Proceedings of the American Physical Society

MINUTES OF THE NEW YORK, NEW YORK, MEETING, FEBRUARY 23–25, 1939

THE 226th regular meeting of the American Physical Society was held in New York City on Thursday, Friday and Saturday, February 23, 24 and 25, 1939 as a joint meeting with the Optical Society of America and the Inter-Society Color Council. The presiding officers at the sessions of the Physical Society were Dean John T. Tate, President of the Society, Professor John Zeleny, Vice President, Professor Walker Bleakney, Dr. Karl K. Darrow, Dr. W. E. Forsythe and Dr. L. H. Germer. All regular sessions for the reading of contributed papers for both the Physical Society and the Optical Society were held on Friday and Saturday at Columbia University in the Pupin Physics Laboratories. Sessions of the Inter-Society Color Council were held on Thursday at 480 Lexington Avenue.

The joint session with the Optical Society of America and the Inter-Society Color Council was held on Saturday morning at ten o'clock in a studio of the National Broadcasting Company, RCA Building, 30 Rockefeller Plaza. This session was a symposium of invited papers on "Television." The President of the Physical Society, Dean Tate, presided. The invited papers were as follows: *Electron Optics as Applied in Television Systems* by V. K. Zworykin, RCA Manufacturing Company; *Application of Electron Multipliers to Voltage Amplifications* by P. T. Farnsworth, Farnsworth Television, Incorporated (this paper was not given on account of the illness of the author); and *Demonstrations in Television* by A. F. Van Dyck, Radio Corporation of America. The attendance at this symposium was about four hundred.

On Friday afternoon after the close of the regular program an informal meeting was held for the discussion of the splitting of uranium atoms, at which Professor Niels Bohr and Professor Enrico Fermi were the speakers.

On Friday evening the Society joined with the Optical Society and the Inter-Society Color Council for dinner at the Columbia University Faculty Club. This dinner was attended by one hundred and forty members and guests. Dean Tate, President of the Physical Society, presided and after introducing officers of the Physical Society, the Optical Society of America, representatives of the Inter-Society Color Council and Professor Niels Bohr, Honorary Member of the Physical Society, called upon Dr. Karl K. Darrow to speak on certain features of the City of New York.

Meeting of the Council

At its meeting on Friday, February 24, 1939 the Council transferred six candidates from membership to fellowship and elected thirty-one candidates to membership. *Transferred from membership to fellowship:* Paul L. Bayley, Enrico Fermi, Millard F. Manning, Karl W. Meissner, Gordon M. Shrum and Walter H. Zinn. *Elected to membership:* Tosia Amaki, Paul A. Anderson, David F. Bleil, Daniel Brandon, Karl Cohen, Clifford V. Franks, Otto R. Frisch, Thomas D. Hanscome, Goro Hayakawa, John T. Hayward, Lawrence R. Hill, Richard A. Johnson, Gilbert E. Klein, Tadao Miki, Shizuo Miyake, Goro Miyamoto, Elizabeth Monroe, Cal F. Muckenhoupt, Mokitiro Nogami, G. Otake, C. Dale Owens, Robert F. Plott, Richard B. Stambaugh, Dean W. Stebbins, D. Gordon Sharp, Eizo Tajima, Ryohei Toya, James L. Tuck, Jesse R. Watson, D. J. Zaffarano and Herbert I. Zagor.

The regular scientific program of the American Physical Society consisted of sixty-four contributed papers of which numbers 47, 56 and 63 were read by title. The abstracts of the contributed papers are given in the following pages. An author index will be found at the end.

W. L. SEVERINGHAUS
Secretary

ABSTRACTS

1. Some Physical Properties of Liquid and Solid HD. F. G. BRICKWEDDE AND R. B. SCOTT, *National Bureau of Standards.*—About six liters of pure gaseous HD were separated from a mixture of H_2, HD and D_2 in a still having a refluxing column and operated in liquid hydrogen. Several properties of this sample of HD were measured with the following results: *Triple Point:* 16.60_4°K and 92.8_5 mm Hg. *Volume of Liquid* between triple point and 20.4°K: $V(\text{cm}^3\ \text{mol}^{-1}) = 24.886 - 0.30911T + 0.01717T^2$. *Relation between Freezing Temperature and Pressure* to $P = 80$ kg cm^{-2}: $\log_{10}(328.4+P) = 1.85904 \log T + 0.24731$. *Latent Heat of Fusion* at triple point: 38.1 cal. mol^{-1}. *Latent Heat of Vaporization of Liquid* at 22.54°K: 257 cal. mol^{-1}. *Heat Capacity of the Solid:* varied regularly from 0.69 cal. mol^{-1} °K^{-1} at 12°K to 2.46 at the triple point. *Heat Capacity of the Liquid:* varied linearly from 4.48 cal. mol^{-1} °K^{-1} at the triple point to 6.29 at 22°K. The difference between the volumes of the liquid and solid phases at the triple point, calculated from the above data by means of the Clapeyron equation, is 2.66 cm^3 mol^{-1}. The following equations were found to represent the vapor pressure of HD[1] as a function of the temperature expressed on the scale[2] recently established at the National Bureau of Standards. *Solid* from 10.4°K to triple point, $\log_{10}P(\text{mm Hg}) = 4.70260 - (56.7154/T) + 0.04101T$. *Liquid* from triple point to 20.4°K, $\log_{10}P(\text{mm Hg}) = 5.04964 - (55.2495/T) + 0.01479T$. These properties of HD are compared with those of H_2 and D_2.

[1] R. B. Scott and F. G. Brickwedde, Phys. Rev. **48**, 483 (1935).
[2] H. J. Hoge and F. G. Brickwedde, Nat. Bur. Stand. J. Research **22**, March (1939).

2. Field Currents at High and Low Pressures. B. E. K. ALTER AND R. T. K. MURRAY, *Polytechnic Institute of Brooklyn.*—The fact that field currents can be obtained from metals immersed in gases at high pressure has been employed to study the field emission at high pressure and in a vacuum from the same cathode. The electrodes were steel spheres whose separation could be varied with a micrometer screw driven by an electric motor through reduction gears, the whole assembly being enclosed in a cylindrical steel container which could be evacuated or operated at pressures up to 130 atmospheres. Linear log current against reciprocal potential curves for constant distance, linear log current against distance curves for constant potential, and linear potential against distance curves for constant current were obtained. The measured fluctuations in the emission obtained in a vacuum were greater than those obtained at high pressure. Since under high pressure positive ion bombardment of the cathode is prevented, the observed fluctuations cannot be due to positive ion impact. This supports the theory that the emitting points are changed by local heating produced by the high current densities at the points. The increased fluctuations of the currents in a vacuum can be accounted for by positive ion impact on the cathode.

3. Field Measurements and Possible Correction of Aberrations for Magnetic Electron Lenses. L. MARTON, *389 Park Ave., Collingswood, New Jersey.*—Experiments with two magnetic coils indicate that an improvement in the image quality can be obtained by opposing the currents in the coils and placing the object between the two field maxima. The position of the object with respect to the latter may be determined by measuring the field distribution ballistically with a field coil. Applying the same method for studying the fields in an actual electron microscope, the latter are found to have maximum values of the order of 7000 gauss. Some general relationships between lens design and image quality are discussed.

4. Optical and Magneto-optical Activity of Nickel Sulfate, α-Hexahydrate, in the Short Infra-Red Spectrum. L. R. INGERSOLL, *University of Wisconsin;* PHILIP RUDNICK AND F. G. SLACK, *Vanderbilt University.*—Previous measurements[1] of the optical activity of crystalline nickel sulfate, α-hexahydrate, in the visible and near ultraviolet regions have indicated active absorption bands in the infra-red region. Measurements of the natural rotatory power, the Verdet Constant, and of the transmission for this crystal have now been made through the spectral range from 0.60 mu to 2.0 mu. The method used in measuring the rotations is a modification of that previously described by Ingersoll.[2] The results show distinct anomalies in both the optical rotation and the magneto-optical rotation at approximately 0.69 mu and 1.16 mu, with corresponding absorption in these regions. Curves will be presented. The anomaly occurring at 1.16 mu in the optical rotatory curve is an exceptionally good example of anomalous rotatory dispersion and indicates a relatively very strong term of the Drude type in the rotatory dispersion equation. Preliminary calculations indicate that the single electron model of Condon, Altar and Eyring[3] will not account for this activity but that it may be accounted for on the basis of a pair of coupled linear oscillators on a model proposed by Kuhn.[4] Work on the analysis of the experimental results is being continued.

[1] F. G. Slack and Philip Rudnick, Phil. Mag., in press.
[2] L. R. Ingersoll, Phys. Rev. **9**, 257 (1917).
[3] E. U. Condon, William Altar and Henry Eyring, J. Chem. Phys. **5**, 753 (1937).
[4] E. U. Condon, Rev. Mod. Phys. **9**, 446 (1937).

5. Magnetic Susceptibilities in Weak Fields. L. G. HECTOR AND MAHLON F. PECK, *The University of Buffalo.*—The Hughes induction balance method for measuring magnetic susceptibilities in weak fields first reported by Hector and Eckstein[1] has been improved in sensitivity to a point where diamagnetic liquids and some gases can be measured. The fields used vary from 5 to 35 oersteds. Carbon tetrachloride, benzene and toluene appear to have the same values of susceptibilities at these field strengths as are found when they are measured by classical methods in intense fields. On the other hand, present measurements indicate that water is approximately six percent more diamagnetic and oxygen approximately seven percent more paramagnetic in these weak fields than in the intense static fields ordinarily employed.

[1] L. G. Hector and G. R. Eckstein, Phys. Rev. **49**, 643 (1936).

6. Preparation of Single Crystals of Iron, Cobalt, Nickel and Their Alloys. P. P. CIOFFI AND O. L. BOOTHBY, *Bell Telephone Laboratories, Inc.*—The raw materials used were carbonyl iron, Katanga electrolytic cobalt and specially purified nickel. For all of the crystals except iron, the materials were further purified by heat treatment in pure moist hydrogen just below the melting point in a pure alumina crucible. The temperature was then raised until they melted together; subsequently, the temperature was lowered, in some cases automatically at the rate of 2°C/hour until solidification was complete. The alloys were homogenized by holding just below the melting point for 24 hours. Sometimes the resulting ingot was a single crystal weighing about 400 grams, more often it consisted of two or more crystals. A single crystal of cobalt weighing 300 grams was formed by this method in spite of the fact that it undergoes a phase transformation at 400°C. Smaller crystals (about five grams) of iron were made without melting by holding for a long time at 1480°C, then at 880°C in pure dry hydrogen. In the direction of the cubic axis the iron crystal was found to have a maximum permeability of 1,450,000 at $B=17{,}500$. The hysteresis loss and coercive force are considerably larger than have been expected for a crystal of this purity. The magnetic properties of the iron-nickel and nickel-copper crystals have been determined by Williams and Bozorth (see succeeding abstract).

7. The Magnetic Anisotropy of Iron-Nickel and Copper-Nickel Alloys. H. J. WILLIAMS AND R. M. BOZORTH, *Bell Telephone Laboratories, Inc.*—The magnetic anisotropy constant K_1 has been determined for nickel and a number of alloys of the Fe-Ni and Cu-Ni series. Specimens were cut from the large single crystals prepared by Cioffi and Boothby (see preceding abstract). The constants were determined either from torque measurements on single crystal disks in a magnetic field of high strength, or from the area between the magnetization curves for the [100] and [110] directions. For the latter method the specimens were cut in the form of hollow rectangles with each side parallel to a direction of the form <100> or <110>, as previously described.[1] For most of the crystals constants were determined at −196°C, 22°C and 200°C. For the two copper-nickel alloys (13 and 24 percent copper), K_1 was determined at a series of temperatures between −196 and 20°C and was found to obey the law: $K_1=K_{10}e^{-\alpha T^2}$, found to hold for nickel.[2] This relation permits extrapolation to 0°K. The constant so obtained (K_{10}) falls off rapidly with increasing copper content. In the iron-nickel series the composition for zero anisotropy is found to be near 70 percent nickel. Comparison is made with the data of others.[3]

[1] H. J. Williams, Phys. Rev. **52**, 747–51 (1937).
[2] N. L. Brukhatov and L. V. Kirensky, Physik. Zeits. Sowjetunion **12**, 602–9 (1937).
[3] J. D. Kleis, Phys. Rev. **50**, 1178–81 (1936).

8. Theoretical Constitution of Metallic Beryllium. CONYERS HERRING* AND A. G. HILL, *Massachusetts Institute of Technology.*—Preliminary results have been obtained in a theoretical calculation of the binding energy of metallic beryllium by the method of Wigner and Seitz. Assuming that the Fermi energy of an electron with wave vector k is proportional to k^2, the calculated binding energy is about 65 kcal./g atom. This can be compared with the value of 75 kcal./g atom estimated by means of the Born cycle method.[1] The ratio of the Fermi energy in the metal to that for completely free electrons in this approximation is 0.62, calculated by the method of Bardeen.[2] Calculations of the energies of some of the electronic states near the top of the Fermi distribution show that the above assumption is not very good, and that the final computed value of the binding energy may be expected to be much larger than 65 kcal./g atom.

* National Research Fellow.
[1] Bichowsky and Rossini, *Thermochemistry of the Chemical Substances* (1936).
[2] J. Bardeen, J. Chem. Phys. **6**, 367 (1938).

9. On the Theory of Paramagnetic Relaxation. J. H. VAN VLECK, *Harvard University.*—The times of relaxation associated with the transfer of energy between spin and lattice are computed for a specific model, *viz.* a titanium or chromium ion surrounded by six water dipoles, which was previously used by the writer[1] in connection with static susceptibilities. An explanation is obtained of why titanium alum shows[2] no dispersion at radio frequencies at liquid-air temperatures. However, the calculated relaxation time for titanium at helium temperatures is considerably greater than the value computed by Kronig,[3] and far too large for agreement with experiment[4] unless the elevation of the lowest excited states is of the order 10^2 cm^{-1}, rather than 10^3 cm^{-1} as apparently indicated by magnetic theory.[1] The calculated relaxation times for chrome alum are also probably somewhat too high, but the discrepancy is not as great. The use of a definite model thus apparently does not alleviate all the difficulties encountered in previous rather schematic calculations.[3, 5]

[1] J. H. Van Vleck, J. Chem. Phys. **7**, 61, 72 (1939).
[2] Gorter, Teunissen and Dijkstra, Physica **5**, 1013 (1938).
[3] R. de L. Kronig, Physica **6**, 33 (1939).
[4] W. J. de Haas and F. K. du Pre, Physica **5**, 969 (1938).
[5] I. Waller, Zeits. f. Physik **79**, 370 (1932); W. Heitler and E. Teller, Proc. Roy. Soc. **155**, 629 (1936).

10. A Theory of Ferromagnetism. P. R. WEISS AND J. H. VAN VLECK, *Harvard University.*—An approach to the problem of ferromagnetism different from the well-known Heisenberg approximation can be obtained from Bethe's[1] method for calculating the critical constants of the ordering phenomena in alloys. The interaction between a central atom and its nearest neighbors is taken into account rigorously while the effect of the atoms outside this first shell, which is supposed to be exerted on the central atom only through the first shell, is approximated by a Weiss field which acts only on the first shell. The central atom is exposed only to the external applied field. The Weiss field is then determined as a function of the external field simply by equating the moments of the central atom and of an atom in the first shell calculated in their respective fields. The critical point is that temperature at which the ratio of the Weiss field to the external field becomes infinite. Several lattice types have been investigated and their results will be given. An expansion of the partition function

in powers of J/KT (J=the exchange integral) makes possible a comparison of the method with the rigorous theory as developed by Opechowski.[2]

[1] H. A. Bethe, Proc. Roy. Soc. **A150**, 552 (1935).
[2] W. Opechowski, Physica **4**, 181 (1937).

11. The Lack of "Sucking" Action by the Cathode Blast of Mercury Vapor in a Pool Rectifier. L. TONKS, *General Electric Company.*—Experiments of von Engel and Steenbeck[1] point to a "sucking" action by the blast of mercury vapor leaving the cathode pool of a rectifier which operates on the side arms to reduce the vapor in them to but a small fraction of its value in the condensing dome. This effect has been sought using ionization gauges on a side arm and at the top of the condensing dome and using thermocouples on the tube wall at the mercury condensation edge and at the top of the dome. The rectifier used had a dome capacity of 2.2 liters and a diameter of 7.7 cm at the side arms which were 5 cm in diameter. Both with free and anchored cathode spot *no trace of "sucking" action was found.* Theory gives a maximum decrease of pressure to $\frac{1}{2}$ the dome value, compared to the value $\frac{1}{16}$ found by von Engel and Steenbeck. The experiments showed that with the anchored spot the vapor pressures were only $\frac{1}{2}$ to $\frac{1}{3}$ what they were with the free spot but that the wall temperatures were higher. Both factors are explained by the evaporation of the spray thrown by the free spot onto the hot tube walls.

[1] M. Steenbeck, Wiss. Veröff. a. d. Siemens-Werken **15** (3), 42 (1936).

12. Ultracentrifuge for Liquids.* A. VICTOR MASKET, F. W. LINKE AND J. W. BEAMS, *University of Virginia.*—The air-driven vacuum type tubular centrifuge[1] has been adapted to the separation of mixtures and solutions. The chamber surrounding the tubular centrifuge was evacuated to less than a micron to avoid heating. Vacuum pump oil was circulated by a pump first through a thermostat and then the vacuum-tight oil glands, rapidly enough to maintain the hollow shafts at constant temperature. This temperature was the same as that of the spinning tube. Machines with the air turbines above as well as below the vacuum chamber were used. The liquid material to be centrifuged entered at one end of the spinning tube through a hollow shaft at a continuous rate and was separated when it reached the other end into a light fraction at the center and a heavy fraction at the periphery. These two fractions flowed out of the spinning tube through separate partitions in a hollow shaft and were separately collected. A solid rod mounted coaxially and inside the spinning tube increased the efficiency. Auxiliary Oilite or Bakelite bearings prevented the materials being centrifuged from coming in contact with oil leaking from the vacuum-tight oil glands. All surfaces with which the material being centrifuged came in contact were stainless steel or gold plated.

* Supported by a grant from the Research Corporation.
[1] J. W. Beams, Rev. Sci. Inst. **9**, 413 (1938).

13. Separation of Bromine Isotopes by Centrifugation. RICHARD F. HUMPHREYS, *Yale University.*—A Beams air-driven ultracentrifuge has been used to obtain a partial separation of the bromine isotopes. The technique employed was that of "evaporative centrifuging" first suggested by Mulliken.[1] A working interpretation for the separation factor has been developed, and the theory given by Mulliken for the molecular weight gradient produced has been altered to cover the case of nonequilibrium set up by removal of the vapor from the rotor. There results an expression for rate of removal in terms of coefficient of diffusion of the gas and the degree of nonequilibrium. Ethyl bromide was centrifuged in a field of 388,000 g and removed in fractions of one-tenth, all transport of the material both to and from the rotor being accomplished by vacuum distillation to reduce evaporation losses to a minimum. The enrichments obtained have been determined spectroscopically by means of relative intensity measurements of isotopic lines in the spectra of AgBr and $H\,Br^+$.

[1] R. Mulliken, J. Am. Chem. Soc. **44**, 1033 (1922).

14. Formation and Properties of Unsupported Flowing Liquid Films. BRIAN O'BRIEN, *University of Rochester.*—If a continuous film of liquid is projected from a long narrow slot, the film will, in general, collapse a short distance beyond the orifice due to surface tension. This can be prevented by a suitable component of velocity of the emerging liquid. Such films in the form of figures of revolution are useful as transparent gas tight enclosures about high intensity light sources, the liquid serving as a light filter. A 10-kw carbon arc has been operated for many hours within a water film in the form of a cylinder 8 cm diameter and 25 cm high without break in the flowing film. If broken such a film immediately reforms. Cylindrical films up to 30 cm diameter and 60 cm length have been produced in thickness of approximately $\frac{1}{5}$ mm. Their properties have been studied in some detail.

15. The Striated Luminous Glow of the Piezoelectric Quartz Resonator at Flexural Vibration Frequencies. J. R. HARRISON AND I. P. HOOPER, *Tufts College.*—Previous work has shown that the luminous glow due to the electrical discharge of a piezoelectric quartz resonator when vibrating in vacuum is sometimes striated in an unexpected way. This has been observed with X cut quartz rods vibrating at flexural vibration frequencies in the XY plane of the crystal. Double exposure photographs of this phenomenon are now shown which indicate the form and position of the striations on the quartz rod. The pressure of the residual gas and the applied voltage both have a marked effect on the position and number of the striations as is shown.

16. Nuclear Isomers in Radioactive Strontium. DAVID W. STEWART, *University of Michigan. (Introduced by J. M. Cork.)*—A further investigation has been made of the isomeric forms of Sr^{89} obtained in the bombardment of strontium with deuterons or neutrons. In agreement with earlier results,[1] the two periods of 3.0 hours and 55 days assigned to this isotope have been found to decay with the emission of negative electrons, producing stable Y^{89}. Accompanying the three-hour beta-activity is gamma-radiation, which is particularly interesting because it is complex and therefore of importance in interpreting the

nature of the isomerism. The energy of this radiation has now been determined by the measurement of recoil electrons ejected from a carbon radiator in a 12-inch cloud chamber. From a distribution of 475 tracks, at least two gamma-ray lines have been identified, with energies of 0.55 and 1.1 Mev, and relative intensities of at least 3 : 1. This intensity ratio may actually be much greater, and may approach 10 : 1. By combining these data with those on the upper limits of the two beta-spectra, a tentative energy-level diagram has been derived which indicates that the metastable state of Sr^{89} decays in the three-hour period with beta-particle emission followed by gamma-radiation. The ground state of Sr^{89} decays directly in the 55-day period.

[1] D. W. Stewart, J. M. Cork and J. L. Lawson, Phys. Rev. **52**, 901 (1937).

17. The Band Structure of Metallic Copper. MARVIN CHODOROW, *Massachusetts Institute of Technology.*—A general method of calculating wave functions and energies of electrons in crystals, due to Slater,[1] has been further developed and applied to Cu. In this method, the wave function inside the inscribed spheres of the atomic cells is expanded in a series of radial functions and spherical harmonics. Outside these spheres, where the potential is approximately constant, the wave function is expanded in a series of plane waves. The method is found to be feasible only for highly symmetrical points of the Brillouin zone, e.g., $k=2\pi/a(0,0,0)$, $2\pi/a(\frac{1}{2},\frac{1}{2},\frac{1}{2})$, $2\pi/a(0,0,1)$. For other values of k, the calculations become too cumbersome. In the application to Cu, the potential used was not a Hartree self-consistent field but a semi-empirical potential obtained from consideration of the solutions (for $l=2$) of the Fock equations for Cu^+. This potential partially takes into account the exchange interaction of a "d" electron with the other electrons of the atom. The width of the bands containing the "d" electrons is found to be appreciably narrower (about 1.7 ev) than those calculated by Krutter.[2] The conduction band is very similar to one containing free electrons, but is split into two sections by the perturbations of the other bands.

[1] J. C. Slater, Phys. Rev. **51**, 846 (1937).
[2] H. Krutter, Phys. Rev. **48**, 664 (1935).

18. Reducing the Reflection from Glass by Multilayer Films. C. HAWLEY CARTWRIGHT AND A. FRANCIS TURNER, *Massachusetts Institute of Technology.*—The reflecting power of a glass surface may be reduced to substantially zero by a film having an optical thickness of about 1250A and an index of refraction of 1.2 to 1.3. The Lorentz-Lorenz equation indicates that the index of refraction can be lowered by decreasing the density and indeed the index of any evaporated material can be decreased to the desired value by controlling the evaporating conditions. However, a decrease in density below normal is accompanied by a decrease in mechanical strength, seriously limiting the number of the materials suitable for rugged single films. Zero reflection by the use of a single film occurs when the two reflection vectors add to zero. This result can also be attained by the use of multilayer films so applied that the three or more reflection vectors add to zero. An abnormally low index of refraction is no longer required and a greater choice both of film materials and methods of application is possible. A rather rugged transparent film which practically eliminated reflection of visible light was made by evaporating sapphire and then quartz.

19. The Rossi Transition Curve for Small Angle Showers. W. M. NIELSEN, *Duke University.*—A study has been made of shower production in layers of iron over a range of thicknesses up to 320 g/cm². Simultaneous measurements of 7° showers and 28° showers were made with a counter arrangement similar to that recently employed.[1] With this arrangement a minimum of two particles from the producing material is necessary to discharge the four counters. The results differ somewhat from those of Schmeiser and Bothe[2] in showing no significant increase in the prominence of a second maximum at about 220 g/cm² on the 7° curve compared with the larger angle shower curves. We conclude that the processes which contribute to the showers which are observed at the possible second maximum are not necessarily restricted to small angles.

[1] Karl Z. Morgan and W. M. Nielsen, Phys. Rev. **52**, 564 (1937).
[2] Schmeiser and W. Bothe, Ann. d. Physik **32**, 161 (1938).

20. The Design and Construction of Reliable Geiger-Müller Counters. GORDON L. LOCHER, *Bartol Research Foundation of the Franklin Institute.*—Some general features of design and construction of Geiger-Müller counters which are stable over long periods of use are reviewed, and some criteria for discrimination between acceptable and unacceptable practices are discussed on the basis of experience with the production of more than 1500 tubes. Desirable practices in the construction of ordinary γ- and β-ray tubes include: (1) the exclusive use of clean (heated) bare tungsten wires, (2) shielding of welds to prevent breakdown at sharp points, (3) removal of moisture and grease from all internal surfaces, (4) removal of any material from the cylinder which may become transferred to the wire, in use, (5) treatment of all internal surfaces to eliminate free alkali metals, or materials that may generate them, in use, (6) elimination of photoelectric response of the cathode to any light that can penetrate the glass envelope, (7) establishment of very high surface resistance of all internal insulating surfaces, (8) use of a gas content whose pressure is not too low and whose constitution will not alter with use, (9) avoidance of dust inside the tubes, and (10) the treatment of the external surface of the glass envelope to make the surface resistance extremely high. The localized character of the discharge of a normal counter (especially the high current density at the wire) makes it imperative that excessive current shall not be allowed to pass through the tube, in operation. It is pointed out that the probability of production of a spurious discharge in a faulty counter is usually highest immediately after a previous discharge; hence such counters may seem to have "high sensitivity" to radiation, and a relatively low background rate, whereas they are unreliable, and worthless for measurements. Some experiments with gas mixtures are discussed.

21. Comparison of Counter and Electroscope Measurements in the Stratosphere. S. A. KORFF AND W. E. DANFORTH, *Bartol Research Foundation of the Franklin Institute.*

—Comparison of the several methods of measuring cosmic-ray intensities in the stratosphere is presented. It is shown that the results obtained by Millikan[1] using an electroscope and those found by Korff and Johnson[2] at about the same geomagnetic latitude using single Geiger counters are in good agreement. A geometrical factor is computed in order to take account of the different distributions of sensitive volume in the two cases. This comparison indicates that the correction to the electroscope observations due to the passage of simultaneous shower particles (or of single rays of great ionization) through it is less than ten percent. The observations of Korff, Curtiss and Astin[3] using low pressure counters are also found to agree with those of Millikan. It can be shown that such low pressure counters measure a quantity statistically proportional to the intensity observed with electroscopes. In so doing they take account of the passage through the counter of simultaneous shower rays and of rays of high specific ionization, while high pressure counters measure the number of ionizing events independently of the size of the event. The counter measurements made by Swann, Locher and Danforth[4] are found to be consistent with the electroscope measurements made by Millikan on the Settle-Fordney flight, but both give higher intensities at great altitudes than is found in the counter and electroscope flights made with small balloons. Hypotheses to explain this difference are discussed.

[1] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **53**, 855 (1938).
[2] S. A. Korff and T. H. Johnson, Abs. Phys. Soc., Dec. 1938.
[3] S. A. Korff, L. F. Curtiss and A. V. Astin, Phys. Rev. **53**, 14 (1938).
[4] W. F. G. Swann, G. L. Locher and W. E. Danforth, J. Frank. Inst. **222**, 673 (1936).

22. The Origin of the Rays Which Produce the Bursts of Cosmic-Ray Ionization. C. G. MONTGOMERY AND D. D. MONTGOMERY, *Bartol Research Foundation of the Franklin Institute.*—The transmission through the atmosphere of the electrons and photons necessary to produce the observed size-frequency distribution of large bursts of cosmic-ray ionization is investigated. From the observations that the size-frequency distribution of bursts is independent of elevation, while the variation with elevation of the total number of bursts is not exponential, we conclude that the burst producing electrons are *not* transmitted through the atmosphere by the mechanisms of the cascade theory, but that in the lower atmosphere there must be a considerable number of electrons of high energy which are secondary to a penetrating component of the cosmic radiation. This conclusion is strengthened by observations of large showers from the air. It seems likely that these showers are also of secondary origin, since the spreading that a primary cascade would experience in traversing the atmosphere makes it unlikely that the observed high density of rays would occur by this process.

23. Electrophoretic Demonstration of Patent Pores of Human Skin. HAROLD A. ABRAMSON, *The Biological Laboratory, Cold Spring Harbor, and Mt. Sinai Hospital, New York.*—To investigate the paths by which the electrophoretic introduction of drugs into the intact human skin occurs, dyes of different charge like methylene blue and sodium prontosil were employed. Following electrophoresis of $\frac{1}{2}$ percent methylene blue, the skin appears grossly to be uniformly dyed. The pattern of the patent pores which take a major part in the electrical transport of substances into the skin may then be developed by rubbing and washing vigorously to remove the most superficial layers of the skin. The developed pattern consists of many small uniformly stained, blue spots from about 0.07 mm to 0.5 mm in diameter. Practically all of the spots are at the site of the orifices of sweat glands (pores). Similar patterns are therefore obtainable in the palm of the hand. The patterns persist for several weeks. During this time, the uniformly dyed pores decolorize in the center with the formation of circular or elliptical blue rings, doughnut forms, which surround the pore orifices. The pore pattern with negatively charged prontosil corresponds to the methylene blue pattern but persists only a few days. These results confirm the liquid bridge theory of skin permeability of Abramson and Gorin for the electrical transport of ragweed protein into the skin.

24. Compact Pressure-Insulated Electrostatic X-Ray Generator for Cancer Therapy. J. G. TRUMP AND R. J. VAN DE GRAAFF, *Massachusetts Institute of Technology.*—A compact, pressure-insulated, electrostatic x-ray generator has been developed for use in cancer treatment and research. A further object of the work was the investigation, using a small and thus flexible machine, of the design factors involved in pressure-insulated electrostatic generators with a view to the subsequent development of higher voltages in compact apparatus. The generator is housed in a steel tank 34 in. in diameter and 100 in. high. At air pressures of 10 atmospheres gauge, 1250-kv x-rays are obtained with currents of one milliampere on the single 14-in. belt. A substantial increase in voltage can be obtained by the use of Freon gas. The dependence of voltage and current on pressure and on gas is discussed. The problem of belt charge is analyzed and a method is described for controlling the electrostatic fields within the column in order to realize the high charge densities possible at high pressure. The construction of a supporting column of high breakdown strength, of the x-ray tube, and other features of the design are described. At 1250 kv the x-ray intensity per milliampere of target current is 250 roentgens per minute at 50 cm from the target in the direction of the electron beam with two-mm lead and five-mm copper filtration. The present work follows the development of a 1000-kv, air-insulated, x-ray source* which has been in use for almost two years at the Huntington Memorial Hospital.

* J. G. Trump and R. J. Van de Graaff, J. App. Phys. **8**, 602 (1937).

25. A Measurement of Gamma-Radiation in Roentgens. T. N. WHITE, *National Cancer Institute;* L. MARINELLI AND G. FAILLA, *Memorial Hospital, New York.*—For the measurement of gamma-rays in roentgens, certain requirements must be fulfilled. Heretofore most measurements of this type have been made by "thimble chambers" of small size placed at a distance from the source. The necessary condi-

tions may be met also by a different geometrical arrangement of source and ionized volume, which offers certain advantages. With a small gamma-ray source at the center, measurements were made of the ionization in spherical air shells of thickness 0.04 to 3.5 cm and inner radii of 1 to 3.8 cm approximately. The air shells were defined by Lucite shells of suitable thickness. The gamma-ray output of radium in roentgens was obtained from these measurements by extrapolating to zero thickness of the air shell. By extending Lauritsen's analysis[1] of the influence of geometrical factors, a formula was derived which supplies a partial explanation of the variation of ionization in the air shells with respect to thickness.

[1] C. C. Lauritsen, Brit. J. Radiol. 11, 471 (1938).

26. A Portable Gamma-Ray Detector. L. MARINELLI, *Memorial Hospital, New York.*—The use of a commercial grid glow tube (KU 618) as a point counter will be described. The circuit requires essentially a 0.01-mf condenser, a resistance of five megohms and a source of potential of about 200 volts. The instrument provides a rather inexpensive means for the detection of gamma-ray sources and stray radiation as well as for demonstrations in radioactivity. An a.c. operated instrument, provided with a counting circuit and weighing seven pounds, will be shown. In its present form the natural counting rate of the device increases tenfold when exposed to the gamma-radiation of five mg of radium at a distance of five meters.

27. Some New Features in the Million-Volt X-Ray Installation at the Memorial Hospital. G. FAILLA, *Memorial Hospital, New York.*—The General Electric Company announced recently the completion of a million-volt x-ray generator to be installed in the new Memorial Hospital. For the accurate treatment of patients it is very desirable that the beam of radiation be adjustable in direction through 90° in a vertical plane. Since the generator weighs about two tons it is simpler to move a "collimator" with respect to the tube target. If the collimator is made of overlapping five-inch thick lead plates the device becomes too cumbersome. To provide a beam of x-rays which is adjustable both as to direction and cross section, the target is surrounded by a mercury tank into which is inserted at the appropriate angle a hollow "cell" of the proper shape and size. It is important to keep the patient under observation during the treatment. To accomplish this a window is provided in the thick concrete wall at one corner of the treatment room. A glass cell which fits into this window is filled with a transparent salt solution of sufficient absorptive power to protect the observer from scattered x-rays.

28. The Effect of Pressure on the Intensity of the Recombination Spectrum of Mercury. ROBERT C. GARTH, *Brooklyn College;* GEORGE E. MOORE, *Bell Telephone Laboratories;* AND HAROLD W. WEBB, *Columbia University.*—The effect of vapor pressure on the intensity of spectral lines in the recombination glow of mercury vapor was investigated. The pressure was varied from 0.1 mm to 1.7 mm and the concentration of ions maintained at approximately 2.5×10^{11} per cc as measured by the Langmuir probe method. The combined intensity of 5461 and 5770–90 was measured with a photometer, and photographic methods were used for measuring other lines in the visible and ultraviolet. It was found that the intensities in general increased with pressure, although the exact behavior of a line depended on its position in the spectral series. This result indicates that the rate of recombination is a function of the concentration of the neutral atoms as well as of the recombining ions and electrons, or that the metastable and other excited atoms influence recombination. The band spectrum of mercury was observed at pressures above 1.0 mm.

29. The Spectral Distribution of Energy in the Recombination Spectrum of Mercury. GEORGE E. MOORE, *Bell Telephone Laboratories;* ROBERT C. GARTH, *Brooklyn College;* AND HAROLD W. WEBB, *Columbia University.*—The distribution of energy in the recombination (afterglow) spectrum of Hg was measured in the spectral range from 2200A to 20,000A. The relative intensity of the strongest lines was found to vary in much the same way as in the arc. The intensity of the higher lines was relatively much stronger than in the arc so that the computed population of some of the higher energy levels was greater than for the lower levels in the same series. By determining the quanta due to radiative transitions into and out of various spectral levels, it was shown that most of the recombination occurred directly into the levels about 1.5 to 2.5 volts below the ionization potential. Continua were observed beyond the limits of eight different series, all being much less intense than the strong lines of the series. The dependence on the concentration of ions was studied and it was found that the intensity of the higher lines increased more than that of the lower. Recombination coefficients were calculated from the absolute intensities.

30. Spectra of SnH and PbH at High Pressure. W. W. WATSON AND R. SIMON, *Yale University.*—Although no band spectra are produced by Sn or Pb arcs in hydrogen at low pressure, a number of SnH and PbH band systems appear in a d.c. arc in hydrogen at four to five atmospheres pressure. A (0,0) $^2\Delta\rightarrow{}^2\Pi$ transition for SnH has first heads at 4054A and 4447A. The analysis gives $B=5.31$, $A=2182.7$ for $^2\Pi$, $B=4.91$, $A=-1.75$ for $^2\Delta$ and shows a sharp cut-off at $K'=17$. The apparently analogous transition for PbH occurs in the near ultraviolet, one principal head lying at 3810A. In the red and infra-red regions both molecules have spectra with unique intensity anomalies, such as a variation in the relative intensities of band branches with v, probably attributable to a near approach to case c conditions. The PbH red spectrum already described[1] has been extended to 9100A, revealing an additional electronic transition. The operation of the high pressure arc and its usefulness in the investigation of molecular spectra are discussed.

[1] W. W. Watson, Phys. Rev. 54, 1068 (1938).

31. Binding Energy of He^6 and Nuclear Forces. HENRY MARGENAU, *Yale University.*—The binding energy of He^6 is known from the experiments of Bjerge and Broström. In all probability, the ground state of this nucleus is a ^1S state, while the normal state of Li^6 is ^3S. The difference in the binding energies of these two nuclei which is due to the specific nuclear forces (after correction for the difference in the Coulomb energies) is known to be 3.7 ± 0.7 Mev. This value is nicely accounted for theoretically with the use of the customary nuclear parameters if the calculation is carried as far as the Feenberg-Wigner approximation.[1] The question arises as to the value of this difference when excited states are included in the perturbation calculation of the energies of the two nuclei. To answer it, a computation has been made for the ^1S state of the six-body problem similar to that for Li^6.[2] All doubly-excited states, but no others, were included. In zeroth order one obtains for the difference in the binding energies: $\Delta=2g(1-2u+5u^2)(\sigma u)^{3/2}(35.6)$ Mev, and this is equal to 3.7 Mev if the minimizing parameter σ has the same value as for Li^6 (1.4) and g, the ratio of Heisenberg to Majorana forces, is taken to be 0.23. However, with the inclusion of the doubly-excited states, the value of Δ drops to 1.26 Mev for $g=0.20$, to 1.53 Mev for $g=0.25$. Hence the agreement obtained in the Feenberg-Wigner approximation, which gives a very poor answer for the total binding energy of Li^6, is considerably disturbed when attention is given to excited states.

[1] E. Feenberg and E. Wigner, Phys. Rev. **51**, 95 (1937).
[2] H. Margenau and K. G. Carroll, Phys. Rev. **54**, 705 (1938).

32. The Theoretical Binding Energy of He^5. WARREN A. TYRRELL, JR., *Yale University.*—The binding energy of the unstable nucleus He^5 has been calculated both perturbationally and variationally. The functions employed are single particle Legendre functions. The zero-order approximation corresponds to an alpha-particle in the ground state and a p neutron. With values of the nuclear constants previously used,[1] H_{00} is -11.5 Mev. The second-order perturbation contributions of the doubly and quadruply excited functions lower this to -17.8 Mev. The convergence limit for functions of all degrees of excitation will be discussed. Variational calculations have been made with two variation parameters, one for four s particles forming an alpha-particle, and one for a p neutron. With the simplest symmetrized wave function, the plot of the energy E against the two variation parameters shows no minimum. For values of the alpha-particle parameter compatible with He^4 alone, the plot of E against the neutron parameter is almost horizontal for a certain range of the latter. This is in accord with expectation; moreover, the value of E in this region is in fair agreement with the experimentally determined instability.[2] A more refined variational calculation is in progress.

[1] H. Margenau and W. A. Tyrrell, Phys. Rev. **54**, 422 (1938).
[2] J. H. Williams, W. G. Shepherd and R. O. Haxby, Phys. Rev. **52**, 390 (1937).

33. Energy Levels of H^3, He^3 and He^5. KATHARINE WAY, *Bryn Mawr College.*—Wheeler's method of resonating groups was applied to the three-body nuclear problem. Particles 1 and 2 are considered the like particles. The wave function Ψ is then written:

$$\Psi=S_1F[(r_2+r_3)/2-r_1]\varphi(r_3-r_2) - S_2F[(r_1+r_3)/2-r_2]\varphi(r_3-r_2)$$

where the S's are appropriate spin functions and the φ's are deuteron wave functions which were found by numerical integrations of the deuteron wave equation. F is determined by the requirement that $E=\int\psi^*H\psi d\tau/\int\psi^*\psi d\tau$ be a minimum. V_{ij} was written $V_{ij}=-Ae^{-ar_{ij}^2}[(1-g-g_1-g_2)P_{ij}{}^M+gP_{ij}{}^H+g_1]+g_2P_{ij}{}^B]$ with $A=72\ mc^2$ and $1/a^{\frac{1}{2}}=2.25\times10^{-13}$ cm, and $g+g_2=0.22$. In the He problem the Coulomb term was added to V_{12}. For the state $S=\frac{1}{2}$, $L=0$, $g+g_2$ is the only important combination. The calculated energies of this state are -6.1 mMU for He^3 and -6.7 mMU for H^3. Experimental binding energies are 8.1 and 8.9 mMU, respectively. For the state $S=3/2$, $L=0$, $1-3g_1-3g_2$ is the decisive factor. Values of this combination which lead to bound states will be discussed. In the five-body problem when an approximate wave function $Ze^{-\beta R^2}$ (P state) was used for $F[(r_1+r_2+r_3+r_4)/4-r_5]=F(R)$ no virtual level of He^5 was found for any reasonable value of $1+g-5g_1-3g_2$.

34. A Study of Radioactive Be^7. J. E. HILL AND G. E. VALLEY, *University of Rochester.*—This isotope[1] (43 day) has been formed by bombardment of Lithium with protons of energies up to 6.5 Mev. The threshold for the reaction Li^7 (p, n) Be^7, determined by studying the 2.3-min. activity induced by the neutrons in silver plus paraffin, is 1.75 ± 0.05 Mev. This means that the mass of Be^7 exceeds that of Li^7 by 1.0 ± 0.05 Mev. The γ-ray spectrum of Be^7 is being closely examined both by cloud chamber and magnetic spectrograph to determine whether or not radiation other than the prominent 0.44 Mev line is present. In order that these results may not be inconclusive, the secondary electrons measured are recoils from aluminum 25 mg/cm² thick. If such radiation (e.g. annihilation) is present, its intensity is less than ten percent of the 0.44-Mev line. A Be^7 source less than one mg/cm² thick, and emitting about 10^4 quanta/sec., showed no definite evidence of positron emission, when examined in a cloud chamber filled with hydrogen at 110 cm Hg pressure. This is in agreement with previous results, and with the mass difference determined from the $p-n$ threshold.

[1] L. H. Rumbaugh, R. B. Roberts and L. R. Hafstad, Phys. Rev. **54**, 657 (1938).

35. On the Self-Energy of the Electron. VIKTOR WEISSKOPF, *The University of Rochester.*—The self-energy of the electron can be divided into two parts: the energy of the electrostatic field of the charge distribution and the energy of the interaction with the radiation field. It can be shown that in the quantum theory for a single electron the first part diverges linearly, as one expects for a charge with infinitely small radius. In the positron theory, however, this energy diverges logarithmically, which can be explained by the peculiar interaction between the electron and the vacuum. This effect is essentially connected with the exclusion principle. Any theory of particles with Bose

statistics leads to a quadratically divergent electrostatic self-energy. The energy of interaction with the radiation field is mainly due to the oscillations of the electron under the influence of the field fluctuations of the empty space. This energy diverges quadratically. In the positron theory, however, this term is canceled by another energy term, due to the current fluctuations of the vacuum. Here again the exclusion principle is essential. In Bose statistics the corresponding term has opposite sign, so that the total electrodynamic self-energy also diverges quadratically. Thus the "critical length" in the positron theory is about $l \sim (h/mc)e^{-137}$ whereas a theory with Bose statistics leads to $l \sim (h/mc)(137)^{-\frac{1}{2}}$.

36. Competition Between $p-n$ and $p-\gamma$ Reactions. CHARLES V. STRAIN, *The University of Rochester.*—When nickel is bombarded by high energy protons Cu^{61} (3.4 hr.), Cu^{62} (10.5 min.) and Cu^{64} (12.8 hr.) are formed. Each of the first two activities might be formed by either a $p-\gamma$ or a $p-n$ reaction; namely, (1) $Ni^{60}(p-\gamma)Cu^{61}$, (2) $Ni^{61}(p-n)Cu^{61}$ (threshold 2.9 Mev), (3) $Ni^{61}(p-\gamma)Cu^{62}$, (4) $Ni^{62}(p-n)Cu^{62}$ (threshold 4.6 Mev).

In a previous article[1] evidence was given that Cu^{62} was formed by (3) at proton energies below the threshold for reaction of (4). A cloud-chamber study of the positron spectra confirms this conclusion. With proton energies above the threshold of (2) (2.9 Mev) Ni^{61} can be transmuted by either a $p-\gamma$ or a $p-n$ reaction. From the excitation curves of the Cu^{61} and Cu^{62} activities the relative probabilities of the two reactions can be obtained in the energy range of 2.9 to 4.6 Mev. The ratio of the intensities of the $p-\gamma$ to the $p-n$ reaction of the nucleus Ni^{61} can be computed after correcting for the disturbing effect of the Ni^{60} $p-\gamma$ effect. This ratio falls sharply from a high value at three Mev to a value much smaller than $\frac{1}{3}$ at 4.5 Mev. This is a good illustration of the rapidly increasing probability of neutron emission with increasing velocity of the neutron.

[1] C. V. Strain, Phys. Rev. **54**, 1021 (1938).

37. Resonance Scattering of Protons by Lithium. EDWARD CREUTZ, *University of Wisconsin. (Introduced by G. Breit.)*—The scattering of protons from a thick lithium target has been studied in the energy region 260–600 kev at a scattering angle of 156°, using a ball counter. The number of counts per microcoulomb at 458 kev is 2.1 times the value at 408 kev and at 486 kev it has dropped to 1.41 times the value at 408 kev. The observed resonance peak is distorted by absorption of protons scattered deep in the target, but this effect is least for the low energy side, where the curve shows a maximum slope at the same proton energy as the lithium gamma-ray resonance within ±5 kev. Since the effect of absorption tends to move the maximum slope to lower energy, the lower limit of the scattering resonance maximum at 156° is 435 kev, assuming 440 kev as the resonance maximum for the 17-Mev gamma-radiation. The scattering from a thick Be target was found to increase smoothly with energy showing that the resonance effect is not a peculiarity of the counter. This scattering anomaly has been suggested by Professor Breit to indicate that the gamma-radiation obtained when Li^7 is bombarded with 440-kev protons arises from a virtual level of Be^8, and not from an excited alpha-particle, a previously tenable alternative hypothesis.

38. The Scattering of Neutrons by Hydrogen and Deuterium Molecules. MORTON HAMERMESH, *New York University,* AND JULIAN SCHWINGER, *Columbia University.*—The general method of treating the scattering of neutrons by molecules, taking account of the spin dependence of nuclear forces and the symmetry properties of molecules containing several identical particles, has been given by Schwinger and Teller, and applied by them to H_2. We have extended their calculations to a wider range of neutron energies and to several other transitions, and applied them to an analysis of the experimental data of Dunning *et al.* We find that their data can be fitted with a neutron-proton scattering cross section of $(20\pm2)\cdot10^{-24}$ cm², verifying the result obtained by direct measurement; but simultaneous agreement for both *ortho* and *para* H_2 can be obtained only by assuming a departure from thermal equilibrium in the form of a decreased number of neutrons in the region below ~0.01 ev and a possible high energy "tail." The larger value of the neutron-proton cross section increases the elastic scattering of *para* H_2, and makes it more susceptible of measurement. It has already been emphasized that such experiments would enable a determination of the range of the neutron-proton interaction in the triplet state. Calculations have been made for the scattering by *ortho* and *para* D_2, assuming various values of the scattering amplitudes for the doublet and quartet states. From such measurements, the values of these amplitudes may be deduced, thus affording an important source of information concerning nuclear forces.

39. The Scattering of D−D Neutrons. S. SEELY, W. H. ZINN AND V. W. COHEN, *Columbia University.*—Measurements of the total scattering cross sections of various elements for the 2.8-Mev neutrons from the D−D reaction previously reported by us[1] have been extended to a greater number of elements. The cross sections vary quite irregularly with atomic weight. Measurements of the cross sections of some elements for 2.4-Mev neutrons have also been made. Oxygen, in particular, showed a change in cross section with the change in energy of the incident neutrons. The neutron detection system consists of a small helium-filled ionization chamber two cm in diameter at a distance of 32 cm from the target. The ionization chamber is coupled to a linear amplifier, the associated scaling unit being so adjusted as to record only those pulses, as observed in an oscillograph, approximately twenty times the background.

[1] W. H. Zinn, S. Seely and V. W. Cohen, Phys. Rev. **53**, 921(A) (1938).

40. Elastic Scattering of Fast Neutrons. R. F. BACHER, *Cornell University.*—Experiments have been carried out to ascertain the albedo effect of fast neutron scattering by

Pb. The source of neutrons was a Be target located in a brass tube outside the cyclotron chamber proper, and bombarded with 5 to 10 μa of 1.5-mv deuterons. Fast neutrons were detected by a Cd-shielded Al detector which gave the 10-minute period of Mg^{27}. The activity of the detector which was placed four cm from the source was taken with and without Pb surrounding detector and source. When Pb was placed between source and detector, activity was reduced to 65 percent. When both source and detector were surrounded with Pb there was a slight increase in activity. The slight increase observed may well be due to the difficulty of repeating the irradiation. This result indicates that at least the greater part of the scattering is inelastic, with loss of energy by the neutrons sufficiently large so that they no longer activate the Al. This result is in agreement with the large energy losses observed for neutrons which have passed through Pb, but is in disagreement with various determinations* of the amount of elastic scattering which indicate from 60 to 90 percent.

* D. C. Grahame and G. T. Seaborg, Phys. Rev. **53**, 795 (1938); E. Hudspeth and T. W. Bonner, Phys. Rev. **53**, 928(A) (1938).

41. The Ionization Produced in Gases by Fast Neutron Irradiation. PAUL C. AEBERSOLD* AND GLADYS A. ANSLOW,** *University of California.*—A collimated beam of fast neutrons was directed along the axis of a cylindrical, brass ionization chamber of 100 cc volume and the ionization produced in fourteen gases at pressures from three mm of Hg to three atmospheres was investigated using an electrometer tube measuring device. The source was beryllium bombarded by deuterons accelerated to eight Mev in a cyclotron. The collimation was achieved by a channel through a water tank, the channel and the outside of the tank having thick walls of Pb to absorb gamma-rays produced in or scattered from the tank. To suppress gamma-rays from the source the beam was filtered through three cm of Pb. That the main ionization with such an arrangement is due to neutrons can be seen from the very different relative ionization in the various gases compared to that for gamma-rays alone. Moreover, calculations by two methods give small values for the percentage contribution by gamma-rays to the measured ionization. Subtracting this small contribution, the ionization due to neutrons alone is deduced and related to the values to be expected from the production of recoil nuclei in the gas by elastic scattering. The agreement with expectation using Dunning's cross sections is excellent except for N_2 and A for which disintegrations by neutron absorption are appreciable. The results show particularly that the relative ionization in various hydrogenous materials by fast neutrons can be closely approximated on the basis of elastic scattering of the neutrons.

* Fellow of the Finney-Howell Foundation.
** On sabbatical leave from Smith College.

42. On the Nuclear Moments of the Rubidium and Chlorine Isotopes. P. KUSCH AND S. MILLMAN, *Columbia University.*—A comparison of the ratios of the nuclear magnetic moments of two isotopes of the same element as obtained from an observation of hyperfine structure and as found by direct observation tests the validity of the assumption that magnetic interaction between the nuclear moment and the electronic structure is sufficient to explain observed h.f.s. splittings in atomic energy levels. We have applied the molecular beam resonance method to a measurement of the nuclear moments of Rb^{87} and Rb^{85}. Using Rb_2 molecules, the observed resonance minima and the known values of nuclear spins yield 2.730 and 1.340 as the moments of Rb^{87} and Rb^{85}, respectively, referred to the moment of Li^7, 3.250 nuclear magnetons. The observed ratio, $\mu_{Rb^{87}}/\mu_{Rb^{85}}=2.037\pm0.5$ percent, is to be compared with the ratio 2.026 ± 0.2 percent found by Millman and Fox,[1] who measured the h.f.s. of the ground states of the rubidium isotopes by the atomic beam zero moment method. In view of the precision of the present result it is not certain that this difference represents a real physical effect. The nuclear g's of Cl^{35} and Cl^{37} have also been measured. The g values of these two nuclei are 0.546 ± 0.5 percent and 0.454 ± 0.5 percent, respectively. The spin of Cl^{35} is probably 5/2 from the measurements of Elliott[2] on the alternating intensities in band spectra. The moment of Cl^{35} is then 1.365 nuclear magnetons. No information on the spin of Cl^{37} is available.

[1] S. Millman and M. Fox, Phys. Rev. **50**, 220 (1936).
[2] A. Elliott, Proc. Roy. Soc. **127A**, 638 (1930).

43. The Electric Quadrupole Moment of In^{115}. DONALD R. HAMILTON AND NICHOLAS A. RENZETTI, *Columbia University.*—The h.f.s. $\cos^2$ interaction ascribed to a nuclear electric quadrupole moment, Q, has been investigated in the $^2P_{3/2}$ metastable state of In^{115} using the zero moment method of atomic beams.[1] Schüler's and Schmidt's spectroscopic determination of Q, using this state,[2] utilizes three h.f.s. separations; the present method takes advantage of 13 observables, i.e., the fields for zero moment peaks arising from certain of the 40 magnetic levels. These peaks are sensitive to Q; order is reversed and peak ratios, often measurable to $\frac{1}{4}$ percent, are sometimes changed by 30 percent. Their behavior is completely described in terms of the nuclear g factor,[3] the electronic g factor, and constants of the equation $\Delta\nu_F=(aC/2)+bC(C+1)$ giving the position of the levels in zero field. $(C=F(F+1)-I(I+1)-J(J+1).)$ The first term is the usual interaction. The second arises from Q; the constant b, involving atomic wave functions, is directly proportional to Q. Observed peak ratios determine b/a to one percent; a is obtained by field calibration in terms of the first peak of the Cs ground state and the $\Delta\nu$ of this state, 0.3067 ± 0.0004 cm^{-1}.[4,5] We find $a=(8.11\pm0.04)\times10^{-3}$ cm^{-1} and $b=(0.0521\pm0.0007)\times10^{-3}$ cm^{-1}. This gives an actual h.f.s. separation 0.1186 ± 0.0007 cm^{-1}, or 0.1217 ± 0.0006 cm^{-1} for $Q=0$. Schüler and Schmidt give $a=7.97$, $b=0.048$, and total separation 0.120 cm^{-1}. Our b is eight percent higher than their 0.048, from which they deduce $Q=0.8\pm0.2$.

[1] V. W. Cohen, Phys. Rev. **46**, 713 (1934).
[2] H. Schüler and T. Schmidt, Zeits. f. Physik **104**, 468 (1937).
[3] I. I. Rabi, S. Millman and J. R. Zacharias, Phys. Rev. **53**, 384 (1938).
[4] L. P. Granath and R. K. Stranathan, Phys. Rev. **48**, 725 (1935).
[5] S. Millman and M. Fox, Phys. Rev. **50**, 220 (1936).

44. The Temperature in White Dwarf Stars. R. E. MARSHAK AND H. A. BETHE, *Cornell University.*—It is usually assumed that the temperature in a white dwarf is almost constant over the degenerate interior and changes appreciably only in the nondegenerate surface layer. For the temperature at the boundary of the two regions in Sirius B, values between $2\cdot10^7$ (Stromgren) and $6\cdot10^7$ degrees have been given. These values seem to be too high, due to the use of incorrect opacity laws. The actual opacity is 5 to 100 times less than the Kramers value, resulting in a boundary temperature of 0.8 to $1.0\cdot10^7$ degrees. In the interior the energy transport is mostly by conduction, conduction and radiation being about equally important at the boundary. There is an appreciable increase of temperature from the boundary to the center where $T\approx2.5\cdot10^7$ degrees. These high temperatures are only reconcilable with the observed small luminosity if the hydrogen content is very low. The transition region from nondegenerate to degenerate gas cannot be treated by the methods previously used in astrophysics which give much too low values for the density of free electrons. Instead, we propose to use the Thomas-Fermi equation with finite boundary conditions as for metals. This equation has been generalized to include the effect of finite temperature and a mixture of elements.

45. The Self-Energy of the Electron. H. A. BETHE, *Cornell University.*—It has never been decided whether the divergence of the self-energy of the electron is inherent in the fundamental equations of quantum electrodynamics or is due to the use of perturbation methods in their integration. We have found an almost exact method of integration for the particular case of the nonrelativistic Schrödinger theory. In this theory, only the A^2 term in the interaction between electron and (transverse) electromagnetic field need be considered but not the $A\cdot p$ term. In first approximation, the well-known result for the self-energy is obtained, *viz.*

$$W_1\approx\frac{hc}{r_0}\frac{e^2}{mc^2r_0}$$

where r_0 is the "cutting-off" radius. Successive approximations differ by a factor $\gamma=e^2/(mc^2r_0)$ and have alternating sign. For very large γ, perturbation theory is no longer valid; the radiation field will then in general contain many quanta. But just this fact can be used for the integration because the total energy of n quanta ($n\gg1$) will differ only slightly from its mean value of $2nhc/r_0$. Using this mean value instead of the actual energy, the rest of the integration can be carried out exactly and gives for the self-energy the value, $W\sim(hc/r_0)\gamma^{\frac{1}{2}}\sim r_0^{-\frac{1}{2}}$. This shows that the divergence is inherent in the fundamental equations and cannot be removed by improved methods of integration.

46. General Relativity Theory and Flat Space. N. ROSEN, *Massachusetts Institute of Technology.* (*Introduced by M. S. Vallarta.*)—At present it appears that gravitation is unimportant in the problem of the nucleus. It may be that it is actually of fundamental significance in determining nuclear forces but that existing theories have to be modified in order to show it. As a first step in the search for a suitable modification, the problem is considered of treating the general theory of relativity from the standpoint of an underlying flat space. In this way some properties of gravitational forces are obtained.

47. On Thermal and Stress Dependence of Elasticity in Solids. H. LUDLOFF, now at *Cornell University.* (*Introduced by H. A. Bethe.*)—Previously a method was devised by which the elastic constants are determined from the interference figures occurring in diffracting light from ultrasonics in solids. From the interference figures the directional dependence of thermal waves in an atomic lattice can also be directly obtained, so that in related thermodynamical investigations tedious calculations can be avoided. The original theoretical basis of the method can now be further generalized at two points: (1) The change in the interference figures, when the solid is transformed from the elastic to the plastic state, can now be quantitatively determined; and conversely from the observation of the changed interference figures the nonlinear relation between deformation and tension can be derived for any value of tensile stress. (2) Also the change of the interference patterns due to temperature dependence of the elastic constants can now be predicted from the more generalized derivation. Since for ultrasonics the change of the elastic behavior is very sensitive to temperature, the pattern behavior near the melting point should give, according to Brillouin, some information concerning the melting process.

48. Determination of the Nature of a Light Source from Wide-Angle Interference Experiments. O. HALPERN AND F. W. DOERMANN, *New York University.*—It has previously[1] been shown that wide-angle interference phenomena can be used to determine the nature of (electric and magnetic) multipoles which make up the light source. The interference pattern was found to depend in a characteristic matter on the geometrical arrangement, the optical properties of the mirrors used and the nature of the light source. Applying these considerations to a wide-angle interference experiment performed by Selenyi[2] the authors were able to determine the active centers in the fluorescence substance which served as source. The polarization properties of the pattern do not permit to decide whether the source consists of electric dipoles or magnetic quadropoles (which latter can, of course, be ruled out by other considerations). The dependence of the pattern on the angle of divergence of the two primary beams clearly shows that the source consists of electrical dipoles.

[1] O. Halpern and F. W. Doermann, Phys. Rev. **52**, 937 (1937); F. W. Doermann, Phys. Rev. **53**, 420 (1938).
[2] P. Selenyi, Zeits. f. Physik **108**, 401 (1938).

49. Measurement of X-Ray Production in the Range 0.8 to 2.0 Million Volts. L. C. VAN ATTA AND D. L. NORTHRUP, *Massachusetts Institute of Technology.*—Some preliminary focusing tests with an electron beam have been made in the accelerating tube of the Massachusetts Institute of Technology electrostatic generator in its new location in

Cambridge. In the course of these tests it has been possible to make some measurements on x-ray intensity as a function of angle, absorber and voltage in the range 0.8 to 2.0 mv. The x-ray intensity in the forward direction was found to increase approximately as the 5/2 power of the voltage while the concentration in the forward direction increased as would be expected. Absorption coefficients were measured for 1.0, 1.5 and 2.0 mv with lead thicknesses up to 2.5 cm. Intensity measurements were made with a Victoreen condenser type r-meter. The results are presented primarily because of their possible usefulness to those considering the installation of high voltage x-ray equipment.

50. The Uniqueness of an X-Ray Crystal Analysis. A. L. PATTERSON, *Bryn Mawr College.*—It has long been known that the essential problem of x-ray crystal analysis lies in the determination of the phases to be allotted to the quantities $F(hkl)$ whose absolute values can be obtained from x-ray intensity measurements. These quantities when given appropriate phases form the Fourier coefficients for the distribution of electron density in the crystal. A Fourier series whose coefficients are the measured quantities $|F(hkl)|^2$ has been used in x-ray analysis to give a direct determination of interatomic distances in crystals. Langmuir and Wrinch[1] have suggested that if the positions of the peaks in the F^2 series are known, the structure is uniquely determined. In the present paper it is shown that if the peaks in the F^2 series can be resolved, the structure determination can be made unique, except for the fundamental ambiguity of a center of symmetry. The proof depends on a knowledge of the atoms which compose the crystal and the demonstration that there is only one way in which a given set of atoms can produce a given F^2 series. A unique determination depends on the identification of the peaks of the F^2 series, and examples are presented which suggest that caution must be exercised in attempting to ascribe uniqueness to the interpretation of the structure of complex crystals.

[1] I. Langmuir and D. M. Wrinch, Nature **142**, 581 (1938).

51. A General Equation of State: Equations for Ammonia and Steam. J. L. FINCK, *New York, New York.*—In a published paper,* the writer has considered the possibility of enlarging the scope of thermodynamic systems by including metastable as well as the ordinary stable states. To do so, he has shown that it is necessary to consider p, v, T as three independent variables for a system in gaseous or liquid-vapor state. On this basis many phenomena can be explained very simply. In continuing this line of thought, the writer has been able to develop a general, explicit equation of state which may apply to a single gaseous phase, or a liquid-vapor system, where there is a single type of transformation. For the entropy η, and the three independent variables p, v, T, the equation is $\eta=a+bv+cp+dpv+(e+fv+gp+hpv)\ln T$. The latent heat of transformation is $\lambda_{P,T}=T(v_2-v_1)(\partial\eta/\partial v)_{P,T}=T(v_2-v_1)[b+dp+(f+hp)\ln T]$. Using the most recent ammonia and steam tables, the following values of the constants have been found. (η, p, v, T are in British units.)

	Ammonia		*Steam*	
	Liquid-vapor	Superheated	Liquid-vapor	Superheated
a	-6.3238	-31.4922	-6.1496	$+0.8445$
b	-0.6660	$+\ 0.12586$	-0.4308	-0.005090
c	$+0.0_33982$	$-\ 0.07790$	$+0.0_31059$	-0.001210
d	$+0.03280$	$-\ 0.09284$	$+0.02659$	-0.0_34551
e	$+1.0469$	$+\ 6.6863$	$+0.9924$	$+0.12487$
f	$+0.11292$	$-\ 0.01886$	$+0.06808$	$+0.0_38938$
g	-0.0_46312	$+\ 0.01118$	-0.0_41496	$+0.0_31446$
h	-0.004761	$+\ 0.01046$	-0.003639	$+0.0_49145$

These equations check the experimental data over the entire saturation dome, in most cases, to much better than one percent. In the superheated regions the agreement is of the order of three to five percent over the entire pressure and temperature ranges given in the tables.

* J. L. Finck, J. Frank. Inst. **225**, 411–435 (1938).

52. Probability of K Ionization of Nickel by Cathode Rays. D. L. WEBSTER, *Stanford University;* L. T. POCKMAN, *Cornell University;* K. HARWORTH AND PAUL KIRKPATRICK, *Stanford University.*—The probability of K ionization of nickel by cathode-ray bombardment has been experimentally determined in arbitrary units as a function of cathode-ray energy in a range extending from two to twenty-two times the K ionization energy ($V_K=8320$ volts) by measuring the dependence of the $K\alpha$ line intensity from thin nickel targets upon tube voltage. Only small theoretical corrections need be applied to the original data. The targets ranged in thickness from 10^{-6} cm to $2\cdot10^{-5}$ cm and were free except for a backing of cellulose acetate approximately 10^{-5} cm thick. A new technique has been developed for making and mounting thin films of large area (10 cm^2). A comparison of these data with the corresponding data from helium and silver makes possible a direct qualitative estimate of both the influence of relativity and the influence of nonhydrogenic fields on the probability of K ionization. Although these data agree only roughly with nonrelativistic quantum mechanical theories, they agree within experimental error with the relativistic theory of Soden for $V/V_k>4$ if theory and experiment are arbitrarily matched at $V/V_k=22$. For $V/V_k<4$, the theory falls below the experiment, in qualitative agreement with Soden's work on the limitation of the Born Approximation.

53. The Electronic Structure of Alloys. MILLARD F. MANNING, *University of Pittsburgh.*—Considerable progress has been made, particularly by Hume-Rothery, in the correlation and interpretation of the phonomena connected with solid solutions of metals. Except for the work of Jones, there have been few connections established between this work and the quantum-mechanical theory of metals. The case when the solvent is copper and the solute is one of the elements following it in the periodic table is the easiest to discuss. For this case the highest occupied levels around the copper atoms will be lower than highest levels corresponding to the solute atoms at the same atomic volume and crystal structure. This means that for dilute

solid solutions the solute atoms will have a positive charge and the copper atoms will have a negative charge. This negative charge around the copper atoms accounts for the expansion of the lattice and for the lowering of the freezing point. The negative charge on the solute atoms accounts for a number of properties. In particular, it offers an explanation for the fact that the coefficient of diffusion of copper in copper cannot be found by extrapolation of the observed coefficients of diffusion in copper of the elements following copper in the periodic table.[1]

[1] J. Steigman, W. Shockley and F. C. Nix, Washington Meeting, December, 1938.

54. Inertial Mass. PETER FIREMAN, *Magnetic Pigment Company, Monmouth Junction, New Jersey.*—The question is raised as to the reality of inertial mass as a specific attribute of matter: Is there in the inertial force of a mass anything apart or beyond the force of gravitation? In the author's opinion, inertia is always a manifestation of gravitational force, at times more obvious and at times less obvious. Obvious instance: a body resists external force owing to its weight. Less obvious instance: a highly polished steel sphere is resting on a perfectly smooth plane. A push starts it rolling; it keeps moving indefinitely. Why? Resting on a point, it was in a state of unstable equilibrium. The push disturbed its equilibrium, depressed its center of gravity in the direction of the motion due to the push. The disturbance is kept up, the depression continues and there is nothing to restore the original balance. Consequently the sphere keeps rolling on and on.

55. Difference in Scope of Theoretical Physics and Pure Mathematics. JOSEPH T. O'CALLAHAN, S.J., *College of The Holy Cross.*—With the ever increasing importance of mathematics in the study of physics, there has been manifest in recent years a tendency to regard theoretical physics merely as a branch of mathematics. To oppose this tendency it is necessary to insist upon the difference in the scope of the two sciences. Briefly the difference is this: theoretical physics incorporates in the problem some actual physical data, whereas no physical data are incorporated in any pure mathematical problem. This difference is elaborated to show that mathematics, as such, merely requires compatibility of elements forming the concepts; while the constructs of physics require a further compatibility with some actually existing reality. A short reference to experimental physics shows that there are three entirely different types of "law" involved, characteristic respectively of experimental physics, theoretical physics and pure mathematics. The example of the inverse square law of attraction is used to concretize the discussion.

56. A Re-evaluation of the Atomic Constants. FRANK G. DUNNINGTON, *Rutgers University.*—The experimental work on all significant determinations of the atomic constants e, m and h has been reexamined and the results recalculated with two changes: (1) all assumptions as to values of combinations of atomic constants have been eliminated so that the results given represent what the experiments actually yield and (2) a consistent set of auxiliary constants has been used throughout. A Birge-Bond diagram will be given to present the results graphically and illustrate clearly the discrepancy. A least squares solution of these results has been made *without* using the Rydberg formula. The results are:

$$e=(4.8025\pm0.0007)\times10^{-10}\text{ e.s.u.},$$
$$m=(9.1073\pm0.0024)\times10^{-28}\text{ g},$$
$$h=(6.6133\pm0.0034)\times10^{-27}\text{ erg}\cdot\text{sec.},$$
$$e/m_0=(1.7590\pm0.0004)\times10^{7}\text{ e.m.u.},$$
$$h/e=(1.3771\pm0.0007)\times10^{-17}\text{ e.s.u.}$$

As to where the discrepancy originates, this solution together with an analysis of each type of measurement as to the fundamental laws involved indicates that either: (1) the existing body of experimental results is substantially correct and the Rydberg formula is in error, or (2) the Rydberg formula is correct and all the measurements of h/e and the radiation constants are in error, the error being in some cases presumably experimental, and in other cases in the theory involved.

57. Absorption Spectrum of Heavy Benzene at 2730–2250A. H. SPONER, *Duke University.*—The absorption spectrum of C_6D_6[1] at 2730–2250A was photographed in the first order of a three-m grating spectrograph. As in C_6H_6 the spectrum consists of a number of series with bands progressing in intervals of 878 cm^{-1} (totally symmetrical frequency in the upper state), each interval containing a progression with 140-cm^{-1} spacing. The whole system corresponds to a forbidden electronic transition $^1A_{1g}\rightarrow{}^1B_{2u}$ made allowed by the interacting twofold degenerate vibrations of symmetry $E_g{}^+$. In agreement with this the first bands of the two major series represent vibrational transitions $0\rightarrow497$ and $579\rightarrow0$, the 579 and 497 cm^{-1} being carbon frequencies of symmetry $E_g{}^+$ in the ground and excited states, respectively. This conclusion was drawn from the fact that the distance between the above-mentioned two bands is $38789-37713=1076=579+497$ and from the occurrence of other progressions displaced from the main series by 82 cm^{-1} toward long waves, thus indicating transitions $579\rightarrow2\times497$ and $2\times579\rightarrow497$. The frequency difference of 140 cm^{-1} is considered as an $n-n$ transition of the carbon $E_u{}^+$ vibration (in analogy to Kistiakowsky's and Solomon's explanation of the 160 cm^{-1} frequency difference in C_6H_6). Plausible interpretations can be given for other progressions. The analysis is in agreement with the one proposed for light benzene.[2]

[1] I am much obliged to Professor D. H. Andrews for lending me the heavy benzene.

[2] To be published shortly in cooperation with G. Nordheim, A. L. Sklar and E. Teller.

58. Further Studies on the Infra-Red Absorption Spectra of the Fatty Acids. R. C. HERMAN AND R. HOFSTADTER, *Princeton University.*—The monomer and dimer spectra of two more acetic acids, CD_3COOH and CD_3COOD, as well as light and heavy propionic acids, C_2H_5COOH and C_2H_5COOD, have been obtained with a rocksalt spectrometer. The wave numbers of the principal bands in the

monomer spectrum of CD_3COOH are: 3640, 2225, 1760, 1335, 1215, 1162, 1065, 925, 820, 796 cm^{-1}. Those in CD_3COOD are: 2660, 2270, 1760, 1280, 1160, 1060, 1000, 925, 812, 785 cm^{-1}. Although it has not been possible to make a complete assignment of bands, certain regularities have been observed in the monomers of the four acetic acids: CH_3COOH, CH_3COOD,[1] CD_3COOH, CD_3COOD. These will be discussed. The heat of association of heavy propionic acid has been found by using a method previously described.[1] The results of a single determination give a value of 6400 calories per bond per mole.

[1] R. C. Herman and R. Hofstadter, J. Chem. Phys. **6**, 534 (1938).

59. The Infra-Red Absorption Spectrum of Phenol Vapor. V. WILLIAMS, R. C. HERMAN AND R. HOFSTADTER, *Princeton University.*—The absorption of the single molecules of phenol has been examined in the infra-red from 1μ to 13μ with a rocksalt spectrometer. The spectrum of the vapor was obtained at 93°C and 164°C at pressures of 14 mm and 19 mm, respectively. The regions from 2.3μ (4350 cm^{-1}) to 3.5μ (2860 cm^{-1}) and from 9μ (1111 cm^{-1}) to 12μ (850 cm^{-1}) were repeated at higher pressures (about 180 mm) in order to bring out weak bands. Our absorption curves do not show the association bands near 3μ (3333 cm^{-1}) found in solid and liquid phenol and in solutions of phenol in CCl_4,[1] but do show the free O—H band at 2.7μ (3705 cm^{-1}). This indicates that we have obtained the monomer spectrum. We find a sharp band at 8μ (1250 cm^{-1}) and a relatively broad band at 8.5μ (1176 cm^{-1}). The center of gravity of these two bands lies close to a band whose variations in position and intensity with temperature were studied by R. R. Brattain[2] with the same instrument. In this region of the spectrum of solid phenol, J. Lecomte[3] finds bands at about 8.4μ (1190 cm^{-1}) and 8.8μ (1137 cm^{-1}).

[1] J. J. Fox and A. E. Martin, Proc. Roy. Soc. London **162A**, 419 (1937).
[2] R. R. Brattain, J. Chem. Phys. **6**, 298 (1938).
[3] J. Lecomte, J. de phys. et rad. **8**, 489 (1937).

60. Accommodation Coefficient of Helium *vs.* Nickel. BARBARA G. RAINES, *Bryn Mawr College.*—The variation with temperature of the accommodation coefficient of helium against nickel was investigated in the range 90–369°K by measuring the heat losses of an "A" nickel wire at 90, 194, 273 and 369°K both in vacuum and in an atmosphere of spectroscopically pure helium which at equilibrium attained a pressure of the order of 10 dynes/cm^2. After flashing in vacuum, the nickel wire was allowed to come to equilibrium before the helium was introduced. The accommodation coefficient (a_0) for helium against gas-free nickel was determined by extrapolating the heat loss through the gas to zero time after its admission. Within the experimental error, a_0 was constant over the entire temperature range, the average of seven determinations being 0.067 ± 0.006. The mean values at the four temperatures do, however, show a slight increase with rising temperature, being 0.061, 0.066, 0.071 and 0.074 at 90, 194, 273 and 369°K, respectively. The equilibrium values (a_e) of the accommodation coefficient (attained after about four minutes) were found to be 0.51, 0.45, 0.36 and 0.33 at 90, 194, 273 and 369°K, respectively. The accommodation coefficients here reported have not been corrected for roughening of the surface of the wire due to heat treatment.

61. An Apparatus for Determining the Orientation of Crystals by X-Rays. F. E. HAWORTH, *Bell Telephone Laboratories, Inc.*—An apparatus has been developed in which orientations of single crystals, and the crystals in polycrystalline materials, can be studied with x-rays by rotating the specimen and moving a photographic film at the same time. The apparatus combines the best features of both the Weissenberg goniometer[1] and that of Dawson[2] by having the x-ray beam incident along the axis of a cylindrical film and thus recording a Debye-Scherrer circle instead of a layer line. The motion of the film and rotation of the specimen may be continuous or in steps. For motion in steps an automatic mechanism is used which exposes the film for a length of time controlled by an electric clock, and then moves the film and rotates the specimen an amount controlled by a revolution counter geared to the motor. When the cylindrical film is flattened the Debye-Scherrer circles become straight lines and a transparent net with rectangular coordinates is used to measure the angles. The data are then easily plotted in stereographic projection.

[1] K. Weissenberg, Zeits. f. Physik **23**, 229 (1924).
[2] W. E. Dawson, Phil. Mag. **5**, 756 (1928).

62. An Investigation into the Gettering Powers of Various Metals for the Gases Hydrogen, Oxygen, Nitrogen, CO_2 and Air. LOUIS F. EHRKE AND CHARLES M. SLACK, *Westinghouse Electric & Manufacturing Company.*—Measurements of the "gettering" or clean-up ability of aluminum, magnesium, thorium, uranium, misch metal, zirconium and barium for the common gases were made. In most cases the measurements were quantitative and represent gettering powers unassisted by an electric discharge or other source of ions. The effect of temperature conditions on the gettering and keeping properties of several of the getters is given. The superior gettering powers of the diffuse layers produced by vaporizing the getters in the presence of a gas, as compared to those of the bright getter deposits produced in a high vacuum, were confirmed. Barium and misch metal were found to be the most active of the materials tried, and the convenient forms in which barium is now commercially obtainable would seem to make it first choice for most work, though it is not effective in the presence of Hg vapor. Magnesium and aluminum showed little activity without the presence of a discharge. Thorium and uranium showed considerable activity for H_2 and O_2, but the high temperatures needed for flashing make them rather inconvenient to use.

63. Thermal Conductance of Metallic Contacts. C. STARR AND R. B. JACOBS, *Massachusetts Institute of Technology.*—In cryogenic apparatus, the thermal conductance between two clean metallic surfaces, in contact in a vacuum, is sometimes of importance. Such contacts may be employed

for thermal switching purposes, and must be free of grease in order to operate at low temperatures. The properties of clean gold, silver and copper contacts, operating in vacuum, were studied at room and liquid nitrogen temperatures as a function of contact pressure up to three kg/cm^2. The thermal conductance of the contacts was found to increase with increasing contact pressure; the relationship was linear for copper only. The flatter the contact surfaces, the better was the conductance. At room temperatures, gold and silver were both equally better than copper, but at liquid nitrogen temperatures the order of merit was silver, gold, copper. Copper and gold grow progressively worse with time at low temperatures, perhaps due to adsorption phenomena. Silver did not exhibit this behavior, and as its contact conductance is least affected by temperature, it is the logical choice as a thermal contact material for low temperature work.

64. Determination of the Radon Content of the Spring Waters of Fairmount Park. J. LLOYD BOHN AND FRANCIS H. NADIG, *Temple University.*—Fairmount Park has an area of over 3000 acres within the city limits of Philadelphia, and has numerous springs which are the subject of this investigation. Of 12 springs already determined the values run from 2×10^{-10} to 35×10^{-10} curies per liter of water. Some of these values are rather high for springs in the United States and Canada[1] except those near known radium deposits. The more active springs issue from an early Cambrian formation while the less active ones issue from a Precambrian formation known as Wissahickon gneiss. Data on the radon content of tap and river waters and on the radium content of some of these waters will be included.

[1] Bulletin of the National Research Council on Radioactivity, Number 51, by A. F. Kovarik and L. W. McKeehan.

AUTHOR INDEX TO ABSTRACTS OF THE NEW YORK MEETING