wave rectification will be shown. The rectifier will be in operation during the period of the science exhibit, booth 90.

21. The Mechanism of Electron Emission from Coated Cathodes. EMERY MESCHTER, *Cornell University.*—Emission from oxide-coated and other complex cathodes is explained qualitatively in terms of certain fundamental quantum-mechanical ideas to which Gurney has called attention. Perturbation of the highest levels in the atoms forming the coating results in the broadening of these levels into bands. The degree to which these bands are filled determines the strength and sign of the double layer formed at the surface, and hence the work function of the surface. Double layers formed by metallic atoms of low ionization potential may be changed in strength or reversed in sign by the admixture of nonmetallic atoms which possess a high virtual level. The most common of such atoms is oxygen, but among other possibilities might be listed sulfur, fluorine, chlorine and iodine. The char-

acter of the resulting double layer depends on the arrangement of the atoms of the one or more elements composing the coating. Experimental work has indicated the upper limit of the ionization potential of the metallic atom.

22. The Charge on the Electron. J. A. BEARDEN, *Johns Hopkins University.*—The satisfactory agreement of the ruled grating measurements of x-ray wave-lengths by different observers[1] and the failure to find an explanation of the discrepancy in the value of e thus obtained with the Millikan oil-drop value have made a repetition of Millikan's experiment necessary. The first part of the experiment has been a precision determination of the viscosity of air by the rotating cylinder method. This has been done as a check on former results (Millikan, Kellstrom and Bond). In the final measurements it is intended that a pure inert gas will be used. The design of the apparatus, the machining of the cylinders and guard rings, and the alignment of the apparatus are such as to insure a final value of the viscosity with an accuracy of about one part in 10^4. The speed of the driving mechanism is constant within 5 parts in 10^6. The value of the viscosity of air obtained, together with Millikan's oil-drop data, gives e in agreement with the x-ray value.

[1] Phys. Rev. **48**, 385 (1935).

23. Contact Potential Difference Between Different Faces of Silver Single Crystals. H. E. FARNSWORTH, *Brown University.*—Two crystals were cut and etched so as to expose (100) facets on a plane surface of one, and (111) facets on a plane surface of the other. Measurements by the Kelvin null method of the potential difference between these faces are being made in a high vacuum as a function of heat treatment. Outgassing has been continued at various temperatures below visible red heat for a period of 160 hours. After this time the (111) face is positive with respect to the (100) face by about 0.4 volt. While this is a preliminary value only, the results indicate that the true value is probably greater than this.

24. The Shenstone Effect in Bismuth. ALFRED H. WEBER, *St. Joseph's College, Philadelphia,* AND CHARLES B. BAZZONI, *University of Pennsylvania.*—Shenstone's original experiments[1,2] on the variation of the photoelectric sensitivity of Bi as a function of electric currents passed directly through the metal were repeated and extended. In the present preliminary investigation (1) the effect reported by Shenstone was verified; (2) the change of the effect with successive runs on the same Bi specimen was studied (Shenstone used fresh Bi samples for each of his curves); (3) the effect of occluded gases, presumably, on the photoelectric sensitivity was investigated; and (4) curves of the decay of the effect were obtained. Two cast Bi plates and a Bi single crystal were employed as specimens. The obvious conclusion to be drawn from the present experiments is that the variations in the photoelectric sensitivity of Bi when electric currents are passed directly through this metal are due to changes in the quantity of gas occluded by the metal.

[1] A. G. Shenstone, Phil. Mag. **41**, 916 (1921).
[2] A. G. Shenstone, Phil. Mag. **45**, 918 (1923).

25. Note on Quantum Absorption Probability in the Case of the Photoelectric Effect. A. T. WATERMAN, *Yale University.*—If, in the derivation of the expression for the photoelectric current by the Dubridge method, the probability of absorption of a quantum of radiation by an electron is assumed to be proportional to u^β, i.e., to some unknown power of the velocity component normal to the emitting surface, then the photoelectric current for frequencies near the threshold retains the same form of dependence upon frequency and temperature, in the first approximation, independent of β. The coefficient of the expression for the current (or the constant term in the expression for $\log I/T^2$), however, contains the factor $(m/2\zeta)^\gamma$, m being the electronic mass and ζ the thermodynamic potential, while $\gamma=\frac{1}{2}$, 0, $-\frac{1}{2}$, for $\beta=0$, 1, 2, respectively. Using experimental values for absolute magnitudes of the photoelectric current, it appears that the value of β should be in the neighborhood of 2, i.e., that the probability of absorption of a quantum is proportional to the square of the electron's normal velocity component, in approximate agreement with the prediction of quantum mechanics.

26. Critique of the Quantum Theory of Metallic Conduction. ERNST WEBER, *Polytechnic Institute of Brooklyn.*—Although quantum theory has shown many successes in its applications to metal physics, still there are some fundamental inconsistencies, as for example the concept of the "free path" of the quantized and spinning electron, its treatment by periodic functions without boundary conditions applicable to the metal, nevertheless the assumed potential barrier at the surface; the "gas" character of the electrons and the tremendous internal pressure, yet no admitted compressibility; and the fact that there is no room for superconductivity. The inference is drawn that other than ideal "gas concepts" should be applied to the electron swarm and a theory of electric conduction is proposed which, while essentially a continuum theory, leaves room for quantum theoretical treatment of the new parameters for microscopic phenomena. Conductivity variations with thickness of films, resistance variations in the magnetic field, and the galvanomagnetic phenomena can be described in simple terms.

27. Application of a New Mathematical Method to Vibration-Rotation Interaction. JENNY E. ROSENTHAL AND LLOYD MOTZ, *Columbia University.*—Standard methods of treating the vibration-rotation interaction, such as perturbation or W.K.B. calculations, require the expansion into infinite series of the rotational term in Schrödinger's equation. This procedure is highly questionable because it involves integrations over a region where this infinite series diverges. A method of solution is proposed here which does not require such expansions. Its applicability is contingent upon the presence in the differential equation of a small parameter multiplying the second order derivative. For example, if z is the radial component of the eigenfunction, the equation for the rotating harmonic oscillator is:

$$\frac{d^2z}{d\xi^2}-\frac{\xi}{\alpha}\frac{dz}{d\xi}+\left[\frac{\lambda}{\alpha}-\frac{j(j+1)}{(1+\xi)^2}\right]z=0,$$

where $\xi=r/r_e-1$, $\alpha=B_e/\omega_e\ll 1$, $\lambda=E/\omega_e-\frac{1}{2}$. The substitution: $z=y\exp\left[-\alpha j(j+1)\int\sum_{k=0}^{\infty}\alpha^k\varphi_k d\xi\right]$, with y the eigenfunction for no rotation, leads to a solution if we equate to zero the coefficients of successive powers of α. The eigenvalues are obtained from the behavior of the solution not at the limits but at the intermediate point $\xi=0$, which is a singular point of the equation. This method has been used for the determination of energy levels of both the harmonic and the anharmonic oscillator. It is particularly suited to the calculation of higher order corrections which may be obtained with a comparatively small amount of labor. The results check Dunham's standard W.K.B. calculation to the fifth order. An explanation is given for this somewhat unexpected confirmation.

28. The Calculation of Intermolecular Forces and Energies. MAURICE L. HUGGINS, *Kodak Research Laboratories.*—The resultant force between two molecules may be considered as the sum of forces of the following types: (1) interpenetration repulsions; (2) attractions of the London "dispersion" type; (3) forces between dipoles; and (4) valence or exchange forces. In many instances the last can be neglected. Methods for evaluating the other three are discussed in the paper and applied to specific examples.

29. On the Interaction of Heavy and Light Particles at Very High Energies. L. W. NORDHEIM AND G. NORDHEIM, *Purdue University.*—An attempt has been made to estimate the probabilities of the emission of electrons and neutrinos by very energetic protons passing through matter, due to the Fermi interaction, as suggested by Heisenberg.[1] An interaction "Ansatz" which gives both the correct magnitude and the correct range for the nuclear forces has been used.[2] It involves therefore a cutting off at high energies of the interaction of the light particles in a system of reference where the heavy particle is at rest. For the case when the proton does not actually penetrate the nucleus the probability of the effect mentioned can be worked out by a generalized Weizsäcker method involving a more careful estimate of the integration limits and of the action of the Coulomb field of the nucleus on the protons. The effect proves to be small. The total energy loss of protons of about 10^{11} ev is in Pb of the order of the ordinary collision losses and in air a few percent of it. The photon and neutrino absorption coefficients due to induced nuclear β-transformations were also worked out and found to be very small. The magnitude of these effects depends essentially only on the integral strength of the nuclear forces and not much on the particular interaction Ansatz.

[1] W. Heisenberg, Zeits. f. Physik **101**, 533 (1936).
[2] Suggested by J. R. Oppenheimer at the Harvard Tercentenary Physics Symposium.

30. A Test of the Cellular Method of Obtaining Lattice Functions. W. SHOCKLEY, *Massachusetts Institute of Technology.*—In the absence of a rigorous theory for solving the wave equation in the cellular potential field introduced by Wigner and Seitz, approximate methods have been developed by Slater, Wigner and Seitz, and others. These utilize the solutions obtained in spherical coordinates in the cell to construct lattice functions, which are required to be continuous in value and derivative only at certain points of the intercellular boundary, for example the midpoints of the faces for body and face-centered lattices. The purpose of this paper is to test certain of these methods for the case where the exact solutions are known, namely the case of the "empty lattice" for which the potential is everywhere constant and the lattice points are geometrical figments, the exact solutions then being plane waves. For body and face-centered lattices it is found that within the first Brillouin zone the agreement is excellent. In the next zone the energy may be in error by a factor of $\frac{1}{2}$. Slides comparing the approximate and exact solutions will be shown, and the implications of these results in regard to the work done on various crystals will be discussed.

31. The Sign of the Nuclear Magnetic Moment of K^{39}. H. C. TORREY AND I. I. RABI, *Columbia University.*—The method of nonadiabatic transitions in an atomic beam[1] has been used to determine the sign of the nuclear magnetic moment of K^{39}. It is found that this sign is positive and that the hyperfine structure of the $^2S_{\frac{1}{2}}$ state is normal. This result is in apparent contradiction to spectroscopic data.[2] In view of this disagreement, and inasmuch as it has not been possible, heretofore, to compare results of these two methods, it was thought advisable to determine the sign of the nuclear magnetic moment of Na^{23} for which the spectroscopic evidence[3] is very good. In this case the two methods agree on a positive sign.

[1] I. I. Rabi, Phys. Rev. **49**, 324 (1936); J. M. B. Kellogg, I. I. Rabi, J. R. Zacharias, Phys. Rev. **50**, 472 (1936).
[2] D. Jackson, H. Kuhn, Nature **137**, 108 (1936).
[3] L. P. Granath, C. M. Van Atta, Phys. Rev. **44**, 935 (1933).

32. An Attempt at Direct Measurement of the Magnetic Moment of the Rb^{85} Nucleus.* S. MILLMAN AND I. I. RABI, *Columbia University*, AND J. R. ZACHARIAS, *Hunter College.*—The atomic beam method of "zero moments" gives values of the nuclear spin i and $\Delta\nu$ of the hfs multiplet. Nuclear moments μ_r are then calculated with electronic wave functions assuming cosine interaction. We wish to point out that, when the magnitude of μ_r is not neglected in comparison with μ_j, these zero moment states are close doublets in H for $j=\frac{1}{2}$. Indeed

$$\Delta H/H=\left(\frac{2i+1}{i}\right)\left(\frac{\mu_r}{\mu_0}\right)\left\{1-\left(\frac{2m}{2i+1}\right)^2\right\}^{\frac{1}{2}}$$

independent of the form of the (ij) interaction. In virtue of the high resolution attainable with these experimental methods we can measure $\Delta H/H$ and evaluate μ_r directly. Although our apparatus cannot resolve a zero moment peak into two we were able to measure ΔH by supplementing the weak deflecting field with a strong field which separates spatially the atoms which form the doublet.

The fields for the zero moment peaks are then measured separately for each component. We find $\Delta H/H = 1.8 \times 10^{-3}$ and $\mu_r = 1.8$ nuclear magnetons. These results cannot be regarded as in definite disagreement with 1.44 n.m. from the methods mentioned above, since our precision is not yet better than 30 percent. We thank Dr. Marvin Fox for important aid in the early stages of this experiment.

* Reported at the Harvard Tercentenary Conference.

33. The Signs of the Nuclear Magnetic Moments of Li^7, Rb^{85}, Rb^{87} and Cs^{133}. S. MILLMAN, *Columbia University*, AND J. R. ZACHARIAS, *Hunter College*.—The atomic beam method of nonadiabatic transitions for determining the signs of nuclear magnetic moments has been applied to Li^7, Rb^{85}, Rb^{87} and Cs^{133}. The method requires a magnetic state filter supplemented by a device which induces transitions between magnetic levels. The filtering mechanism usually[1, 2] consists of a weak deflecting field, a strong refocusing field and a selecting slit inserted between the two fields. The apparatus used by Millman, Rabi and Zacharias[3] for the direct measurement of the nuclear magnetic moment of Rb^{85} possesses this filtering feature. The insertion of a nonadiabatic field between the selector slit and the weak field adapted this apparatus for the present work. The procedure used in filtering and identifying the atoms in the magnetic states which make nonadiabatic transitions will be described. The results show that the moments of all of these nuclei are positive in agreement with known hfs measurements.

[1] Kellogg, Rabi and Zacharias, Phys. Rev. **50**, 472 (1936).
[2] Torrey and Rabi, Abstract No. 31.
[3] Millman, Rabi and Zacharias, Abstract No. 32.

34. The Viscosity of Sols Made from X-Irradiated Agar. H. KERSTEN AND C. H. DWIGHT, *University of Cincinnati*.—Powdered agar was irradiated with x-rays from a copper target, added to water, heated, and the viscosity of the resulting sols measured. It was found that irradiation decreases their viscosity, as well as their pH.

35. L-Satellites in the Atomic Number Range $73 < Z < 79$. F. K. RICHTMYER, C. H. SHAW AND R. E. SHRADER, *Cornell University*.—The satellites of the x-ray lines $L\alpha$ and $L\beta_2$ are relatively strong in the atomic number range $40 < Z < 50$; but they grow rapidly weaker and are either absent or experimentally not observable in the rare earths. The satellites of $L\alpha$ appear again a little above,[1] and those of $L\beta_2$ a little below[2] Yb(70); and continue up to U(92). The Koster-Kronig theory, based on the Auger effect, qualitatively explains this behavior. The present work was undertaken to determine, quantitatively by the ionization-chamber method, (1) the increase in intensity of these satellites from the neighborhood of Yb(70) to higher atomic numbers, as a check on, and a refinement of the Koster-Kronig theory; and (2) the satellite structure for comparison with the known structure in the lower atomic number range. Preliminary data on intensities of the entire satellite group, relative to the parent line for $L\alpha_1$, are as follows:

	I satellites
Z	$I_{L\alpha_1}$
Ta(73)	<0.2 percent
Os(76)	0.8
Pt(78)	1.3
Au(79)	(5.)*

* Data from Richtmyer, Barnes and Ramberg, Phys. Rev. **46**, 843 (1934).
[1] Richtmyer and Kaufman, Phys. Rev. **44**, 605 (1933).
[2] Coster, Phil. Mag. **43**, 1070 (1922).

36. The Structure of Glasseous Selenium. K. LARK-HOROVITZ AND E. P. MILLER, *Purdue University*.—Thin rods of glasseous selenium have been investigated with silver $K\alpha$ and copper $K\alpha$ radiation. Three bands have been observed in the diffraction pattern, $\lambda/2 \sin\theta$ of which are equal to 3.42, 1.73, 1.13. These values agree with recent results on liquid selenium obtained by J. A. Prins:[1] 3.38, 1.79, 1.15. Exposures in a vacuum camera with monochromatic copper radiation have been evaluated by the Fourier method in the manner described before.[2] Three sharp peaks are found in the distribution curve at distances $r = 2.35$, 3.7, 4.8A. These peaks correspond to the distances for next neighbors in the crystal, 2.32, (3.46, 3.69), 4.34A. Also the number of atoms at these distances corresponds to the number of atoms in the crystal. These results are discussed in connection with the different theories of the structure of glasses.

[1] To appear in Trans. Faraday Soc., September 1936. We are indebted to Professor Prins for communication of these results before publication.
[2] Bull. Amer. Phys. Society, Abstract No. 21, November (1936).

37. Electron Diffraction Patterns of Sulphur and Selenium Molecules. J. D. HOWE AND K. LARK-HOROVITZ, *Purdue University*.—By use of the Universal camera[1] described sometime ago, the diffraction of electrons from the vapor of selenium and sulphur at low temperature has been investigated. The diffraction pattern for sulphur is different from the one described by other observers,[2] the values of $\sin\theta/\lambda$ being given as 0.130, 0.238, 0.343, 0.465, 0.745. The pattern cannot be interpreted on the basis of a diatomic molecule; after several attempts with other models it was found that a puckered ring S_8 structure, as the one observed in the S crystal, described the results adequately. The diffraction pattern of selenium is very similar to the one obtained for sulphur, $\sin\theta/\lambda$ being given as 0.157, 0.290, 0.454, 0.698. Also this pattern must be attributed to a higher molecular structure, and a structure like the one found for sulphur but corresponding to Se_6 seems to account best for the results.

[1] H. J. Yearian and J. D. Howe, R. S. I. **7**, 26 (1936).
[2] L. R. Maxwell, S. B. Hendricks, V. M. Mosley, Phys. Rev. **49**, 199 (1936).

38. An Arrangement for Simplifying the Analysis of a Spectrum Plate. J. G. BLACK, *Morehead Teachers College and University of Michigan*.—A recording drum fastened rigidly to the screw shaft of a microphotometer having a millimeter thread, prints a scale on a piece of paper tape as the plate advances, in such a way that each mark of the scale identifies a plate position. The tape moves under a fixed straight edge and across the tape a sharp line is quickly made with a pencil each time a line center passes. By this line the galvanometer deflection is recorded on the

moving tape. The 10 inch glass plate is put aside; replaced by a paper tape about 88 feet long. This tape is laid beside a standard tape having the iron lines and interpolations made between recorded iron lines. Each unknown spectrum is supplied with a light iron comparison to furnish landmarks at intervals on the tape.

39. The Absorption Spectrum as a Quantitative Test for Free Hydroxyl Radicals. O. OLDENBERG AND F. F. RIEKE, *Harvard University and Johns Hopkins University.*—In preceding papers by A. A. Frost and O. Oldenberg the absorption spectrum served as a test for free OH radicals. Their presence during rapid gas reactions could be traced by means of spectra taken in snapshots. First, only a *qualitative* test was made. Secondly, the test was made *quantitative* in a *relative* sense. Finally, in order to obtain an *absolute quantitative* test for free OH the absorption spectrum was calibrated against a known concentration of free OH produced, according to the method of Bonhoeffer and Reichardt, in thermally dissociated water vapor. At high temperature and one atmosphere pressure the width of the individual absorption lines is sufficiently large for observation in the second order of a 21-foot grating. On the basis of this calibration the combination of OH and H after the interruption of an electric discharge through water vapor was studied quantitatively. Because of the small width of the absorption lines at the low temperature and pressure of the discharge the high resolving power of quartz Fabry-Perot plates was needed.

40. Rotation of Water Molecules in Nonpolar Solvents. E. L. KINSEY AND J. W. ELLIS, *University of California at Los Angeles.*—Infrared absorption records of water dissolved in carbon bisulphide, previously reported as indicating a more vaporlike than liquidlike absorption, show the following interesting results. For the 1.38μ band the two long wave-length components of the set of three, into which the spectrograph resolves this band in the vapor, appear in the solution in the unshifted vapor position. The relative intensities however are reversed. The third component is completely absent. Of the three weak bands at the extreme long wave side of this group only one, the long wave-length component, appears in the solution. In the 1.87μ band, which the spectrograph resolves into more than a dozen bands for the vapor, only three occur in the solution, again unshifted. If Mecke's analysis of the vapor bands is used it is seen that in each region in the solution the P branch is strong, the Q branch is weak, and the R branch is absent. The strongest transitions occurring in absorption therefore are those for which the total angular momentum decreases. Those for which it remains constant are weak. Those for which it increases are absent.

41. The Lithium I like Spectrum of Phosphorus P XIII. HOWARD A. ROBINSON, *Ohio State University.*—Recent spectrograms taken on the new 5 meter grazing incidence spectrograph located in Professor Siegbahn's Institute at Uppsala, Sweden, have made possible the extension of the Li I like isoelectronic sequence to include P XIII. The first members of the principal series cannot be observed for reasons given previously.[1] The second members ($2s-3p$) lie at 35.137A and 35.098A respectively. Other transitions such as $2p-3d$ and possibly $2p-3s$ have been located. The deviation from the hydrogen like term values is very small; for the ground state being approximately 1.94 and for the $2p$ state 1.98. The ionization potential is roughly 608 electron volts.

[1] H. A. Robinson, Zeits. f. Physik **100**, 636 (1936).

42. Hyperfine Structure in the Resonance Lines of Mg I and Mg II. RUSSELL A. FISHER, *Northwestern University.*—By employing an atomic beam excited in an electrodeless discharge in argon as source, measurable structure has been observed in the resonance line of Mg I λ2852 and in the two resonance lines of Mg II λ2803 and λ2796. The resolving element was a Fabry-Perot interferometer with aluminum films and spacers of 1, 2, 3 and 5 cm. λ2852 was found to consist of a strong component accompanied by a second weaker component of approximately 1/10 its intensity, the weaker component lying 0.066 cm^{-1} to the higher frequency side. While this separation is entirely at variance with that reported by Jackson and Kuhn* in their absorption measurement, it is supported by observations made with each of the four spacers mentioned above. The lines λ2803 and λ2796 show identical structures consisting of a strong central component with a much fainter component lying on each side at $+.100$ cm^{-1} and $-.025$ cm^{-1} respectively. The satellite of λ2852 may be attributed to one or both of the two less abundant isotopes of Mg. The fact that the two satellites in the Mg II lines are fainter relative to the strong component than is the satellite in the Mg I line suggests that they may be interpreted as belonging to Mg^{25} and that their total separation of 0.125 cm^{-1} is that of the $3s\ ^2S$ state of Mg II. If this interpretation is accepted the satellite of the Mg I line must be attributed to Mg^{25} also.

* Jackson and Kuhn, Proc. Roy. Soc. **154**, 679 (1936).

43. Remark on the Creation of Pairs by Nuclear Electrons. JULIAN K. KNIPP, *Purdue University.*—As has been pointed out by Uhlenbeck and Goudsmit, if the interaction between a number of particles does not depend critically on the energies of the particles, the energy distribution function for the particles will be given roughly by the statistical factor, which gives the number of states per energy interval. Consider the case of beta-decay with the creation of two electrons, a positron and a neutrino. The coulomb field of the nucleus will cause the creation of fast positrons and slow electrons to be favored. Otherwise the interaction will not depend greatly on the energies. Thus the statistical factor should give the form of the energy distribution of the observed positrons for light nuclei, where the coulomb interaction of the nucleus is of less importance. For heavy nuclei it should not give enough high energy positrons. Experimental data exist only for heavy nuclei. Comparison of the statistical distribution with the experimental distribution of positrons from Th C+C″ obtained by Alichanow, Alichanian and Kosodaew has been carried out and shows that the statistical factor for this case (heavy nuclei) gives too few fast positrons. A detailed calculation of the interaction is being made by Møller. In the

Born approximation it cannot be expected that there will be much improvement in the form of the distribution function over that given by the statistical factor.

44. Theory of Neutron Velocity Distributions in Aqueous Solutions. W. H. FURRY, *Harvard University.*—The discussion of velocity distributions of slow neutrons in aqueous solutions has been extended to cases more general than treated previously.* If more than one solute obeying the Breit-Wigner law of absorption is present, one finds, for resonances not too broad or too close together and concentrations not too high, that the distribution is of a sort readily interpreted in terms of the formalism already given. Aside from the resonance regions the curve is essentially of the v^{-2} form given by Fermi, its amplitude being decreased on crossing each resonance region by the amount absorbed there, which is a typical nonlinear function of the concentration. Corresponding results are obtained for the case when a solute absorbing according to a v^{-1} law (boron) is also present. For broad resonances or very high concentrations the approximations used break down; such a situation is, however, not a very likely one experimentally. In the case of a single solute a procedure is available for calculating the exact curves numerically without much difficulty.

* Phys. Rev. **50**, 381 (1936).

45. Interaction Between Light Nuclei. M. PHILLIPS,[1] L. EISENBUD AND E. U. CONDON, *Princeton University.*—On the basis of the concept of a static potential we have attempted to calculate the scattering cross sections for neutrons or protons on H_1^2, H_1^3, He_2^3, He_2^4 and for deuterons on deuterons. The interaction potential between individual particles was assumed to be of the form $J(r_{ik})=Ae^{-\alpha r^2 ik}$. A straightforward attack on the problem leads to difficulties which are connected with symmetrization of the wave functions and the use of exchange interaction operators. Simple considerations using ordinary forces and unsymmetrized wave functions yield elastic scattering cross sections in approximate agreement with existing experimental data. The present state of nuclear theory does not appear to justify a refinement of this crude treatment. An exact formulation of the problem is given and the new features which are introduced by exchange forces are discussed.

[1] A.A.U.W. Fellow.
[2] Massey and Mohr, Proc. Roy. Soc. **156**, 634 (1936).

46. On the Nuclear Three Body Problem. R. D. PRESENT, *Purdue University,* AND W. RARITA, *Columbia University.*—All evidence points to a nuclear Hamiltonian comprising a Majorana-Heisenberg interaction $\{(1-g)P^M+gP^H\}V$ between unlike particles and an attractive singlet interaction between like particles which is equal to that for unlike particles. The experimental mass defects of H^2 and H^3 together with the cross section σ for slow neutron-proton scattering will determine the range (b) and depth (B) of nuclear forces and the proportion g of Heisenberg force (we use throughout the potential $Be^{-2r/b}$). An exact analytic expression relating σ, g and b is derived for this potential and g is found to be very insensitive to σ. An exact solution of H^2 gives the relation between B and b. The final relation which fixes the constants is furnished by a precise variational treatment of H^3 with the above Hamiltonian and the following wave function:

$$\psi=\partial^{-\frac{1}{2}}\alpha_1(\alpha_2\beta_3-\alpha_3\beta_2)\phi_1+\partial^{-\frac{1}{2}}\alpha_1(\alpha_2\beta_3+\alpha_3\beta_2)\phi_2+\beta_1\alpha_2\alpha_3\phi_3$$

where ϕ_1, ϕ_2 and ϕ_3 each represent an exponential times a power series in the interparticle distances of proper symmetry (ϕ_2 and ϕ_3 are brought in by the Heisenberg term). The convergence of energies obtained from successive improvements in ψ is rapid and the eigenvalue may be closely estimated. With $E(H^2)=-4.35$ mc^2, $E(H^3)=-16.55$ mc^2 and $\sigma=13\times10^{-24}$ cm^2, preliminary results give: $b=1.73\times10^{-13}$ cm, $B=242$ mc^2 and $g=0.215$. The binding energy of He^3 is readily obtained and accurate wave functions for H^3 and He^3 will be calculated. The Breit-Feenberg operator is used for the small triplet neutron-neutron interaction.

47. Absorption of Resonance Neutrons. H. H. GOLDSMITH AND J. H. MANLEY, *Columbia University.*—Measurements of the absorption of various neutron groups in Cd, Rh and Ir have yielded the following preliminary results: (1) The ratio of the capture cross section of Cd for Rh neutrons to the cross section for In neutrons is 1.7. The Cd cross section, in this case, should vary approximately as $1/v^5$. This gives a velocity ratio between Rg and In neutrons of about 1.1 in good agreement with the ratio obtained from the boron absorption method. (2) The absorption of Rh neutrons in Rh is not exponential. The absorption coefficient varies from 2.5 to 0.7 cm^2/g for absorbers which vary in thickness from 0.2 to 2.0 g/cm^2. The absorption in Rh of the B neutrons is considerably greater than that of the A neutrons. (3) The absorption coefficient of Ir for the neutrons detected by Ir varies from 1.5 to 0.85 cm^2/g for thicknesses of 0.3 to 1.0 g/cm^2. The absorption in Ir of the neutrons detected by Rh, In, Ir, Ag (A and B groups) and I indicates that the cross section of Ir varies more slowly with neutron energy in the region 1–100 ev than that of any other element yet investigated. Additional measurements of the absorption of the neutrons detected by Rg, Ag and I in various elements have been made.

48. Experiments on the Magnetic Properties of the Neutron. J. R. DUNNING, P. N. POWERS AND H. G. BEYER, *Columbia University.*—Certain experiments have been made to detect an alignment or polarization of neutrons, due to their magnetic moment, on passing through strongly magnetized material.[1, 2] First the scattering of a beam of thermal neutrons on passing through two sheets of iron magnetized to saturation was investigated, varying the directions of magnetization. No changes in neutron transmission larger than the probable error were observed. In further experiments, the neutrons were first passed through a magnetized sheet of iron (polarizer) at 30° and 45°, and then scattered from the pole face of a second magnet which should serve as an "analyzer" if the scattering cross section depends on parallel or anti-parallel orientation of the neutron with respect to the field. The difference 2.01 ± 0.65

Polarizer Field Direction	Parallel to Analyzer Field	Anti-parallel to Analyzer Field	Zero Field, i.e. Unpolarized
No. Counts	12,700	11,500	15,600
No./Min.	50.81±0.48	49.40±0.44	48.80±0.40
Difference		1.41±0.66	2.01±0.65

between the unpolarized or random orientation and the parallel case is not considered to prove conclusively any effect. The smaller difference, if real, between the parallel and anti-parallel conditions may be caused by a large fraction of the neutrons losing their space quantization and re-orienting themselves parallel after leaving the polarizing plate. The nuclear cross section (scattering plus capture) is so large compared to the observable magnetic interaction cross section that detection of such possible effects is clearly difficult.

[1] Bloch, Phys. Rev. **50**, 259 (1936).
[2] Schwinger, unpublished.

49. The Bombardment of Palladium with Deuterons. J. D. Kraus and J. M. Cork, *University of Michigan.*—Observations have been made of the active isotopes formed when palladium (46) is bombarded by 6.5 Mev deuterons. Chemical separations show strong activities in the palladium and at least two active silver isotopes. This silver activity is not the Fermi activity which would have resulted from the bombardment of silver itself (22 sec. and 2.3 min.) but has half-life periods of 32 minutes and 7½ days. An estimate is made of the maximum energies of the observed beta radiations.

50. Radioactive Isotopes from Aluminum. M. L. Pool and J. M. Cork, *University of Michigan.*—It has been apparent for some time that aluminum bombarded by high energy deuterons yields radioactive isotopes other than $_{13}Al^{28}$, which decays with a half-life period of 2.3 minutes. As ordinary aluminum generally contains contamination of SiO_2 the 2.5 hr. period due to $_{14}Si^{31}$ is usually observed. Chemical separations of a specimen of very pure aluminum activated by 6.5 Mev deuterons show an additional activity in the magnesium precipitate which emits solely positives and has a half life of 15.8 hours. If this cannot be ascribed to a contamination it must mean the formation of $_{12}Mg^{23}$ which would be due to the emission of an $_2He^5$ particle plus a neutron or some equivalent transformation.

51. Induced Radioactivity in Lead. R. L. Thornton and J. M. Cork, *University of Michigan.*—The abundance of the normal stable isotopes of lead (203 to 209) suggests the possibility of producing radioactive isotopes of thallium or bismuth in addition to any activity in the lead. The existence of isotopes 205 and 209 is questionable. Should 209 exist, then neutron activation or deuteron bombardment should yield radio lead (210), which is radium D. Bombardment of a pure lead specimen by a beam of 2 microamperes of deuterons at 6.5 Mev for about 12 hours gave no sure indication of the formation of radium D. Another active lead isotope of a half-life period 3.0 hours, however, is observed. This emits negative beta-particles and hence is undoubtedly isotope 209. Other shorter period activities have been observed but have not yet been chemically resolved.

52. The Magnetic Susceptibility of Molecular Hydrogen Calculated by Quantum Mechanics. Enos E. Witmer, *University of Pennsylvania.*—For gaseous molecular hydrogen the molar magnetic susceptibility is given by the formula

$$\chi_M = -\frac{Le^2}{6mc^2}\Sigma\overline{r^2} + \frac{Le^2}{6m^2c^2}\sum_{n'\neq n}\frac{|P(n;n')|^2}{h\nu(n;n')}.$$

As stated in a recent abstract (No. 3, New York Meeting, October 29–31, 1936) the first term on the right was evaluated for different internuclear distances R, using the eleven-term wave function of James and Coolidge. These values were averaged by using a Morse wave function for the vibrational state $v=0$. The value of the average depends on the nature of the extrapolation of the curve through the calculated points. The maximum possible value of the first term is -4.09×10^{-6}, the value -4.15×10^{-6} is probably a minimum, the estimated best value being nearer to the latter value. Using the approximation of Van Vleck and Frank for the second term, the maximum possible value calculated from the five term function is 0.31×10^{-6}; it is probable that 0.25×10^{-6} is a minimum, and the best value is 0.285×10^{-6}. The maximum and minimum possible values of χ_M are then -3.78×10^{-6} and -3.90×10^{-6}. The best calculated values are from -3.83×10^{-6} to -3.87×10^{-6}. The average of the best experimental values is -3.97×10^{-6}. Increasing the factor ν_1 in the approximation of Van Vleck and Frank would bring the calculated values into better agreement with the experimental values.

53. A Theory of the Ferromagnetism of Alloys. F. Bitter, *Massachusetts Institute of Technology.*—Excluding pressure effects, the magnetization of an alloy may be considered to be a function of three variables, the concentration of the alloy, the temperature, and the magnetic field. A theory is developed which gives the dependence of spontaneous magnetization on temperature for any homogeneous phase. The expression obtained reduces to the usual form $I/I_0=\tanh(CI/KT)$ for pure substances. The equations contain five arbitrary constants, four of which are C, and I_0 for the two pure phases. Among the new points brought out are that in alloys, spontaneous magnetization need not increase with decreasing temperature and that there may be more than one critical temperature. Further, the conditions for the existence of a single homogeneous phase are discussed, and it is shown that a chemical separation may take place at the critical temperature analogous to the chemical separation that takes place on freezing, and that this chemical separation may be modified by the application of a magnetic field.

54. On the Choice of the Action Function in the New Field Theory. B. Hoffmann and L. Infeld, *The Institute for Advanced Study, Princeton, N. J.*—There are difficulties connected with the action functions, hitherto used in the

new field theory initiated by Born, apart from their lack of uniqueness. They permit isolated magnetic poles to exist, and the field equations have to be supplemented by extra conditions equivalent to equations of motion. Further, the f_{kl} field is not regular in the case of an electrical particle, and space-time is also singular for this case. By requiring that solutions having physical significance must have f_{kl} fields free from singularities we are led to a unique action function, so far as the significant lower order terms are concerned, which gives a theory in which isolated magnetic poles cannot exist and in which the equations of motion are a consequence of the field equations. Moreover, the gravitational field is now regular and electromagnetic and gravitational mass are shown to be the same. The Hamiltonian of the new action function turns out to be $\mathsf{H}=\frac{1}{2}\log(1+P)$, $P\equiv D^2-H^2$, and the electric field vector in the spherically symmetric case is now given by $E_r=r^2(1+r^4)^{-1}$. Thus, E_r goes over to the Maxwellian case for large r and, in accordance with the regularity condition, tends to zero as $r\rightarrow 0$.

55. The Influence of Dipole-Dipole Coupling on Electric and Magnetic Susceptibilities. J. H. VAN VLECK, *Harvard University.*—The partition function, and hence the entropy, specific heat, and susceptibility, are calculated as power series in $1/T$ for a dielectric or paramagnetic body inclusive of dipole-dipole coupling. This kinetic treatment is in principle rigorous but practically handicapped by poor convergence. However, it shows that the usual, essentially static, Lorentz method wherein dipole-dipole interaction merely adds a term $4\pi P/3$ to the local field is justified only in the first approximation and involves assumptions comparable to supposing in the Heisenberg theory of ferromagnetism that all states of the same crystalline spin possess the same energy. The Fowler-Debye hypothesis of hindered rotation consequently may not be necessary to explain the nonoccurrence of the spontaneous polarization which the Lorentz $4\pi P/3$ procedure would predict below a "Curie point" $\theta=4\pi N\mu^2/9k$ in polar liquids. This hypothesis seems inadequate in HCl, as here $\theta=260°$, whereas Pauling showed that free rotation is destroyed only below 100°K. If a Gaussian distribution rather than identity of energies is assumed, the spontaneous behavior is impossible. In the magnetic case, the dipole-dipole coupling is important at, and only at, the new very low temperatures. It is uncertain whether coupling of this type (in distinction from exchange interaction) can ever produce ferromagnetism.

56. Entropy and Magnetic Susceptibility of Paramagnetic Salts Below 1°K. M. H. HEBB AND E. M. PURCELL, *Harvard University.*—The results of Giauque, Kürti, DeHaas and their collaborators on the production of extremely low temperatures by the adiabatic demagnetization method are discussed. At these temperatures the Debye specific heat is negligible and the entropy depends on the distribution of the paramagnetic ions among the Stark components produced by the crystalline electric field and on the magnetic and exchange coupling of the ions. The splitting produced by the crystalline field is calculated by the method of crystalline potentials. This splitting is of the order of a few tenths of a cm^{-1}. The contribution to the entropy from the coupling of the ions is evaluated by Van Vleck's method.* Below 1°K the Curie temperature scale deviates from the true thermodynamic scale due to the influence of the crystalline field and the ion coupling. The extent of this deviation is uncertain on account of the latter effect but calculations based on the Lorentz local field seem to fit the experimental data better than do those based on a more elaborate theory* which attempts to take account of fluctuations of the moments of surrounding ions about their mean values.

* See preceding abstract.

57. On the Density of Energy Levels of Heavy Nuclei, JOHN BARDEEN, *Harvard University.*—The present calculation of the density of energy levels of a heavy nucleus is based on the statistical model of Van Vleck.[1] As in Bethe's calculation,[2] the particles are assumed to move in a simple potential hole, but the depth of the hole varies with the velocity of the particle. If exchange forces act, the interaction energy of a given particle with the remainder of the nucleus decreases as the velocity of the particle increases. This results in a lower density of states of the individual particles at the top of the Fermi distribution. Bethe's formula for the density of excited levels of the nucleus as a whole may be applied to the present situation if this change in the density of the individual particle states is taken into account. The spacing between the levels is several hundred times larger than that found by Bethe, and, if one uses the Gamow value for the radius of a radioactive nucleus ($\sim 9\times 10^{-13}$ cm), is much too large to be reconciled with the frequent occurrence of resonance levels for slow neutrons. If one uses the new value for the radius suggested by Bethe[3] ($\sim 13\times 10^{-13}$ cm), the present theory gives values agreeing roughly with experiment.

[1] J. H. Van Vleck, Phys. Rev. **48**, 367 (1935).
[2] H. A. Bethe, Phys. Rev. **50**, 332 (1936).
[3] At the New York Meeting, October, 1936.

58. Concentration of Chlorine Isotopes by Centrifuging. J. W. BEAMS AND A. VICTOR MASKET, *University of Virginia.*—A specially designed type of air driven centrifuge[1] has been employed to concentrate the isotopes of chlorine. A hollow metal rotor (60 cc capacity) was both supported and spun in a vacuum by a metal tube (stainless steel hypodermic needle tubing 1.3 mm bore). The rotor was partially filled (16 cc) with CCl_4 and evacuated through the tube while at full speed. One cubic centimeter of liquid CCl_4 was collected in dry ice traps every 6.5 minutes. Light, medium and heavy fractions were collected and separately re-centrifuged. Density measurements of the successive fractions were roughly in agreement with the theory.

[1] Beams and Pickels, R. S. I. **6**, 299 (1935); Beams and Haynes, Phys. Rev. **50**, 491 (1936).

59. Atomic Masses of Hydrogen, Helium, Carbon, and Nitrogen Isotopes. KENNETH T. BAINBRIDGE AND EDWARD B. JORDAN, *Harvard University.*—The mass separations CH_4-O, H_2-D and $D_3^+-C^{++}$ yield the masses:

$$H = 1.00815 \pm 0.00002; \quad D = 2.01478 \pm 0.00003;$$
$$C = 12.00428 \pm 0.00017;$$

where the doublet separation $D_3^+ - C^{++} = 0.04219 \pm 0.00005$ mass units and the other doublets[1] have already been reported. The mass of helium $= 4.00395 \pm 0.00007$ from the doublet separation $D_2 - He = 0.02561 \pm 0.00004$ mass units. The mass of $C^{13} = 13.0079 \pm 0.0002$; $N^{14} = 14.0076 \pm 0.0002$; and $N^{15} = 15.0050 \pm 0.0003$ from earlier measurements.[1, 2] An additional link between the lighter and heavier masses is provided by the doublet $Li^{7+} - N^{14++} = 0.01443 \pm 0.0001$ which yields $Li^7 = 7.01822 \pm 0.00014$. The carbon and nitrogen mass values were checked from mass spectrographic data by the use of the doublets $CO - N_2$, $CH_4 - NH_2$, $OH - NH_3$ and $O - NH_2$. The doublet measurements were made in the linear section of the recording plate on lines of very nearly equal density.

[1] E. B. Jordan and K. T. Bainbridge, Phys. Rev. **49**, 883 (1936).
[2] J. and B., Phys. Rev. **50**, 98 (1936).

60. Atomic Masses of Beryllium, Boron, Neon and Argon. EDWARD B. JORDAN AND KENNETH T. BAINBRIDGE, *Harvard University.*—The mass differences of the following doublets have been calculated from measurements made on lines of approximately equal density in the linear region of the recording plate of the mass spectrograph:

1. $O^{16}D_2^+ - Ne^{20+} = 0.03065 \pm 0.00010$ mass units.
2. $B^{10+} - Ne^{20++} = 0.01675 \pm 0.00015$ mass units.
3. $B^{10}H_2^+ - C^{12+} = 0.02875 \pm 0.00020$ mass units.
4. $B^{10}H^+ - B^{11+} = 0.01160 \pm 0.00010$ mass units.
5. $B^{11}H^+ - C^{12+} = 0.01714 \pm 0.00010$ mass units.
6. $Be^9H^+ - Ne^{20++} = 0.02391 \pm 0.00020$ mass units.
7. $Be^9H^+ - B^{10+} = 0.00696 \pm 0.00020$ mass units.
8. $B^{11+} - Ne^{22++} = 0.01360 \pm 0.00015$ mass units.
9. $B^{10}H^+ - Ne^{22++} = 0.0251 \pm 0.00050$ mass units.
10. $Ne^{20}H^+ - Ne^{21+} = 0.00726 \pm 0.00020$ mass units.
11. $OD_2^+ - A^{40++} = 0.04189 \pm 0.00020$ mass units.
12. $Ne^{20+} - A^{40++} = 0.01130 \pm 0.00010$ mass units.

The first three mass differences given above can be used in conjunction with those reported[1, 2] for the $C^{12}H_4 - O^{16}$ and the $H_2 - D^2$ doublets to make up a complete mass circuit from which the masses of the atoms involved can be calculated:

$$C^{12} = 12.00402 \pm 0.00017 \text{ mass units.}$$
$$B^{10} = 10.01633 \pm 0.00013 \text{ mass units.}$$
$$Ne^{20} = 19.99917 \pm 0.00019 \text{ mass units.}$$

The mass of B^{11} can now be computed either by means of doublet number 4 or doublet number 5. The values obtained by the two methods agree within the probable error and give a value

$$B^{11} = 11.01295 \pm 0.00013.$$

Similarly the mass of Be^9 can be computed by using doublets number 6 and 7. The average value obtained is

$$Be^9 = 9.01517 \pm 0.00016.$$

Other masses which can be obtained and checked from the values reported above are:

$$A^{40} = 39.97580 \pm 0.00031, \quad Ne^{22} = 21.99870 \pm 0.00040.$$

The value obtained for Ne^{21} is

$$Ne^{21} = 21.00013 \pm 0.00029.$$

The authors wish to thank Dr. E. L. Gamble of the Massachusetts Institute of Technology for preparing the boron hydrides which were used in these experiments.

[1] E. B. Jordan and K. T. Bainbridge, Phys. Rev. **49**, 883 (1936), Abstract 124.
[2] K. T. Bainbridge and E. B. Jordan, Phys. Rev. **49**, 883 (1936), Abstract 123.

61. Nuclear Disintegrations Accompanying Cosmic-Ray Showers. ARTHUR BRAMLEY, *Swarthmore, Pa.*—Nuclear disintegrations can occur as follows: (1) Through the nuclear photoelectric effect of a shower of electrons or photons a neutron[1] is emitted. The action of a shower, whether pairs[2] produced by heavy particles or photons[3] by light, is enhanced through the production of secondaries.[4] (2) On the Heisenberg-Oppenheimer picture of showers, as pairs produced by heavy particles, the nucleus can lose either electrons or positrons[5] through unsymmetrical emission. The nucleus assumes a new isotopic number. (3) Excitation of the β-particle field of proton by photon, electron or proton with subsequent emission of positron[5] and neutrino yields a new nucleus. In extreme cases, the nucleus loses all its charge, Ze. In the shower of N rays with average energy $\lesssim 10$ Mev, the probability of (1) is $\gtrsim N/Z^2$; for (2) with average energy $\lesssim 100$ Mev, it is ~ 0.5; for (3) in same energy range it cannot be estimated until more knowledge is acquired of the β-particle interaction for high energy electrons and neutrinos and for the nucleus as a unit.

[1] Locher, Phys. Rev. **50**, 394 (1936).
[2] Heisenberg, Zeits. f. Physik **101**, 533 (1936).
[3] Bramley, Science, August 28, 1936.
[4] Bhabha and Heitler, Nature, September 5, 1936; Oppenheimer, Phys. Rev. **50**, 389 (1936).
[5] Anderson and Neddermeyer, Phys. Rev. **50**, 263 (1936).

62. Radio-Transmitted Coincidence Counter Measurements of Cosmic-Ray Intensities in the Stratosphere. THOMAS H. JOHNSON, *Bartol Research Foundation and The Carnegie Institution.*—Instruments for registering double coincidences of GM counters have been sent into the stratosphere by small balloons. The results, though still preliminary, are in substantial agreement with those of Regener and Pfotzer and of Swann, Locher and Danforth. Each coincidence is transmitted as a pulse of high-frequency radio waves and is received and recorded photographically on the ground. At regular intervals the cosmic-ray signals are interrupted for transmission of signals produced by a neon tube flicker circuit whose frequency depends upon the height of a mercurial barometer. Counter voltage is produced by six-fold multiplication of the 180 volt B-battery. The apparatus hangs from the balloon by a cord which slowly unwinds from a spool. This turns the multiplier switch and signal commutator. The first model, four of which have been launched, weighed 14 pounds but improved design has reduced this to 8 pounds including batteries for five hours. Elimination of radio interference and greater distance reception have been achieved by locating the receiver on Mt. Washington. On the most successful flight signals came in with undiminished intensity for 110 minutes, and then suddenly stopped. During this time the balloon had ascended 55,000 ft. and cosmic-ray intensity had passed through a maximum equal to about

sixty times the ground intensity. The method will be used for measurements of vertical cosmic-ray intensity in the stratosphere in unpopulated latitudes.

63. Automatically Recorded Coincidence Counter Measurements of the Cosmic-Ray Latitude Effect. D. N. READ AND THOMAS H. JOHNSON, *Bartol Research Foundation and The Carnegie Institution of Washington.*—The instrument described last year will have completed its eighth voyage on the Grace Line from New York to Talcahuano, Chile, 36°S. Of the first seven voyages all but the first two have yielded successful records of cosmic-ray intensities from definite angles as a function of geographical position. Some trouble has been experienced from temperature effects but the following conclusions seem to be established. (1) The local magnetic field, as well as the geomagnetic latitude, is an important variable in determining the vertical intensity. (2) The vertical latitude effect is between 12 and 16 percent as compared with Millikan and Neher's value of 8 percent for rays from all directions. (3) A very slight latitude effect towards the west at 45° from the vertical, compared with a much greater effect at the same angle towards the east, indicates not only the excess of positive but the almost complete absence of negative primaries in the radiation responsible for the sea-level geomagnetic effects. Measurements at a zenith angle of 45° in north and south azimuths are being made as a further test of the Lemaitre-Vallarta theory of the north-south asymmetry. The apparatus will be on exhibition during the meeting.

64. Cosmic-Ray Ionizations under Various Thicknesses of Lead Shield in Northern and Equatorial Latitudes at Different Altitudes. R. T. YOUNG, JR., *Worcester Polytechnic Institute,* AND J. C. STREET, *Harvard University.*—Measurements with an ionization chamber have been carried out at Cambridge, Mass. (sea level), Mt. Evans, Colo. (3200 and 4300 m) and at corresponding elevations in Peru. Since it was desired to study the occurrence of small bursts with the same equipment, a small chamber (230 cc volume) was used. Due to statistical fluctuations the ionization measurements may be in error by 3 percent. It was found that within limits of error the latitude ionization ratios, Northern: Equatorial, were independent of shield at each elevation studied. The results are listed in the table.

BAROMETRIC PRESSURE cm Hg	GEOMAGNETIC LATITUDE	LATITUDE RATIO
76	53N − 1S	1.16
51	49N − 1S	1.27
45	49N − 1S	1.30

An analysis of the lead absorption curves has been made in terms of a penetrating and a soft component of the radiation. Counter data on the absorption of vertical rays and on showers are available at two stations (53N, bar. 76 and 49N, bar. 51) at which ionization measurements were made. By comparison with the counter data an estimate has been made of the contributions of both the penetrating and soft components to the ionization. The analysis shows that the ionization due to secondaries associated with the soft component varies with the shielding in the same manner as the production of showers determined by counters. This contribution of secondaries is important even under thick shields, e.g., 40 percent of the total ionization at an elevation of 3200 m and with a 20 cm lead shield. It is believed that the secondary ionization under thick shields is associated with the second shower peak observed by Ackemann and Hummel.

See the following:

1. R. H. Woodward and J. C. Street, Phys. Rev. **49**, 198 (1936).
2. R. H. Woodward, Phys. Rev. **49**, 711 (1936).
3. M. Ackemann, Naturwiss. **22**, 169 (1934).
4. J. N. Hummel, Naturwiss. **22**, 170 (1934).

65. Cosmic-Ray Bursts Photographed with a Cloud Machine Controlled by Noncollinear Counters. GORDON L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—A series of 640 pairs of pictures has been made at sea-level with a semi-automatic Wilson cloud machine controlled by various noncollinear arrangements of Geiger-Müller counters, to study the disintegration products of cosmic-ray bursts in paraffin, aluminum, and lead. The general type of burst picture obtained under a given set of circumstances depends not only on the kind and amount of burst-generating material, but also on the number, area, and configuration of the coincidence counters used for control. Photographs of bursts typical of the several arrangements, and of some unusual bursts, will be shown.

66. Photoelectric Geiger-Müller Counters for Visible and Ultraviolet Light.* GORDON L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—New developments in the technique of making photoelectric counters of high sensitivity, responding to visible light, are described. Composite cathode surfaces consisting of oxidized hydrides of barium, thallium, lithium, and sodium have been used with good success. Barium (threshold~4900A) and thallium (threshold~3500A) composite surfaces have spontaneous counting rates that are consistently lower than those of lithium and sodium. Measurements made by O. Mohler, using a composite barium counter on the Cook Observatory reflecting telescope (mirror silvered, Cassegrain aluminized), show a rate of 80 impulses per min. on a 5.2 magnitude, type B3 star, as compared with a "sky rate" of 40 per min., and a rate of 8.5 per min. in darkness. The response of this counter, which has a cross section of 3 cm by 1 cm, to the unresolved light from a tungsten ribbon lamp in fused quartz, at 1763°K, is 3.1×10^{10} impulses per min., per cm^2 of tungsten, per steradian. Its response to unresolved light from a Hefner candle is about 180 times that of a good zinc counter of the same dimensions. Curves of the spectral distributions of response of various counters, made with a double quartz monochromator, will be shown, and various problems relating to the construction and use of photoelectric counters will be discussed.

* To be called for after paper No. 65.

67. Stopping of Fast Electrons.* ARTHUR BRAMLEY, *Swarthmore, Pa.*—Electrons with energy $\gtrsim 137\ mc^2$ lose energy primarily by radiation and production of photon showers. Since the cross section for shower process is $\sim 1/10$ that for radiation, the rate of loss of energy is practically unchanged from that given by radiation theory.[1] The electron can also lose energy by the disintegration of the nucleus. (1) The losses from that process, which is the equivalent of the nuclear photoelectric effect, are negligible. (2) The electron excites the β-particle field of the nucleus which dissipates the energy by (I) radiation, (II) emission of neutrino,[2] (III) emission of positron with formation of a new nucleus. The cross section is uncertain.

Experiments[2] on electrons of energy $\sim mc^2$, indicate that energy losses exist besides those from ionization which are several times the theoretical radiation losses. If this conclusion can be extrapolated to higher energies, then it casts doubt on the assumption that the energy losses recorded for electrons in Pb plates[3] are radiative. Experiments[2] on elastic scattering at large angles require that radiation losses be less than estimated.

* To be called for after paper No. 66.

[1] Bethe and Heitler, Proc. Roy. Soc. **146**, 83 (1934).
[2] Skobeltzyn and Stepanowa, Nature **137**, 234 (1936); Klarmann and Bothe, Zeits. f. Physik **101**, 489 (1936).
[3] Anderson and Neddermeyer, Phys. Rev. **50**, 263 (1936).

68. Perturbation Theory and Heavy-Particle Interactions.* D. R. INGLIS, *University of Pittsburgh.*—Perturbation theory is applied to the nuclei He^4 and Li^6.[1] The form of interaction used by Feenberg and Knipp is here about adequate, the calculated binding energy of Li^6 being $58\ mc^2$ when the parameter C is adjusted to fit He^4 *by this method.* (Although this method gives He^4 only about $2\ mc^2$ less binding than does the equivalent two-body method with the same parameters, the Li^6 energy is quite sensitive to this small difference.) Symmetrization of this form by using its proton-neutron interaction operator between all pairs is not satisfactory. A more satisfactory simple symmetric form (which is also expected to have comparatively slight quadratic dependence on the number of particles in heavy nuclei) is suggested: $U=\Sigma((1-g)P^{(q)}+gP^{(\sigma)})\mathrm{Be}^{-\alpha r^2}$, containing a linear combination of space permutation and spin permutation.

* To be called for after paper No. 33.
[1] Cf. Phys. Rev. **50**, 399 (1936).

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