Proceedings of the American Physical Society

Minutes of the Washington Meeting, April 26–28, 1934

THE 191st regular meeting of the American Physical Society was held in Washington D. C. at the Bureau of Standards on Thursday and Friday, April 26 and 27, and at the National Academy of Sciences on Saturday, April 28, 1934. There were three parallel sessions for the reading of ten minute contributed papers on Thursday morning and afternoon and Friday morning and afternoon, and two parallel sessions on Saturday morning and afternoon. One of the sessions on Thursday morning was devoted to ferromagnetism and one on Thursday afternoon to nuclear physics. After the session on nuclear physics there was a tour of inspection of the laboratory at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The presiding officers were Arthur H. Compton, President of the Society, R. W. Wood, Vice-President, S. K. Allison, H. L. Curtis, Paul D. Foote, W. E. Forsythe, R. C. Gibbs, L. G. Hoxton, A. W. Hull, F. Wheeler Loomis, G. W. Stewart, W. F. G. Swann and John Zeleny. The attendance at the meeting was not less than five hundred.

The Society held a dinner at the Hotel Washington on Friday evening with two hundred and eight present. The President, A. H. Compton, presided and the after-dinner speakers were R. T. Birge, W. L. Bragg of the University of Manchester, L. J. Briggs, George B. Pegram, B. F. J. Schonland of the University of Cape Town, and R. W. Wood.

Business Meeting of the Society: The President called a short business meeting of the Society at the National Academy of Sciences on Saturday morning, April 28, 1934, to amend Article VI of the By-Laws.

On motion it was unanimously voted:

to amend Section 1 of Article VI—Journals—of the By-Laws reading "each fellow or member of the Society who has paid his dues in full, shall receive *The Physical Review* published by the Society, and *Science Abstracts Section A—Physics*" by adding "except that a member or fellow not residing in the United States, Canada, or Mexico, shall be entitled to receive *The Physical Review* only after payment in addition to dues of an amount to be fixed by the Managing Editor."

Meeting of the Council: At its meeting held on Thursday, April 26, 1934, the deaths of three fellows (William J. Hammer, George O. Squier, and Augustus Trowbridge) and one member (Edward H. Kurth) were reported. Three candidates were transferred from membership to fellowship and twenty-nine were elected to membership. *Transferred from membership to fellowship:* Paul P. Cioffi, Halsey A. Frederick and Robert J. Van de Graaff. *Elected to membership:* William H. Abbitt, Russell Baldock, Louis A. G. Blanchet, Benedict Cassen, Yee Fung Cheng, John C. Clark, Wesley M. Coates, Sister Mary St. Helen Donahue, L. G. Ellis, William P. Gilbert, Norman P. Goss, George T. Harness, R. Bruce Horsfall, Jr., H. G. Houghton, W. Rudolph Kanne, James W. Kern, Wilbert F. Koehler, John W. Mauchly, Allen E. Murray, T. J. O'Donnell, Jacob Olthoff, John E. Owen, Robert D. Sard, Eva A. Schick, William P. Taylor, Henry C. Torrey, John G. Trump, Stanley N. Van Voorhis, L. A. Woodward.

The regular scientific program of the Society consisted of one hundred and fifty-three papers of which numbers 3, 27, 29, 43, 58, 72, 89, 106, 122, 136, 141, 151 and 152 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. Time Constants of Tungsten Lamps. W. E. Forsythe and M. A. Easley, *General Electric Company, Nela Park, Cleveland, Ohio.*—The time constants of some regular and some special incandescent lamps have been measured with the rotating flashometer.[1] The time from turning on the current to the reaching of the normal intensity as well as the time from turning off the current until the intensity reached one-tenth that of the normal was measured and the results are shown in Table I. The variations of intensity of the light of a number of incandescent lamps when operated on 60 cycle and 25 cycle a.c. have been measured with the apparatus for measuring the maximum intensity[2] of a source of short duration and these variations are shown in Table II.

Table I. *Time characteristics of some incandescent lamps.*

Lamp	Time Required to Reach Normal intensity after current is turned on	Ten percent normal intensity after current is turned off
40 w Vacuum	0.17 sec.	0.06 sec.
40 w Gas-Filled	0.12 "	0.04 "
100 w	0.21 "	0.06 "
300 w	0.32 "	0.10 "
500 w	0.50 "	0.17 "
250 w Photoflood	0.18 "	0.10 "
250 w Floodlight	0.42 "	0.13 "
250 w Hydrogen Signal Lamp	0.34 "	0.04 "
400 w Hydrogen Signal Lamp		0.06 "
1000 w Hydrogen Signal Lamp		0.15 "

Table II. *Variation of the intensity of the light from some incandescent lamps operated on 25 cycle and on 60 cycle a.c.*

Lamp	Maximum Intensity of Light for Lamps on 25 cycle a.c.	60 cycle a.c.
40 w Vacuum	104% Normal I	101% Normal I
40 w Gas-Filled	127% " "	110% " "
100 w	112% " "	104% " "
300 w	107% " "	100% " "
500 w	105% " "	100% " "

[1] Rev. Sci. Inst. (1934).

[2] Rev. Sci. Inst. 3, 488 (1932).

2. A Device for the Absolute Measurement of Radiation Intensity. James D. Hardy, *The Russell Sage Institute of Pathology.*—In the course of experiments on the measurement of the total radiation from the human body, an instrument has been developed which will determine the amount of radiant energy (calories/sec./$\overline{\mathrm{cm}}^2$ of radiating surface) from low temperature, nonluminous, sources with an accuracy of one percent. The method of making the measurements is that of comparing the radiation from the source to be measured with that of a standard blackbody at room temperature. The results are then independent of the many peculiarities of the radiating source and the receiver is demonstrated by the following comparison. The radiation calibration obtained from a standard black body at 20° to 40°C was compared to that obtained from an incandescent standard calibrated by the U. S. Bureau of Standards. The two were found to be in agreement to better than one percent. The sensitivity of the device is such that a temperature change of 1°C or 1.4×10^{-4} cal./sec./$\overline{\mathrm{cm}}^2$ in the standard radiator will cause a deflection of 20 divisions on the galvanometer scale.

3. New Experiments on Metallic Conduction. E. Weber, *Polytechnic Institute of Brooklyn.*—Previous investigations on the current distribution in a long copper bar 4 inches wide and 1/32 inch thick have been continued and lead to several new results. Given the measured distribution of the electric field strength over the entire bar, a weak magnetic field applied perpendicular to the flow of current (and heat) produces changes in this distribution in longitudinal as well as transverse direction. Attempts are made to explain these changes by the familiar thermoelectric and thermomagnetic effects on the basis of the Sommerfeld-Franck theory but fail to be satisfactory. The effects measured are in the order of $3\cdot10^{-5}$ volts/cm down to 10^{-7} volts/cm. In addition a transient state of the readjustment of the current distribution after changes of the applied voltage has been observed which may last as long as 20 minutes and may indicate that in addition to electronic flow some slowly adaptable phenomenon is involved in metallic conduction.

4. Low Noise Amplifiers. G. L. Pearson, *Bell Telephone Laboratories, Inc.*—Amplification of indefinitely small signals is limited by the inherent noise in the first stage of a high gain amplifier. The disturbances are due to thermal agitation in the input circuit and voltage fluctuations arising in the vacuum tube. In order to obtain the largest signal-to-noise ratio for a given signal power the tube noise should be small in comparison with thermal noise. The requirements for a low noise amplifier tube are a low microphonic response, high insulation, high vacuum, low grid current, good temperature saturation, and high transconductance. Tests on four different types of standard Western Electric tubes show their noise to be exceptionally low, especially when operating conditions slightly different from those normally recommended are used. The magnitude of the noise referred to the grid circuit at two different frequency ranges, expressed in equivalent mean square volts per cycle of the frequency band, is given in the following table:

Tube	*Noise* 5–205 c.p.s.	10,000–12,000 c.p.s.
No. 102G (triode)	2.2×10^{-16}	0.54×10^{-16}
No. 264B (triode)	6.6	1.0
No. 262A (triode)	17.	0.84
No. 259B (screen)	7.7	2.8

5. Space-Charge Effects in Piezoelectric Resonators. W. G. Cady, *Wesleyan University.*—When the resonator vibrations are parallel to the electric field, the piezoelectric polarization causes a space-charge in the crystal, which in turn produces a secondary electric field with an equation consisting of two terms of opposite sign. Through the converse piezoelectric effect the first of these terms sets up a stress tending to diminish the effective elastic modulus and thus to lower the resonant frequency, while the second has the opposite effect. A general equation is first derived for the potential and field distribution between infinite parallel conducting plates caused by a space-charge of any arbitrary distribution in an infinite slab of dielectric between the plates, the thickness of the slab being less than this distance. This equation is then applied to the case of a resonator vibrating as indicated above. Polarization and space-charge are deduced as functions of the strain, and thence a solution is found for the problem of the resonator with air-gap. The observed variation of resonant frequency with gap thus receives a complete theoretical explanation.

6. Dielectric Behavior of Dilute Binary Solutions. Frank E. Hoecker, *University of Kansas. (Introduced by J. D. Stranathan.)*—Most of the data given in the literature on dilute solutions of a polar liquid in a nonpolar solvent show anomalous behavior at low concentrations of the solute. The author, studying dilute solutions (as low as $C_2=0.004$ mol percent) of ethyl alcohol with $C\,Cl_4$, C_6H_6 and CS_2 as solvent, has found this same peculiar behavior. By treating the dissolved solute more as if it were a vapor alone occupying the entire volume of the solution, he has, however, been able to show that it is probably a fictitious effect. When extremely dilute solutions are studied in this manner, the presence or absence of effects due to the solvent or to association are at once evidenced by a departure from linearity of the curve obtained by plotting $3(K-1)/(K+2)$ of the solute *versus* its equivalent pressure. When C_6H_6 or $C\,Cl_4$ is used as solvent, there is excellent agreement between data obtained from dilute solutions and those on the vapor. Unexpected peculiarities in the behavior of CS_2 solutions are at present the subject of further investigation.

7. Elimination of Peculiarities in Dielectric Behavior of Water Vapor. J. D. Stranathan, *University of Kansas.*—Peculiar breaks in the curve of $(K-1)$ *versus* pressure have been reported for water vapor by at least two observers. At or near room temperatures, the slope increases very markedly at a pressure of approximately 1 cm of Hg. These peculiar breaks have been variously attributed to association, adsorption on the metal plates of the condenser, and conductivity introduced by condensation on the insulators. Using a brass condenser and either quartz or Pyrex insulators, the author has been able to eliminate completely these breaks for water. The curve is a straight line up to very near saturation. The author can obtain a curve which breaks similar to those previously reported for water vapor, however, by forcing the vapor into the condenser too rapidly, probably causing local condensation. In fact, it is only by using extreme care to limit the rate at which the vapor is allowed to pass in that the straight line can be obtained. The data yield an electric moment of 1.83×10^{-18} for the water molecule, a value in close agreement with that of Sänger obtained from data at high temperatures only.

8. Diffusion of Hydrogen through Palladium and through Palladium-Nickel Double Layers. W. R. Ham, *The Pennsylvania State College.*—The diffusion of hydrogen through a double layer consisting of 10 mil palladium welded to 5 mil nickel by means of 1/2 mil copper foil was found to be very nearly reversible at all temperatures and to follow the ordinary law of diffusion (1) $R=A\epsilon^{-b/T}$, in which the value of b is similar to that of nickel; *viz.*, 6600° approximately. The diffusion of pure dry hydrogen through carefully degassed palladium gives the same value as above mentioned. However, palladium shows a complex behavior for the diffusion of hydrogen if the metal has been in contact with certain gases at elevated temperatures. Nitrogen in particular seems to very slowly diffuse through it, and greatly increases for a long time the ability of the palladium to transmit hydrogen. Nevertheless after treatment with nitrogen a simple formula such as (1) still represents the results for a limited time over a range from 250° to 750°C, the value of b for nitrogen charged palladium being as low as 3900° in some cases and the value for A in general much greater than for degassed palladium. However, fresh massive palladium, 30 or 40 mil thick, may be very permeable to hydrogen. This permeability appears too great to be ascribed to a nitrogen compound. Carbon monoxide is suggested as an alternative to nitrogen. To remove the cause of the great permeability baking at 1000°C for several hours in a hydrogen atmosphere appears necessary, whereupon the rate of diffusion may be only a fiftieth of its original amount.

9. Econodynamics. Hobart C. Dickinson, *Washington, D. C.*—Econodynamics is suggested as a name for the science dealing with the underlying natural laws of society as related to money, work and the products of work because of the remarkable similarity between these laws and those of thermodynamics. Heat and work are forms of mechanical energy, and thermodynamics deals with their transformation. Work and money are likewise related to social energy and econodynamics deals with their relationship. Conservation of energy, the first and second laws of thermodynamics, the postulates of thermodynamics, and the distribution of energy among the molecules of a gas, all find their near counterpart in the field of econodynamics. Conservation of money, the equivalence between money and work, the law of price equilibrium in a competitive market, the law of supply and demand, and the normal distribution of income among men, are found to bear striking resemblances, respectively, to the corresponding concepts of thermodynamics. A mechanical model, termed the economonstrator, has been constructed to illustrate the operation of these economic laws as related to economic phenomena characterizing phases of social development. This model will be demonstrated.

10. Variation with Temperature of the Coefficient of Thermal Expansion of Nickel Monocrystals near the Curie Point. Clarke Williams, *Columbia University.*—The coefficient of thermal expansion of mono- and polycrystalline nickel has been measured at five degree intervals between 250°C and 400°C. The value of the coefficient increases smoothly from $15.3\times10^{-6}/°C$ at 250°C to a maximum of $18.0\times10^{-6}/°C$ at 355°C. At this temperature the coefficient decreases rapidly to a value of $16.5\times10^{-6}/°C$ at 370°C, the Curie point, and thereafter remains nearly constant. The maximum value of the coefficient and the temperature at which the maximum occurs are lowered by impurity in the specimen.

11. Dependence of Internal Friction on Magnetization in Iron. W. T. Cooke, *Columbia University.*—The specimen, in the form of a rod 28 cm long and 5 mm diameter, forms part of a composite piezoelectric oscillator (J. Zacharias, Phys. Rev. **44**, 116 (1933)). The decrement *in vacuo* of the mechanical system is obtained by measuring the equivalent resistance and inductance of the oscillator with an alternating-current bridge. Approximately uniform magnetization is obtained by the use of special coils. The decrement increases with magnetization, reaches a maximum near the knee of the magnetization curve, and then decreases. The largest value is about four times that when demagnetized.

12. A New Magnetometer for Crystal Ferromagnetism and Its Application to Iron-Cobalt Alloy Crystals. L. W. McKeehan and J. W. Shih, *Yale University.*—The quinquefilar pendulum magnetometer of Weiss and Foëx (J. de Physique [4] **1**, 274 (1911)), hitherto used only for substances of small and constant susceptibility (paramagnetic or diamagnetic), has been modified so as to be useful for small ferromagnetic specimens (a few millimeters in greatest extent). For these it possesses several advantages over previous magnetometric and ballistic methods. The modifications are: (1) Use of a thick solenoid to produce a high and uniform magnetic field. (2) Use of two opposing Gaugain (or Maxwell) coils to produce a low but accurately calculable field gradient in the direction of motion. (3) Use of a microscope and a fixed scale to read the deflections of the pendulum. A new technique for accurately shaping very small spheroidal specimens—a sort of potter's wheel with progress inspection by an optical profile gauge—has been developed. Some iron-cobalt crystals in the body-centered range (at room temperature) have been examined. The easy direction of magnetization, [100] at the iron end of the series, is replaced by [111] at a composition, not yet accurately fixed, lying between 30 and 70 percent cobalt.

13. On the Magnetization of Imperfect Crystals. Francis Bitter, *Fellow of the Guggenheim Foundation, Westinghouse Research Laboratories, East Pittsburgh.*—For various reasons it seems likely that if the calculations of the Heisenberg theory of ferromagnetism could be carried out without arbitrary simplifications, the result would be, for actual crystals magnetized in a direction of easy magnetization, a magnetization curve proceeding to saturation in infinitesimal fields. Experimental results indicate that in most crystal fields of the order of 10 oersteds are required to produce an intensity of magnetization approaching saturation. Calculations are carried out on the properties of imperfect crystals, that is crystals elastically deformed in a random manner, using Becker's theory of the magnetic behavior of homogeneously distorted crystals. It is shown that the magnetization curves of imperfect crystals are characterized by typical breaks occurring near the points (H_1, I_1) and (H_2, I_2) as shown in the following table. The constant c is determined by the extent of the random distortions of the crystals, and is of the order of 1/10. Few observations are sufficiently accurate to afford a certain check, but from the best available it seems very likely that randomly oriented permanent distortions of the order of magnetostrictive strains are usually present. Observations on nickel crystals by Kaya show the above breaks clearly.

Direction of magnetization	H_1	I_1/I_{Sat}	cH_2	I_2/I_{Sat}
[100] in iron	0	$1/3$	1	1
[110] " "	0	$\sqrt{2/3}$	$\sqrt{2}$	$1/\sqrt{2}$
[111] " "	0	$1/\sqrt{3}$	0	$1/\sqrt{3}$
[100] in nickel	0	$1/\sqrt{3}$	0	$1/\sqrt{3}$
[110] " "	0	$\frac{1}{2}\sqrt{2/3}$	$\sqrt{3/2}$	$\sqrt{2/3}$
[111] " "	0	$\frac{1}{4}+\frac{3}{4}\cos\alpha$	$(1-\cos\alpha)^{-1}$	1

$\alpha=2\cos^{-1}\sqrt{2/3}$

14. New High Permeabilities in Hydrogen-Treated Iron. P. P. Cioffi, *Bell Telephone Laboratories.*—The initial and maximum permeabilities of hydrogen-treated iron (Phys. Rev. **39**, 363-367 (1932)) have been increased to 14,000 and 280,000, respectively, by using pure hydrogen and avoiding contamination from furnace gases during heat treatment between 1300°C and the melting point. This value of initial permeability is close to the theoretical limit of 16,000 calculated for iron by M. Kersten (Zeits. f. Physik **71**, 562 (1931)). These results are not now attributable to absorbed hydrogen as was at first supposed. The treatment results in a decrease of O, C, N and S in the metal to a few thousandths percent each, but practically no decrease in metallic impurities. Introduction of N or S into hydrogen-treated iron makes the permeability drop. After the addition of nitrogen, heat treatment in hydrogen at 1200°C is adequate to restore the former magnetic characteristics. After the addition of sulphur, similar heat treatment above 1300°C is required.

15. Magnetic Material of High Permeability Attained by Heat Treatment in a Magnetic Field. R. M. Bozorth, J. F. Dillinger and G. A. Kelsall, *Bell Telephone Laboratories.*—Radical changes have been produced in the magnetic properties of some ferromagnetic materials by heat treatment in a magnetic field. For example, the maximum permeability of a permalloy containing 65 percent Ni has been increased from 10,000 to 250,000 by heating to 700°C and cooling slowly in a field of 15 oersteds. By so treating specimens which have been previously treated in hydrogen at 1400°C, the maximum permeability has been increased to 600,000. This material has a coercivity of 0.012 oersted, and a hysteresis loss of 50 ergs per cm^3 per cycle for a maximum induction of 10,000 gauss. The maximum permeability is the highest, and the coercivity and hysteresis loss for the condition given are the lowest, measurement of which has been reported for any strongly ferromagnetic material. High values of maximum permeability are generally attained by such heat treatment in Fe-Co-Ni alloys in the γ-phase, provided the Curie point is higher than about

500°C. The hysteresis loops tend to have sharp corners and vertical sides; we have observed changes in induction of as much as 25,000 gauss when the field is increased by about 10^{-5} oersted. On such vertical sides, the time lag in magnetization in specimens 0.15 mm thick is as great as one minute.

16. Magnetic Hysteresis at Low Flux Densities. W. B. Ellwood, *Bell Telephone Laboratories.*—The energy loss per second in a ferromagnetic material subjected to small alternating fields has been separated into three parts on the basis of dependency on frequency f and flux density B. One part, proportional to f^2B^2, has been identified with eddy-current loss. A second part, proportional to fB^3, has been identified with the product of the frequency by the magnetic hysteresis according to Rayleigh's law at these low flux densities. The remainder, proportional approximately to fB^2, has been the subject of much controversy as to its origin and even as to its existence. It has been variously termed "magnetic viscosity," "after effect" and "square law hysteresis." In studying this loss in a ring of compressed iron dust, loops have been measured ballistically by a new method with a relative precision in B as high as 0.01 percent. The range in the maximum flux densities is from 2 to 100 gauss. The loops are exceedingly slender, maximum flux density B being nearly 1000 times B for $H=0$ for the smallest loops. For B from 10 to 100 gauss the areas are nearly proportional to B^3 in accordance with Rayleigh's law. Comparison is made with the losses as determined on an a.c. bridge.

17. The Approach to the Theoretical Magnetization Curve. T. D. Yensen, *Westinghouse Elec. and Mfg. Co., East Pittsburgh.*—The paper exhibits magnetization curves for iron, iron-silicon and iron-nickel alloys, showing that the approach to the theoretical curves, based on the Langevin-Weiss theory, is a function not only of lattice orientation but also of the purity of the metal or alloy.

18. A New Mechanical Model for Hysteresis. F. S. Goucher, *Bell Telephone Laboratories.*—A new hysteresis model is described consisting of a row of wooden blocks resting on a glass plate and separated from each other by springs of suitable stiffness. If a compressional force be applied to one end of the system and carried through cycles of various range, the motion of the first block is such as to give loops on the force-displacement diagram provided that this block at least has slipped. If we consider only those cycles which cause the slipping of several blocks but not all, the areas of the hysteresis loops A and the corresponding maximum displacements D_m are related to the maximum compressions, F_m, as follows: (1) $D_m/F_m=a+bF_m$ and (2) $A=bF_m{}^3/3$; a and b being constants of the apparatus. Since sliding friction is nearly independent of the velocity of motion these equations will presumably hold for all frequencies of force variation up to those in which the accelerations become important. The most surprising aspect of these relations is that they are the same in form as those used by Rayleigh for the behavior of magnetic materials in low fields in which we have the maximum magnetizing force H_m instead of F_m and the maximum flux density B_m instead of D_m. These relations are also independent of frequency. The model will be demonstrated.

19. The Color of Smoky Quartz. Nora M. Mohler, *Smith College.*—The geological evidence concerning the color of smoky quartz indicates that it is caused by radioactive action. This theory is supported by the evidence, presented here, of the absorption spectra of smoky quartz and of the same quartz after it was decolored by heat and recolored by exposure to radium, and the spectra of irradiated clear crystalline and fused specimens. The study was made with a rotating sector photometer and a quartz spectrograph, and covers the 200 to 700 mμ region. Broad bands occur in all the spectrograms, with maxima at 16,500, 20,500, 25,000 34,000, 38,000 (wave number per cm), and there is increased absorption beyond 43,000. All specimens showed some fluorescence or short-lived phosphorescence after irradiation; after the second exposure to radium the fused quartz showed a marked change in the relative importance of the bands. A theory is suggested based on the calculation of energy changes accompanying the shift of an electron to a silicon ion from one of the surrounding oxygen ions, and the subsequent rearrangement of electrons on the oxygen ions.

20. Segregation of Polonium in Bismuth Crystals. Alfred B. Focke, *National Research Fellow, Yale University.*—A determination of the location of foreign atoms embedded in a single crystal, and a test of Zwicky's *Secondary Structure* (Proc. Nat. Acad. Sci. **16**, 211 (1930)) are made possible by measurements of the ranges of α-particles emitted from crystals grown from a melt containing polonium and bismuth. In the greater part of the work a Geiger point counter was used, although some measurements were made on cloud-chamber tracks. The crystals used were of two concentrations, 1 to 10^7 and 1 to 10^8 of polonium to bismuth, and they were subjected to various heat treatments. In all of these crystals it was found that the polonium was segregated into planes parallel to the perfect cleavage plane, (111), and that these planes were separated by distances which had a probability variation about $(0.55\pm0.01)\mu$ as a mean. The measurements indicate that alternate planes are preferred. This preference was greatly exaggerated by the addition of 0.01 percent Te, since in this case the only planes found to contain polonium were separated by distances of $(1.10\pm0.07)\mu$, or just twice the spacing for bismuth-polonium alone. The exact uniformity of spacing required by Zwicky was not found, although the average spacing obtained from any twenty consecutive planes gave very uniform results.

21. Radioactivity of Samarium, and "Columnar Ionization." Dorothea Lyford and J. A. Bearden, *The Johns Hopkins University.*—An FP 54 vacuum tube has been used to measure the number of ions formed by single α-particles in an ionization chamber. Thus by calibrating the chamber with α-particles of known range (e.g., polonium) one can measure the range of another α-particle by measuring the deflection of a galvanometer. By this method one can test for the presence of an α-particle disintegration in substances when unavoidable contamination of very active radioactive substances is present in small quantities. Also it gives directly the range of the α-particle in question. The radioactivity of very pure samarium oxide (prepared by Hopkins and Kremers, Bur. Stand. Sci. Papers 421, 318 (1921)) has been examined by this method and it was found that the range of the emitted α-particle is 1.28 cm and that 3.9 α-particles are emitted per cm^2 per minute from a Sm_2O_3 surface. These values are about 13 percent higher than those found by Hevesy, Pohl and Hosemann (Zeits. f. Physik **83**, 43 (1933)). As a preliminary to the above experiment a test was made of "Columnar Ionization" in a spherical ionization chamber. In such a chamber it was found that what appeared to be a complete saturation voltage for the chamber only collected about 50 percent of the total number of ions formed by an α-particle.

22. The Half-Life of Actinouranium. Forrest Western, *Missouri Valley College*, and Arthur E. Ruark, *University of Pittsburgh.*—Additional information on the half-life of actinouranium is obtained, following the plan outlined in Phys. Rev. **44**, 675 (1933). Aston has obtained the isotopic composition of the lead in a Morogoro pitchblende and a uraninite from Great Bear Lake; the chemical analyses are due to von Grosse and Marble, respectively. Computations were based on two extreme values, 0.03 and 0.04, of the actinium "branching ratio" B. Half-life values in units of 10^8 years are:

	$B=0.03$	$B=0.04$
Morogoro	3.23	4.54
Great Bear Lake	4.65	6.21
Mean from these minerals and 2 others previously reported	3.38	4.45

Judging from the spread of the data, the mean, for a given assumed value of B, is probably within 25 percent of that which would be obtained if many unaltered minerals were available for study.

23. X-Ray Wave-Lengths from Crystals and Ruled Gratings. Arthur E. Ruark, *University of Pittsburgh.*—Energies of photoelectrons ejected by x-rays from thin foils have been measured by Kretschmar and by Robinson and his colleagues, using the magnetic spectrograph. Their values are compared with those computed from wave-lengths of the incident rays and x-ray terms of the atoms in the foils, using (a) wave-lengths measured with crystals, based on the actual calcite spacing rather than the conventional one; (b) ruled grating wave-lengths, which are higher by 0.25 percent. Using Birge's value of e, 4.7668×10^{-10} e.s.u., Bearden's value for the calcite spacing becomes $(3027.91\pm1.0)10^{-11}$ cm. To get photoelectron energies from crystal wave-lengths, accurate x-ray terms are worked out by a new plan, which avoids uncertainties involved in using absorption-edge wave-lengths. Term differences are obtained from x-ray line spectra, and are added to the value of an appropriate low term obtained from optical spectra. Birge's values of universal constants are employed in getting photoelectron energies. These energy values average 0.36 percent higher than those computed from crystal wave-lengths, or 0.61 percent higher than those from ruled-grating wave-lengths. This fact supports, but does not conclusively prove, the correctness of crystal wave-lengths based on the actual calcite grating space.

24. X-Ray Levels of Radioactive Elements with Applications to Beta- and Gamma-Ray Spectra. Frederick A. Maxfield and Arthur E. Ruark, *University of Pittsburgh.*—A complete table of the x-ray levels of radioactive elements, in electron-volts, is presented. The levels for Tl, Pb, Bi, Th and U were computed by adding term-differences from x-ray emission spectra to some small level obtainable from optical spectra; those for other elements were carefully interpolated. The L and M levels agree well with absorption limits measured by Sandström and Lindberg. The energies of certain gamma-rays of Th B.C, Th C″.D, Ra C.C′, Ac B.C and Ac C.C″ are recomputed by using the new levels, and beta-ray energies measured by Ellis and by Graf. For Ellis' data, gamma-ray energies obtained from beta-rays ejected from the K-shell are brought into excellent agreement with those based on beta-rays from other shells. Energies of secondary electrons of Bi 83 and Po 84, arising in Auger processes and studied by Ellis, agree with those computed from the new levels, within the limits of experimental error. The beta-ray spectra of UX_1 and Rd Th are discussed. Gamma-rays of Ra (B+C) were measured by Frilley and Valadares, using crystals. Some lines were identified as x-rays. We propose the following additional classifications:

138.9 X.U.	$K\beta_{1,3}$ (84); $K\beta_2$ (83)
147 X.U.	$K\beta_{1,3}$ (82)
170 X.U.	$K\alpha_1$ (82)

25. The Recovery of Activity after Heating as Revealed in a Wilson Expansion Chamber. Chas. T. Knipp, *University of Illinois.*—The recovery of the activity of a radioactive substance may be studied by proceeding as follows: Place a minute quantity of the salt on the end of a solid cane of Pyrex glass by wetting the tip with alcohol containing a little shellac. Next heat this tip in a soft blast, and hold out in front and in line with it a thin-walled bulb of Pyrex glass *showing* Newton's rings. When the tip begins to soften and assumes a spherical form plunge it into the thin glass of the bulb. This operation will cover the salt with a thin film of glass. The tip may now be used in a Wilson expansion chamber without fear of losing any of the active material, and should last indefinitely as a source of alpha-particles free from emanation. Tips thus prepared were made over ten years ago by the writer and the protective film of glass seems to be intact. If a *freshly* prepared tip is placed in a Wilson expansion chamber and the proper expansion is brought about, tracks will appear but they will be few in number and only about one cm in length. Repeated expansions *immediately* following this will not increase the number or length of the tracks. However, if the apparatus be let stand a day the number of tracks and their lengths will be increased. After three days still longer tracks will result, and they will also be more numerous. After ten days the alpha-ray tracks will seemingly be of full length—about 7 cm—and the number may be as many as 20 to 40. Photographs taken at successive intervals using a given tip accompany the paper.

26. The Photoelectric Properties of the (100) and (111) Faces of a Single Copper Crystal. NEWTON UNDERWOOD, *Hood College, Frederick, Maryland.*—The two faces were cut from the same single crystal, and etched to remove the broken surface pieces and to expose the true crystal structure. Care was taken to prevent any contacts between the prepared planes and foreign objects. The two specimens were heated simultaneously by electronic bombardment at various red-heat temperatures for over 1500 hours in a good vacuum. The photoelectric thresholds were measured by the use of filters as the outgassing proceeded. During readings, the pressure was less than 5×10^{-8} mm Hg. After 500 hours of outgassing the threshold wave-lengths were 2536A for the (111) face and between 2200A and 2300A for the (100) face. The uncertainty is due to the ambiguity in interpreting the data. The results show that the etching produced by evaporation should be avoided in such an experiment. The work is being continued with a monochromatic illuminator to obtain more precise values.

27. Energy Distribution of Photoelectrons from Potassium Films on Silver. JAMES J. BRADY, *St. Louis University.*—The energy distribution of photoelectrons emitted from potassium films deposited on silver has been studied as a function of film thickness. A molecular beam was used to control the number of deposited potassium atoms. The method was the same as that used previously by the author (Phys. Rev. **41**, 613 (1932)). A high vacuum was maintained in the photo-cell by the use of a charcoal trap immersed in liquid air. In some cases the films were deposited on a surface at room temperature; and in others, on a surface cooled with carbon dioxide "snow." Photoelectrons were released by monochromatic light from the film which was formed on a small silvered glass sphere placed at the center of a large collecting sphere. Current-voltage curves were observed for a number of films ranging in thickness from 0.5 of a monomolecular layer to 30 molecular layers. The most probable energy in *each case* was found to be in the order of 0.8 of the (extrapolated) maximum. In the case of the thick and the thin films, if the liquid air was removed from the charcoal, the most probable energy shifted to approximately 0.4 of the maximum. The "temperature tails" to the current-voltage curves were more pronounced when the condensing surface was at room temperature than when it was cooled with carbon dioxide snow.

28. Specific Resistance of Cuprous Oxide. WALTER H. BRATTAIN, *Bell Telephone Laboratories.*—It has been found that the specific resistance of samples of cuprous oxide grown on copper at 1030°C in air is not uniform throughout the body of the sample but that it varies exponentially in the direction of growth of the oxide. For oxide layers on copper quenched from 500°C in water, the specific resistance varies from 800 to 24,000 ohm cm at distances of 0.005 to 0.030 cm from the copper. For oxide layers on copper slow cooled from 500°C the corresponding variation is 10,000 to 60,000 ohm cm. For completely oxidized strips cooled in vacuum from 1030°C the variation was from 200 to 30,000 ohm cm from the center of the strip to outside face, a distance of 0.0125 cm. For completely oxidized strips held for five hours in vacuum at 1030°C before cooling, the corresponding variation was from 600 to 6000 ohm cms. These values show that the specific resistance varies by large factors in a single sample of oxide and that this variation seems to be the rule rather than the exception for oxide grown on copper.

29. Failure of Talbot's Law for Barrier-Layer Photo-Cells. PAUL R. GLEASON, *Colgate University.*—The response measured on a direct-current instrument of a number of barrier-layer photo-cells has been investigated when the light reaching the cell was interrupted regularly with a rotating siren disk or sector. With flash frequencies up to 2000 per second none of the cells integrated the flashes in agreement with the average light reaching them; and the same cell gave different results when light intensity, area of illumination, circuit resistance, or frequency of light interruption was changed. The percentage increase in the average current as the flash frequency was raised from 16 to 2000 per second, ranged from one percent or less for the Photox cell up to more than twenty-five percent under extreme conditions from the Visitron F2, Tungsram type S, and photronic cells. This deviation with frequency remained two percent or less for all cells when the circuit and galvanometer resistance was small compared with the effective cell resistance. The larger deviations appeared when larger circuit resistances were introduced and also when the spacing between the openings in the disk was increased. No complete explanation is offered, although the very complex equivalent circuit of such a cell, its current-illumination characteristics, and its fatigue and recovery curves provide ample material for a qualitative solution of the problem.

30. Proton Currents from a Low Voltage Arc. E. S. LAMAR AND OVERTON LUHR, *Massachusetts Institute of Technology.*—The proton source previously described (Phys. Rev. **44**, 947 (1933)) has been redesigned with the object of obtaining large proton currents in a beam. Ions are drawn out of the arc through a hemispherical grid inserted in the cylindrical electrode. Part of the resulting converging beam passes through a hole in a second electrode which separates the arc chamber from a region maintained at a lower pressure by differential pumping. Total currents of over 0.5 milliampere at current densities of about 8.0 milliamperes per square cm were obtained on the low pressure side. The ratio of proton current to total current was as high as 98 percent with pressures in the discharge tube of 0.3 to 0.4 mm. In order to attain this percentage it was necessary to maintain certain minimum potentials on the cylinder and second electrode, and at the same time to prevent the metal parts from exceeding red heat. The proton currents obtainable are limited by the speed of the differential pumping and the degree of vacuum desired. The observed pressure ratios were improved by a factor of two when the arc was in operation owing to the increased temperature of the gas streaming through the hole.

31. The Acceleration of Protons by Electric Impulses on Transmission Lines. W. T. Ham and J. W. Beams, *University of Virginia.*—A method similar to that previously described (Beams and Snoddy, Phys. Rev. **44**, 784 (1933); **45**, 287 (1934)) has been used to accelerate protons to high velocities without the use of the correspondingly high voltages. Short cylindrical electrodes were equally spaced in a long discharge tube which contains hydrogen at a pressure of about 10^{-4} mm of mercury. The electrodes were connected to a transmission line at points so spaced that an electric impulse on the line should arrive at each of the various electrodes almost simultaneously with a proton being accelerated down the axis of the tube. The electric impulse was obtained by a *Marx* circuit. The protons after passing through an aluminum window were observed either by a zinc sulphide screen, cloud chamber or a special camera. A magnetic field was used to stop any electrons due to possible oscillations. A rough estimation of the distribution in velocities of the protons was obtained. A discharge tube containing 12 electrodes gave a maximum multiplication by the transmission line of between 7 and 8. With 35,000 volts originally applied to the *Marx* circuit some protons with velocities corresponding to voltages in excess of 2×10^6 were obtained. A larger number of protons had velocities corresponding to voltages between 1×10^6 and 2×10^6.

32. Evidence for a Resonance Level in the Nucleus of B^{10}. Ernest Pollard, *Sterling Fellow, Yale University.* (*Introduced by L. W. McKeehan.*)—Previous work by Bothe and Heidenreich on the protons emitted by boron under alpha-particle bombardment has given conflicting evidence as to the nature of the least penetrating of the three groups. Bothe gives the range as about 20 cm. Heidenreich, working with a thin layer of boron, gives 14 cm. The work of Bothe on the angular distribution of the protons and the variation of yield with incident α-particle energy appeared to indicate this group to be caused by an unusual process—possibly a non-capture disintegration. The experiments here described show that the group is complex and that a group of range 18 cm is superposed on the 14 cm group. It is shown that this new group is caused by a broad resonance level through which α-particles of ranges from 1.2 to 1.7 cm can enter the nucleus. This is the first evidence for a resonance level in the B_{10} nucleus. Its energy agrees with that found in boron by Curie-Joliot and Chadwick for neutron excitation. The nuclear energy change agrees with values given by Chadwick for the long-range groups. The discovery of this level leaves open the question as to the origin of the 14 cm group which may possibly be due to a second excited state in the nucleus.

33. Radioactivity Produced by Artificially Accelerated Particles. H. R. Crane and C. C. Lauritsen, *California Institute of Technology.*—Measurements are presented on intensities and half-life of some of the radioactive elements produced when certain light elements are bombarded with fast protons and deutons. In addition we have determined the efficiency of production of these elements as a function of the velocity of the bombarding particle.

34. Interaction between Alpha-Particles. John A. Wheeler, *National Research Fellow, New York University.*—From measurements by Rutherford and Chadwick on the anomalous scattering of alpha-particles by helium, H. M. Taylor deduced a law of force between alpha-particles strongly attractive at small distances. More recent experiments do not agree well with Taylor's original interpretation. The present work has shown that it is not sufficient to take account only of the wave function of zero angular momentum. A method has been developed by which the distribution in angle of the scattered particles determines the Faxen and Holtsmark phase shifts for angular momenta $L=0$ and 2. The resultant curve of phase shift plotted against velocity is very different from Taylor's and indicates that no modification of the coulomb field at distances less than 5×10^{-13} cm can account for the anomalous scattering. Departures from inverse square forces must then extend to unexpectedly large distances or the concept of a potential barrier must be considered inadequate for treating the scattering of complex particles. This conclusion cannot be considered final until more complete scattering experiments have been made.

35. The Emission of Disintegration-Particles by Targets under Bombardment by Protons and by Deuterium Ions at 1200 Kilovolts. M. A. Tuve, L. R. Hafstad and O. Dahl, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—Observations have been made using proton-currents of 1 to 2μA and deuton-currents 0.2 to 0.5μA at 1200 kilovolts on six targets, Be, C, SiO_2, CaF_2, Al, and Ag, with the following results: (1) Using protons no alpha-particle emission in significant numbers of range exceeding that of the primary protons was observed except from CaF_2, which emits a 60-mm group. The group near 71 mm from this target is due to deutons instead of to protons. (2) We have been unable to confirm the Berkeley report of an 18-cm group of protons from all targets. (3) No observable neutron-emission was found except from Be and a probable trace from CaF_2. An increased residual count for C was promptly shown to be due to a strong gamma-ray emission. (4) No evidence has yet been found for any "threshold-effects." Carbon bombarded with 600-kilovolt deutons (mass-4 spot at 1200 kilovolts) gave more than 1/10 the number obtained with 1200-kilovolt deutons. [Incidentally, from range measurements on the mass-3 spot there has been obtained evidence, but not proof, for the existence of stable hydrogen atoms of mass three, comprising perhaps one part in a million of our deuterium samples.]

36. Gamma-Ray Emission of Various Targets under Bombardment by Deuterium Ions. L. R. Hafstad, M. A. Tuve and C. F. Brown, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—Search for neutron emission from various targets led us early in February to the discovery of powerful gamma-ray emission from Be, C, and CaF_2 when bombarded by deutons, with faint or doubtful emission from SiO_2 and Al and none from Ag. With 0.1μA deuton current (60 percent deuterium flowing through ion-source; magnetic analysis 0.2μA of mass-two spot alone entering Faraday cage and striking the target) we found by visual cloud-chamber observations that the gamma-rays from Be and C produced many more tracks than 1/10 mg Ra (unshielded) in the target position, and approximately equalled the effect of one mg Ra (also unshielded) placed in the same position. The numbers of tracks were not appreciably diminished when an 8-mm lead sheet was interposed between the targets and the cloud-chamber. No delayed effects were observable. CaF_2 gave somewhat less emission, and the others were doubtful because of the residual tracks due to the x-rays from the high voltage tube. Such a visual determination of intensities is obviously crude and distinctly provisional, but it bears mention in view of the very much smaller intensities subsequently reported by Lauritsen and Crane for Be and C, suggesting that perhaps deuterium ions comprise only a small proportion of their target currents. Visual observations with similar results were made later with a magnetic field applied to the cloud-chamber. With these targets, a series of photographs has been obtained with the magnetic field on the cloud chamber, but these records have not yet been studied.

37. Some Higher Terms in the Ag II Spectrum. W. P. Gilbert, *Cornell University.* (*Introduced by R. C. Gibbs.*)—The spectrum of silver has been excited in a hollow cathode discharge with a helium atmosphere. Wave-length measurements were made in the region from 500 to 2600A with a 1.5 meter vacuum spectrograph and in the region from 6000 to 11,000A with a Zeiss 3-prism spectrograph. The introduction of a spark gap in series with the Schüler lamp served to enhance the intensity of lines involving higher levels of Ag II and also to excite the lower levels of Ag III. Starting with the terms already reported by Shenstone and by Blair for the $4d^{10}$, $4d^9\,5s$, $4d^9\,6s$, $4d^9\,5p$ and $4d^9\,5d$ configurations as a basis, radiations have been classified sufficiently to establish the $4d^9\,6p^{3,1}\,(PDF)$ and $4d^9\,7s\,{}^3D, {}^1D$ terms. A few other terms have been found whose identity is uncertain but which probably arise from the configuration $4d^8\,5s\,5p$, and in addition a few $4d^9\,5d$ to $4d^9\,5p$ transitions have been identified. The application of a Ritz formula to the $4d^9\,({}^2D_{3/2})\,ns\,{}^3D_3$ series gives 134,021 cm^{-1} for the limit of this series. Thus the absolute value of the $4d^{10}\,{}^1S_0$ term with respect to the $4d^9\,{}^2D_{3/2}$ level of the Ag III ion is found to be 173,185 cm^{-1}, which corresponds to a first ionization potential of 21.4 volts. The recent contribution of Duffendack and Thompson is recognized.

38. Term Values in the Spectrum of Lead V. G. K. Schoepfle, *Cornell University.*—In a previous paper relative values for 15 terms arising from the $5d^9\,6s$ and $5d^9\,6p$ configurations of Pb V were reported. A similar and independent study was made simultaneously by Goble and Mack, who also obtained the $5d^{10}\,{}^1S_0$ term, the value of which has been kindly supplied by correspondence. Further study of this spectrum has been made especially with reference to those terms for which the assignments in the two reports were not in complete agreement. By using the wave-length list (197 to 1439A) by Arvidsson (Ann. d. Physik **12**, 1 (1932)), over 65 terms have now been established, each by three or more lines, involving a total of almost 200 lines. Due to the *jj* like nature of the spectrum, the terms are numbered and J values assigned. Smith (Phys. Rev. **36**, 1 (1930)) gives two probable sets of values for the two terms arising from the $6d$ configuration in Pb IV, and for one set the three possible lines due to the $6p$–$6d$ transition fit into the present term scheme for Pb V.

39. Some Additional Terms in the Spectrum of La III. R. C. Gibbs and G. K. Schoepfle, *Cornell University.*—In a recent report on the spectra of lanthanum Russell and Meggers list some 250 unclassified lines distributed over the range from 2150 to 11,000A. From a survey of these lines and those obtained from a spark operated in a vacuum spectrograph covering the range from 500 to 2100A, it has been possible to extend both the $ns\,{}^2S$ and $nd\,{}^2D$ series of terms to six members, to locate one more pair of ${}^2P$ terms, and tentatively to determine certain of the ${}^2F$ and ${}^2G$ terms. Plots of the n–n^* values against the term values for the S and D terms reveal fairly close Ritzian series. The S terms give a limit (above the lowest level ${}^2D_{3/2}$) that is in close agreement with that reported by Russell and Meggers, who secured a value of 154,630 for this limit by an extrapolation of Δn^* as found from the first two S terms for the previous members of this isoelectronic sequence. Moseley diagrams for the terms in this sequence yield exceptionally smooth curves when extended to the above-mentioned La III terms.

40. The Arc Spectrum of Selenium. J. E. Ruedy and R. C. Gibbs, *Cornell University.*—The arc spectrum of selenium, as excited by means of a positive column discharge in helium, has been photographed over the wave-length range 1000–11,000A. Four different grating spectrographs were used having dispersions of from 11 to 2.5A per mm and the wave numbers obtained are accurate to better than 0.2 cm^{-1}, except those from the vacuum spectrograph measurements. More than 250 new lines have been classified and seven series approaching the ${}^4S$ state of the ion have been carried to five or more members. Perturbations are frequently evident but the $nf\,{}^5F$ series shows none and from it the absolute term values are determined within 0.2 cm^{-1}. The less perturbed of the other series check this result within 1.0 cm^{-1}. The terms arising from the $4p^3\,5s$ configuration built on the ${}^2D$ and ${}^2P$ states of the ion and the low $4p^4\,{}^1S_0$ term have also been located, as well as some of the terms due to the $4p^3({}^2D)\,4d$ and $5p$ configurations. Intercombination lines are strong and the L selection rule is commonly violated. The analogue of the green oxygen auroral line is observed, if a numerical agreement within 0.1 cm^{-1} is sufficient justification for the assignment.

41. On the Spectrum of Singly Ionized Lead. L. T. EARLS AND R. A. SAWYER, *University of Michigan.*—The initial classification of this spectrum was made by Fräulein Gieseler (Zeits. f. Physik **42**, 265 (1927)) and chiefly because of lack of good data in the extreme ultraviolet was incomplete and believed to be somewhat inaccurate. We have rephotographed the spectrum from a hollow cathode discharge in helium from the vacuum region to the near infrared. We have also been greatly aided by hyperfine structure data placed at our disposal by J. L. Rose. It was found possible to correct and extend greatly the classification. About 215 lines are classified. The doublet series from the configurations $6s^2\,n(s,\ p,\ d,\ f,\ g)$ now include 8, 9, 14, 10, 10 members, respectively. The ^2P, ^2F and ^2G series are quite regular, and where comparison is possible with the isoelectronic spectra of Tl I and Bi III, show good agreement with regular and irregular doublet laws. The ^2S and ^2D series show perturbations in position and in separation of ^2D terms, the lowest of which is inverted. These perturbations are apparently due to neighboring sp^2 levels, all of which have been located. The value of the ionization potential of Pb II is practically unchanged, 14.96 volts.

42. Hyperfine and Gross Structure of Pb II for the $6s6p^2$ Configuration in Intermediate Coupling. JOHN L. ROSE, *New York University, University Heights.*—Breit and Wills (Phys. Rev. **44**, 470 (1933)) have derived formulae showing the relation of Johnson's formulae (M. H. Johnson, Phys. Rev. **39**, 197 (1932)) for the gross multiplet structure to the hfs constants in intermediate coupling. A calculation has been made for the relative positions of the $6s6p^2$ terms of Pb II, with values of G^1, X, and a obtained from energy levels of the $6s6p$ and $6s^26p^2$ configurations of Pb III and Bi II, respectively. The calculated results, neglecting perturbations due to even terms of other configurations, are in as good agreement as could be expected with the experimental values found by Earls and Sawyer and reported in the preceding paper. From the gross structure calculations parameters were obtained for finding the hfs constants, a', a'', a''', $a(s)$, of the $6s6p^2$ configuration. The observed splittings of Pb^{207} are then reasonably explained on taking into account the perturbations due to the $6s^26d$ configuration. The hfs of nearly a hundred Pb II lines in addition to those previously observed by Kopfermann (Zeits. f. Physik **75**, 363 (1932)), Rose and Granath (Phys. Rev. **40**, 760 (1932)), and Schüler and Jones (Zeits. f. Physik **75**, 563 (1932)) have been observed from 11,000 to 2300A. A large number of these lines had not been previously reported or classified. The new classification of these lines by Earls and Sawyer is in general agreement with observed isotope shifts of Pb^{208} and Pb^{206} and the observed splitting of Pb^{207}.

43. The 53 Electron Spectra of Caesium and Barium: Cs III and Ba IV. SISTER M. AMBROSIA FITZGERALD, I.H.M., AND R. A. SAWYER, *University of Michigan.*—For the analyses of these spectra new data for barium were obtained in the quartz and vacuum regions by use of the vacuum spark and of a condensed discharge in helium, for caesium new vacuum spark data were used together with previous data from a hollow cathode discharge in helium. These spectra are isoelectronic with I 1, analyzed by Evans and Xe II, by Humphreys, de Bruin and Meggers. The terms analyzed are mainly built on $(s^2p^4)\ {}^3P$ of the next ion. The lowest term is $(s^2p^5)\ {}^2P$ and in the case of Cs III, the ^2P separation was predicted from the s^2p^5p levels of Cs II by use of Shortley's equations (Phys. Rev. **44**, 666 (1933)). The separation as found is 13,870 cm^{-1} and several combinations of the terms with higher levels were located. The ^2P separation for Ba IV was then estimated by the irregular doublet law and located from the data as 17,830 cm^{-1}. The more complete data for Ba enabled the location of a group of terms which combine both with the $(s^2p^5)\ {}^2P$ terms and also with a higher group of terms allowing the classification of about 50 lines in this spectrum.

44. The Structure of Rigid Gels, such as that of Silicic Acid. W. O. SMITH, *Pittsburgh, Pennsylvania.*—The ideal soil is an assemblage of spheres packed at random. It is proposed, for spheres of colloidal size, to call the assemblage an ideal rigid gel and consider it a model for gels such as that of silicic acid. The theory of capillary condensation for an ideal soil is applicable and shows the hysteresis behavior observed when vapors such as water and alcohol are sorbed by the gel of silicic acid; it is presumed that the gel has been initially dehydrated. The initial dehydration curves arise from the dehydration of an unstable assemblage; the assemblage is completely saturated and the particles are packing under stresses exerted by a meniscus in the outer boundary. The inversion point of van Bemmelen, at a vapor pressure p_h, marks a change from saturation to a distribution of discontinuous liquid masses; the radius of the gel particle can be calculated from the relation

$$r\lambda_h = 2/\{[0.9590/(1-P)^{\frac{2}{3}}]-1\},$$

where

$$\lambda_h = -(\rho p_0/\sigma D_0)\log_e (p_h/p_0).$$

P is the porosity; ρ and σ the density and surface tension, respectively, of the liquid; p_0 and D_0 the respective vapor pressure and density over a plane surface of liquid. For Anderson's SiO_2 gels the particle diameter is 9.66×10^{-7} cm; the mean distance between centers of two adjacent particles is 11.2×10^{-7} cm; the number of particles per cc is 1.03×10^{24}. Intersections of the curves of hydration and dehydration are approximately calculated.

45. The Ultracentrifuge. E. G. PICKELS, *University of Virginia.* (*Introduced by J. W. Beams.*)—In recently improved designs of the air-driven ultracentrifuge (see Beams, Weed and Pickels, Science **78**, 338 (1933); J. Chem. Phys. **2**, 143 (1934)), troublesome convection currents have been eliminated by a scheme of temperature equalization. The observation type of rotor has its thin solution chamber (1 mm in depth) insulated above and below by specially treated glass disks, the bottom one having its lower face painted white to act as a uniform scattering surface for the illumination coming from above.

Liquid in a deeper chamber, just below and adjoining the one described, serves through its own convection action as a temperature equalizer for the solution under observation. Photographic records of molecular sedimentations, such as the separation of hemoglobin, have been obtained with this arrangement. In some cases Phenolite disks have been used to insulate the several chambers of the collector type of rotor. An improvement in optical definition has been devised for the microscope centrifuge (see Harvey, J. Frank. Inst. **214**, 1 (1932)), designed for the observation of small organisms under high centrifugal forces. The axis of rotation lies in the plane of the virtual image formed by a small mirror suitably mounted on the rotor.

46. Propagation of Elastic Waves in Ice. Part I. MAURICE EWING, A. P. CRARY AND A. M. THORNE, JR., *Lehigh University.*—The elastic constants of ice were determined by measuring the resonance frequencies of rods of ice for longitudinal and torsional vibrations. From these constants the velocity of longitudinal waves in a thin plate of ice of infinite extent was calculated. Longitudinal vibrations were generated in a sheet of ice on the surface of a lake by means of a small explosion. The velocity of these vibrations for distances up to 2000 ft. was determined by means of an electric seismograph. These two methods gave concordant results for the velocity of longitudinal waves in a thin plate of ice, the values being 11,155 ft./sec. and 11,190 ft./sec., respectively.

47. Propagation of Elastic Waves in Ice. Part II. A. P. CRARY AND MAURICE EWING, *Lehigh University.*—The velocities of transverse waves polarized horizontally and of flexural or surface waves in a sheet of ice on a lake were determined by use of a seismograph. The flexural waves showed marked dispersion with the group velocity approximately proportional to the square root of the frequency. These velocities may be calculated from the elastic constants of ice reported in the preceding paper. The velocities of transverse waves were 6060 ft./sec. and 5840 ft./sec., respectively. In treating the flexural waves it was necessary to take account of the effect of the water in contact with the ice. When this was done the calculated velocities agreed with the observed ones for various thicknesses and frequencies.

48. Is the Sound Absorption Coefficient of a Material a Constant or a Variable? V. L. CHRISLER, *Bureau of Standards.*—In all of the formulae which have been proposed for computing the sound absorption of a room from the measured rate of decay of the sound energy it has been assumed that the absorption of a material is directly proportional to the area of the material. The formula most commonly used in the past is $T=0.05\,V/[a_1(s_1-s_2)+a_2s_2]$ where T is the reverberation time, V the volume of the reverberation room, s_1 the area of the wall, floor and ceiling surfaces, s_2 the area of the absorbent sample, and a_1, a_2, the so-called "sound absorption coefficients" of these surfaces. If the values computed for a_2 and a_1, from the measured reverberation times, with and without the samples, are accepted as the value of the coefficients, then it is found that the coefficient of any given material is not a constant but varies with the area of the sample.

49. Propagation of Sound and Supersonic Waves in Gases. HAROLD L. SAXTON, *The Pennsylvania State College.*—The theoretical velocity of sound and supersonic waves in gases and the absorption constant per wave-length are given by the formulae

$$C^2=\frac{p}{\rho}\,\frac{R+C+C_iK^2/(\omega^2+K^2)}{C+C_iK^2/(\omega^2+K^2)},$$

$$\mu=\frac{2\pi}{R+C}\left\{\frac{R}{C}\,\frac{\omega KC_i}{\omega^2+K^2}+\frac{\omega}{p}\left(\frac{RLM}{R+C}+\frac{4}{3}C\eta\right)\right\},$$

in which C_i is the heat capacity associated with one partially active degree of freedom; K is the probable number of transitions (because of collisions) per mole per second, of molecules having internal energy in the partially active state to molecules not having; L is the coefficient of heat conduction; η is the viscosity of the gas; and the other constants have their usual physical significance. A method of deriving these equations is outlined and their significance discussed. The graphic description of H. O. Kneser of the phase relations among the variables is extended to include particle velocity, and variations in pressure, temperature, density, and extent of excitation of one partially active internal state.

50. An Apparatus for Obtaining High Precision Supersonic Data. H. L. YEAGLEY, *State College, Pennsylvania.*—The apparatus permits a pressure range of several atmospheres and an upper temperature limit of about 200°C. The supersonic generating and receiving system is a triple-quartz-plate type in which the frequency is controlled by mounting one of the plates in the driving circuit, maintained at constant temperature. The amplified oscillations from this circuit are impressed on the supersonic generating plate, the frequency of which is thus maintained constant regardless of changing temperatures and pressures in the gas chamber. The receiving crystal moves vertically on a long aluminum cylinder actuated by a precision micrometer screw. A method of eliminating standing waves is used. The signal, amplified for observation, is the vector sum of the electromagnetic wave produced in the receiver by the transmitted sound and the direct pickup through the capacity coupling in the set. The amplifier consists of two stages of radiofrequency amplification and a peak-tube voltmeter. By the use of this apparatus data can be secured giving results to three significant figures.

51. X-Ray Studies of the Wood Used in Violins. K. LARK-HOROVITZ AND W. I. CALDWELL, *Purdue University.*—By using reflection from the edges and penetration through the *F*-holes, the structure of the wood of violins has been investigated by x-rays. Care has been taken to obtain patterns from different sections of one and the same instrument, so as to compare portions containing different amounts of varnish. The diffraction patterns show that the spruce used for the top has always a definite fiber structure, whereas the maple used for the back has a different character in different instruments. It has been found that in all instruments characterized by an even and smooth tone quality on all the four strings, there is always a lack of orientation in the structure of the maple used for the back. Instruments with a harsh tone quality, especially in the region of high pitch and "fuzziness" of tone quality in general all show a marked degree of orientation in the wood of the back. Samples of untreated maple have been found to show as small an amount of orientation as found in medium quality violins. It seems therefore, that besides shaping the plates for top and back correctly, it is one of the requirements for a good violin that it consist of one plate having no orientation and therefore possessing the same velocity of propagation of sound in all directions.

52. Tone Analysis and Physical Characteristics of Violins. III. R. B. ABBOTT AND T. H. STEVENS, *Purdue University.*—By continuing this work since the February meeting, a "characteristic resonance frequency" for each of several well-known violins has been found. The data were obtained from analyses of tones of the four open strings and the "characteristic frequencies" were calculated from plots made of frequency against power for each violin. These frequencies were found to be the power centroids which are given by the ratio of sum of the products, partial power times frequency, and sum of the partial powers. These characteristic frequencies fall on a quality scale ranging from approximately 1700 to 3500 vibrations per second. The one for a soprano violin was found to be about 3200 and for a mezzo soprano about 2300 vibrations per second, while some with darker tones were much lower. It is proposed to use a quality scale for classifying violins very similar to one in use for voice range which has lower frequency limits of approximately,—bass 80, tenor 120, alto 170 and soprano 250 vibrations per second. To classify violins by the use of "characteristic frequencies" and a quality scale, our results indicate the lower limits should be ten times those of the voice range, namely, alto 1700 and soprano 2500.

53. On the Origin and Maintenance of the Sun's Electric Field. ROSS GUNN, *Naval Research Laboratory, Washington, D. C.*—A theoretical basis is provided for the author's earlier hypothesis (Phys. Rev. **35**, 635 (1930)) of a solar electrical field which was first introduced to describe certain excitation phenomena and the anomalous solar rotation. The systematic motion of the sun's atmosphere across its own magnetic field is shown to reduce the effective electrical conductivity to values far below those calculated for the atmosphere at rest. The conduction current density is calculated and it is shown that an equal replenishing current flows as a result of the known properties of recombining electrons. Hence a steady electric field is produced. The superposed atmospheric velocity and electric fields calculated from theoretical considerations agree in magnitude, direction and distribution with those deduced in earlier papers from observational data regarding the anomalous solar rotation. As a result of electrical effects the effective electron temperature of the chromosphere is found to approximate 26,000°, suggesting that excessive excitation in the chromosphere is due to high speed electrons.

54. Ionization-Measurements near the Ground during the Time of Thunderstorms. G. R. WAIT AND A. G. MCNISH, *Department of Terrestrial Magnetism, Carnegie Institution of Washington, D. C.*—The rate of ionization inside a thin-walled chamber has been recorded on the grounds of the Department of Terrestrial Magnetism, on the outskirts of Washington, D. C. during the past year. A large definite diurnal-variation in the rate of ionization was found. In addition, the ionization was found to increase several fold at the time of thunderstorms. The increase in ionization usually has an abrupt beginning, coinciding with the beginning of the rain. The total amount of increase is roughly proportional to the total amount of rainfall. The ionization begins to decrease as soon as the rain ceases, the decrease with time being of such a character as to be explainable by assuming that decay-products of radium, principally radium B and radium C in equilibrium with it are carried to the earth's surface by the rain.

55. Penetrating Radiation from Thunderstorms.* B. F. J. SCHONLAND, *DeBeers Institute of Physics and Mathematics, University of Cape Town, South Africa.*

* Invited paper.

56. The Total Ionization Produced by Electron Collisions in Nitrogen. GLADYS A. ANSLOW, *Smith College.*—The total ionization produced in nitrogen by electrons with energies up to 1500 volts has been measured with the apparatus used by the author in a previous experiment (Phys. Rev. **25**, 484 (1925)). Accelerated electron beams, with energies up to 400 volts, were tested for homogeneity of energy by applying a retarding potential between the anode and ionization chamber, and were found nearly homogeneous within a range limited by the fall of potential along the filament. The minimum pressures used during total ionization measurements were determined from ionization-pressure curves, and from these pressures the voltage-range equation was calculated. The outstanding characteristics of the total ionization-energy curve are a decrease in ionization at 375 volts and a rapid increase near 750 volts. According to these measurements 750–1000 volt-electrons expend an average of 55 volts in producing each ion pair. The curve for the average total ionization per cm, derived as in the previous work, shows a maximum just beyond 100 volts, similar to that obtained for primary ionization per cm by other authors, and a second maximum not hitherto reported at 750 volts, twice the ionization potential of the K-electrons of nitrogen.

57. Intensity of the Hydrogen α and β-Lines as determined by the Frequency of the Electrical Field in Electrodeless Discharge. OTTO STUHLMAN, JR., AND M. S. MCCAY, *The University of North Carolina.*—Hydrogen was excited at constant pressure to emit the glow discharge by means of a h.f. electrical field associated with a solenoid excited at low current density. Frequency range 5.0 to 7.5 mega-cycles. A dynamically balanced push-pull oscillator was driven at power range 10 to 100 watts. Pressures were constant. Values near 250 microns were used. The intensity of the general radiation was measured with a photoelectric cell. Intensities of the alpha- and beta-lines were obtained photographically using intensity markers. Experimental error 5 percent. Results show that, with constant power input, the intensities of these spectral lines per unit field strength are directly proportional to the frequency of the oscillating electrical field. Intensity ratios alpha to beta were found to be equal to 0.967 at 60 watts; 0.986 at 70 watts and 1.05 at 80 watts, with frequency and pressure constant.

58. Luminosity in the Mercury Discharge. R. D. RUSK AND A. L. PECKHAM, *Mount Holyoke College.*—Collector measurements have been made in the shadow cast by a small nickel disk in a mercury discharge maintained in a longitudinal magnetic field of strengths up to 240 gauss. The disk intercepts primary electrons from the filament and also the more rapidly moving scattered electrons. Both positive ion current and electron current characteristics indicate a plentiful supply of carriers of both signs in the shadow except when the disk was very near the cathode or anode. The concentration of the slow group of electrons in the shadow was but slightly affected by the field, but the ratio of the apparent concentration of the faster scattered electrons (secondaries) in the shadow to the concentration outside was reduced by a factor of three or four while the absolute value of such concentration was increased by a factor of two or three. The shadow however was sharp, and the field decreased the luminosity by a factor of more than ten. This shows that recombination of slow electrons and positive ions is a negligible factor in producing luminosity in such a discharge, and the scattered electrons of intermediate speeds produce less visible effect in the shadow than might be expected.

59. The Initial Stages in Spark Gap Discharge. L. B. SNODDY AND C. D. BRADLEY, *University of Virginia.*—The processes occurring in the breakdown of a point-sphere spark gap to which an impulsive potential is applied have been studied for the period preceding the appearance of luminosity. The electrodes were placed in a Wilson cloud chamber and a potential impulse of such short duration applied that complete dielectric breakdown did not occur (Phys. Rev. **45**, 432 (1934)). From the shape of the cloud tracks the ion distribution during the dark current portion of the discharge is readily obtained. The total duration of the voltage impulse was about 10^{-7} sec. With the point negative the cloud at low voltages appears as a fine cone shaped track with the apex at the point and usually extending between electrodes. With increasing voltages this track becomes broader and an irregular cloud forms around the anode. With the point positive the ion distribution is characterized by streamers, having the appearance of single particle tracks but not always forming directly between electrodes. At times they start at some distance from the cathode and curve inward to the point. By a suitable change in circuit constants it is possible to obtain tracks of this type which do not reach completely to the point.

60. Characteristics of Arcs at Atmospheric Pressure. C. G. SUITS, *Research Laboratory, General Electric Co., Schenectady.*—According to Nottingham and others, the static characteristic of the "normal" arc at atmospheric pressure may be represented by an equation of the form $E=A+B/i^n$, where E is the arc drop, i the arc current, A and B constants, and n is a constant independent of arc length but dependent upon the material of the anode. The exponent n is numerically between the limits 0.3 and 1.5 in magnitude, and varies directly as the boiling point of the anode material. A careful investigation of the case of the copper arc, by a method of relatively high accuracy, reveals that the spread in determining n for copper is as great as the whole range of values through which n varies for all electrode materials. It appears therefore that the result, "n varies directly as the boiling point of the anode material," is not unique and is not supported by these experiments. Experiments with copper and silver arcs, in which the roughness of the electrode surface is varied, show that the condition of the surface has an influence upon the character of the spontaneous fluctuations in arc voltage which are found with many arcs. In particular, an arc between electrodes of highly polished copper is substantially free from arc voltage fluctuations. This arc is blue in color and the spectrum (in the arc stream) is chiefly that of nitrogen with traces of copper. Arcs of this kind may be burned for short periods without anode pitting, although some cathode pitting and oxidation occur. Arcs between electrodes of polished silver exhibit similar properties, but have some striking differences suggesting that the voltage fluctuations take place between two stable states. The volt-ampere characteristics for polished copper and polished silver are identical within the spread of the measurements, suggesting that both cases are nitrogen arcs.

61. Molecular Ions from Heated Salts of Some of the Alkali Metals. LEROY L. BARNES, *Cornell University.*—Heated salts of the alkali metals are frequently used as sources of positive ions of these metals. During the course of some experiments in which potassium salts were being heated on platinum in a magnetic spectrograph, some positive ions of relatively large mass were detected. Careful measurements of the masses of these ions indicate that they are molecules of the salt plus a singly charged atom of potassium. From potassium chloride, at a temperature somewhat below its melting point, an ion having the mass of K_2Cl^+ has been observed. From potassium sulphate an ion having the mass of $K_3SO_4^+$ has been observed. In each case the major isotopic constituents of the ion beam have been resolved. Similar ions are being obtained from salts of some of the other alkali metals.

62. The Ultraviolet Band Spectrum of N_2O_3. EUGENE H. MELVIN AND OLIVER R. WULF, *Bureau of Chemistry and Soils, Washington, D. C.*—In considerable amounts of NO containing small amounts of NO_2, a group of bands occur in the near ultraviolet which are due neither to NO nor to NO_2, as is quite clear from comparison pictures of each of these gases alone. A broad continuous absorption lies to shorter wave-lengths. The behavior of these bands with respect to temperature and the partial pressures of the constituents is rather convincing evidence that they are due to N_2O_3. The bands appear diffuse under low dispersion but possess an ordered arrangement which indicates a process of dissociation of the N_2O_3 molecule in the vicinity of 2400–2200A. With increasing temperature the intensity of the bands clearly decreases, as would be expected due to the thermal dissociation of the N_2O_3. The bands begin rather abruptly in the vicinity of 3850A, thus in the vicinity of the first predissociation process of the NO_2 molecule. The first members are broader and more diffuse than those which follow to shorter wave-lengths, this being probably connected with a predissociation process in N_2O_3.

63. Ionization of Carbon Disulphide by Electron Impact. H. D. SMYTH AND J. P. BLEWETT, *Princeton University.*—Products of ionization by slow electrons in CS_2 have been investigated by using the familiar mass-spectrograph method. Appearance potentials are observed as follows: CS_2^+, 10.4±0.2 volts, CS^+, 14.7±0.5 volts, S^+, 14.0±0.5 volts, C^+, 21.5±1.0 volts. S_2^+ is not observed, presumably because of the linear structure of the CS_2 molecule. Ionization potentials are observed also for free S_2 (10.7 volts) and CS (10.6 volts), present when the filament is run at a high temperature. Heats of dissociation are calculated for the processes $CS_2 \rightarrow C+S+S$ and $CS_2 \rightarrow CS+S$ and are respectively 10.2 and 3.9 volts. These agree within the experimental error with values from band spectra. The first of these heats of dissociation may also be obtained from a thermochemical calculation involving the heat of sublimation of carbon which is somewhat uncertain. Inversely, if the heats of dissociation from the present experiment are assumed correct, the heat of sublimation of carbon may be calculated as 5.4 volts.

64. Rotational Structure of the Fourth Positive Bands of CO. D. N. READ, *Palmer Physical Laboratory, Princeton University.*—The rotational structure of a number of the fourth positive bands of CO ($A\,^1\Pi \rightarrow X\,^1\Sigma$) has been measured and analyzed. The bands chosen include all values of v'' from 1 to 10. The structure consists of P, Q and R branches, to be expected from this type of transition. The same perturbations of the $^1\Pi$ state are observed as in the Angstrom bands ($B\,^1\Sigma - A\,^1\Pi$). The values obtained for the rotational constants of the ground state of CO are $B_0 = 1.9170$ cm^{-1}, $\alpha = 0.01738$ cm^{-1}. The value of B_0 obtained from infrared band data is 1.84. The higher value for B_0 is verified by measurement of the 0–0 band of the ultraviolet system $B\,^1\Sigma - X\,^1\Sigma$. Coster and Brons (Physica **1**, 155 (1934)) have recently reported an abrupt drop in intensity of the rotation lines of the 0–1 Angstrom band, starting at $J' = 38$. It is interpreted as predissociation of the B state. The same phenomenon is observed in the 0–0 band of the $B-X$ system. This sets an upper limit for the heat of dissociation of CO of about 11 volts.

65. The Dissociation Energy of CO and the Electron Affinity of O. W. WALLACE LOZIER, *Princeton University.*—The potential energy of the dissociation products of CO under electron bombardment has previously been measured and reported (Phys. Rev. **43**, 776 (1933)) giving the following results: $C+O^-$ at 9.5±0.1 v, C^++O^- at 20.9 v, and C^++O at 22.8±0.1 v. New measurements on O_2 gave $O+O^-$ at 2.9±0.2 v and 12.0±0.2 v. In these experiments the kinetic energies of the ions were measured and the values quoted above refer to zero kinetic energy. The O_2 results as interpreted yield two values of E_0, the electron affinity of the oxygen atom, both equal to 2.2±0.2 v. The data on CO permit two alternative interpretations. One of these gives $D(CO) = 11.6 \pm 0.1$ v and allows the calculation of two values of E_0 from the CO data as 2.1±0.1 and 1.9 ±0.1 v. The alternative interpretation gives $D(CO) = 9.6 \pm 0.1$ v and necessitates the postulation of excited O^- ions to explain the O^- data in CO. Data from thermochemistry, band spectra, and other electrical measurements can be compared with these data in an attempt to choose the correct one of these two alternatives for $D(CO)$.

66. Vibrational Analysis of BaCl and BeCl Bands. ALLAN E. PARKER, *Columbia University and Yale University.*—Two additional band systems of BaCl have been photographed in the second orders of two 21-foot gratings. Both systems are $^2\Sigma - ^2\Sigma$ transitions with (0,0) bands at λ3922 and λ3692, respectively. The spin-doubling of the $^2\Sigma$ states is too small to produce a resolvable separation of the P_1 and P_2 heads. The band heads of the two systems are given by the following equations:

$$\nu = 25496.9 + [304.6(v'+\tfrac{1}{2}) - 1.04(v'+\tfrac{1}{2})^2] - [279.1(v''+\tfrac{1}{2}) - 0.78(v''+\tfrac{1}{2})^2]$$

$$\nu = 27097.3 + [311.8(v'+\tfrac{1}{2}) - 1.21(v'+\tfrac{1}{2})^2] - [278.9(v''+\tfrac{1}{2}) - 0.72(v''+\tfrac{1}{2})^2].$$

The lower state of each of these systems is identical with the lower state of the green $^2\Pi - ^2\Sigma$ BaCl bands and it is the normal state of the molecule. The two upper states have the same dissociation products. Some rotational structure is observed but not sufficient to permit a determination of the B constants. A band system due to BeCl has been photographed in the second and third orders of a 21-foot grating. The bands are a $^2\Pi - ^2\Sigma$ transition degrading to the red. The following tentative equation gives the position of the Q_1 heads:

$$\nu = 18685.6 + [540.0(v'+\tfrac{1}{2}) - 7.1(v'+\tfrac{1}{2})^2] - [551.5(v''+\tfrac{1}{2}) - 6.2(v''+\tfrac{1}{2})^2].$$

The lower state is undoubtedly the normal state of BeCl. The dissociation products of the lower state are Be $(1s)^2(2s)(2p)\,^1P + \mathrm{Cl} \cdots (3p)^5\,^2P$.

67. The Band Spectrum of Caesium. P. KUSCH AND F. W. LOOMIS, *University of Illinois.*—Measurements of five distinct band systems of Cs_2 have been made, in absorption with high and low dispersion, in magnetic rotation, and in fluorescence. Three of these systems, with maxima at 6250A, 7200A and 7600A, have been reported before, but not analyzed. The fourth with a maximum at 4800A and the fifth, extending from 8950A to limit of sensitivity of the plate, are new. Quantum numbers have been assigned to some 218 bands in the system at 7600A. The upper and lower vibrational frequencies are 34.28 and 41.99 cm^{-1}, and an extrapolation yields 0.48 volt as the energy of dissociation of the ground state. This system and the one beyond 8950A apparently correspond to the green and red systems of sodium, respectively. The origin of the fifth system lies beyond the region of sensitivity of even the new Eastman Q plates. Some regularities in the other systems have been found, but no complete analysis could be made, though a fluorescence spectrum was obtained in the 6250 system which showed the lower state to be the same as in the 7600A system. This 6250A system is extraordinarily complex and appears to contain some bands degraded to the red, some to the blue and some narrow regions of absorption bounded by edges on both sides. No magnetic rotation spectrum was found.

68. A New Band System of Tin Oxide. T. F. WATSON AND F. W. LOOMIS, *University of Illinois*.—A new band system of tin oxide has been observed in the spectrum of a tin arc operated in oxygen at low pressures. The frequencies of the band heads can be expressed by the formula

$$=36{,}803+\{497.8(v'+1/2)-2.56(v'+1/2)^2\} \\ -\{821.9(v''+1/2)-3.6(v''+1/2)^2\},$$

which indicates that the lower electronic state is the same as that of the A and B systems.[1] The large number of isotopes of tin complicates the spectrum so that a rotational analysis is not possible even in the second order of a 21-foot grating with 30,000 lines/inch.

[1] Connelly, Proc. Phys. Soc. **45**, 789 (1933).

69. The Band Spectrum of NaK. F. W. LOOMIS AND M. J. ARVIN, *University of Illinois*.—Two new band systems of NaK, in the green and infrared, have been photographed in absorption and magnetic rotation, and vibrational analyses made. Magnetic rotation measurements have also been made in the known orange system and by this means the bands have been followed nearly to convergence, and accurate energies of dissociation obtained. It has been found that the two infrared systems previously reported are really the two parts of the same system which lie on opposite sides of the potassium resonance lines. The fourth predictable system has not been found and is probably covered by the red K_2 and Na_2 bands. The heat of dissociation of the ground state is 0.62±0.03 volt, which is intermediate between the values for Na_2 (0.76 volt) and K_2 (0.51 volt). The green and infrared magnetic rotation spectra are of the complex type, like the red system of Na_2, which has been interpreted as due to perturbations.

70. Band Spectrum of AlH^+. G. M. ALMY AND M. C. WATSON, *University of Illinois*.—AlH^+ has been excited in a hollow aluminum cathode lamp containing hydrogen and helium. The spectrum obtained is evidently that reported by Holst (Nature **132**, 1003 (1933)) but our analysis is quite different. We have found the (0,0) and (1,1) bands of a $^2\Pi$ (regular)→$^2\Sigma$ transition. The (0,0) band head is at 3632A. Holst finds on the basis of Λ-type doubling that the $^2\Pi$ state is inverted with $A=-39$ cm^{-1}. We find the state regular, $A=108$ cm^{-1}, and following closely the Hill and Van Vleck relation for spin doubling. Our analysis is supported by (1) the definite presence of $P_1(3/2)$ and $Q_1(1/2)$ in the (0,0) band (absent if state is inverted); these lines appear also in the (1,1) band but the evidence is less conclusive due to the density of lines, (2) the ratio of electronic coupling coefficients derived from AlH^+ ($3p\pi$ $^2\Pi$) and Al II ($3p$ ^3P) is 0.86, precisely that for the analogous MgH $3p\pi$ $^2\Pi$ state. The rotational constants are:

$$\begin{array}{ll} B_0'=6.80 & B_1'=6.53 \\ B_0''=6.57 & B_1''=6.19 \\ D_0''=-0.000485 & D_1''=-0.00076 \end{array}$$

Our B_0'' and D_0'' agree with Holst's. With Holst we find the $^2\Sigma$ spin doubling very small. We find the Λ-type doubling in the $^2\Pi$ state too small to check adequately with the theory.

71. Vibrational Analysis of the Hafnium Oxide Band Spectrum. R. WILLIAM SHAW AND HENRY C. KETCHAM, *Cornell University*.—Approximately 100 bands arising from the diatomic molecule HfO have been observed in an arc-flame source. The bands, which are in the region λ6350 to λ3330, are degraded toward the red and in many cases show double heads. In no instance is any rotational structure observed with the Hilger E-1 Littrow spectrograph which was used in photographing the spectra. A vibrational analysis of the band heads groups the majority of the bands into two systems γ and β. A poorly developed α system is indicated. The analysis also indicates that triplet electronic levels, which have quite large separations, are involved. The strongest bands in each system are confined to the zero sequence. In many respects this spectrum is, as might be expected, quite similar to those of TiO and ZrO. Certain of the constants of the systems are, however, larger than might be anticipated.

72. Soft X-Ray Spectra of Al and Mg; Wave-Length Measurements. THOMAS H. OSGOOD, *University of Chicago*.—The L spectrum of each of these metals in the polycrystalline state is known to consist of one wide line, limited sharply on the high frequency side, and gradually decreasing in intensity on the other. The wave-length of this sharp edge has been measured for Al and for Mg by means of a plane grating spectrograph, with a resolving power of about 1000. All earlier work on these particular spectra has been done with concave gratings. To minimize experimental errors, plates were calibrated by the oxygen $K\alpha$ line (23.610A), which in spite of a recent announcement by Chalklin, appears to be single and sharp. Siegbahn also adopts this line as a standard. The present experiments lead to the values: Al, 170.0±0.2A (Compare Siegbahn, 170.47A; O'Bryan and Skinner, 169.8A); Mg, 250.8±0.3A (Compare Siegbahn, 250.20A; O'Bryan and Skinner, 251A).

73. Quadrupole Lines in the Ru K Series. ERNST WILHELMY, *University of Chicago.* (*Introduced by S. K. Allison.*)—By means of a double crystal spectrometer and a high power x-ray tube with a ruthenium target the transitions $K-M_{\mathrm{IV}}M_{\mathrm{V}}$ and $K-N_{\mathrm{IV}}N_{\mathrm{V}}(K\beta_5$ and $K\beta_4)$ in the Ru K Series were detected. $K\beta_5$ shows a noticeable fine structure in the 5 rocking curves which were taken, a weaker component being at about 0.16 X.U. towards the long wave-length side. The wave-lengths are 566.68 and 559.74 X.U., the frequencies $(\nu/R)_{\mathrm{obs.}}1608.04(\nu/R)_{\mathrm{calc.}}1608.45$ and $(\nu/R)_{\mathrm{obs.}}1628.0(\nu/R)_{\mathrm{calc.}}1628.9$. Also the natural widths of the lines could be measured. Both components of $K\beta_5$ together have a full width at half maximum of 11.4±1.4 volts. The width of $K\beta_4$ is decisively larger, namely 28±8 volts, the error being greater here, because $K\beta_4$ lies directly above the foot of $K\beta_2$. The intensity of $K\beta_4$ is about 1/160, that of $K\beta_5$, 1/400 of the intensity of $K\alpha_1$.

74. Origin of $K\alpha$-Satellites. E. RAMBERG, *Cornell University.* (*Introduced by E. H. Kennard.*)—Self-consistent-field functions for sodium atoms from whose inner shells one or two electrons have been removed are used to calculate corresponding atomic energies by the method of Fock and Slater. Designating configurations by the symbols of the vacant electron states, the transitions $1s2p\rightarrow(2p)^2$ are correlated in the following table with observed $K\alpha$-satellites, indicating in each case the frequency separation from the parent line $K\alpha_{1,\,2}$. The transitions $1s2s\rightarrow 2s2p$ are assumed to give rise to very faint lines which have not been reported. Evidence is presented for attributing the lines $K\alpha_5$ and $K\alpha_6$ to transitions in triply ionized atoms, such as $1s(2p)^2\rightarrow(2p)^3$. A simplified theory, previously applied by H. C. Wolfe, disregarding the alteration of the core wave functions by the removal of an inner electron, is used to calculate separations for sodium, chlorine, potassium, and copper, making use of wave functions published by Hartree. The results, taking due account of spin-orbit interaction and changes in coupling, support the above modification of Druyvesteyn's interpretation of the $K\alpha$-satellites.

Observed		Calculated		
Line	$\Delta\nu/R$	Transition	$\Delta\nu/R$	Intensity
$K\alpha'$	0.31	$1s2p\ {}^1P-(2p)^2\ {}^1S$	0.34	1
$K\alpha_3$	0.52	$1s2p\ {}^3P-(2p)^2\ {}^3P$	0.68	9
$K\alpha_4$	0.64	$1s2p\ {}^1P-(2p)^2\ {}^1D$	0.79	5

75. On the Determination of the Shape, Wave-Length and Width of an X-Ray Absorption Limit. F. K. RICHTMYER AND S. W. BARNES, *Cornell University.*—It is customary to represent graphically the observed data on x-ray absorption limits by plots of I/I_0, or even I, against λ where $I=I_0e^{-\mu/\rho\cdot\rho x}$. It is pointed out that such curves are misleading because the shape and wave-length position of the curves $I/I_0=F(\lambda)$ vary with x, the thickness of the absorber. Curves are shown to illustrate this point. Furthermore it is shown that the finite resolving power of the x-ray spectrometer leads to the result that the width of the curves $I/I_0=F(\lambda)$ is also a function of the thickness of the absorber. Assuming reasonable values for the resolution of the spectrometer it is shown that a change of foil thickness corresponding to a change of I/I_0, at the center of the absorption limit curve, from 0.3 to 0.9 may result in a change of the width of the limit, as determined from $I/I_0=F(\lambda)$, of as much as 20 percent. The effect of higher orders and of the nonuniformity of foil thickness upon the curve $I/I_0=F(\lambda)$ is also discussed. It is concluded that determinations of the widths, shapes and wave-lengths of absorption limits are unambiguous only if made from plots of μ/ρ against λ.

76. A Relation Between the Widths of the Lines and Limits in the L Series of Au(79). S. W. BARNES, *Cornell University.*—In accordance with the conclusions of Weisskopf and Wigner (Zeits. f. Physik **63**, 54 (1930)) the assumption is made that the width, in volts, of an x-ray line is equal to the sum of the widths of the two energy levels associated with the transition from which the line arises. Accordingly the difference in widths of two energy levels should be the same as the difference in widths of any two lines which result from transitions from a common initial level to these two levels. Width data for the following pairs of lines indicate a difference of width (in volts) between the L_{II} and L_{III} levels which is constant within experimental error.

Lines		Line widths		$L_{\mathrm{III}}-L_{\mathrm{II}}$
$l-\eta$	=	19.7−19	=	0.7
$\alpha_2-\beta_1$	=	8.2− 7.4	=	0.8
$\beta_6-\gamma_5$	=	16.0−14.9	=	1.1
$\beta_{15}-\gamma_1$	=	11.5−10.4	=	1.1

Preliminary determinations of the widths of the L_{I}, L_{II} and L_{III} absorption limits of Au(79) indicate that their relative widths are such as to be expected from a study of the widths of the proper pairs of lines.

77. The Change in Relative Intensity of the Satellites of $L\alpha$ in the Atomic Number Range 47 to 52. F. R. HIRSH, JR., AND F. K. RICHTMYER, *Cornell University.*—By means of photographic density curves obtained from spectrograms, the intensity of the satellites of $L\alpha$ relative to $L\alpha_1$ (ratio of areas of lines) has been determined for the elements Ag (47) to Te (52). This ratio drops from about 0.10 at In (49) to less than 0.01 at Sb (51). It is difficult to correlate this rapid change of intensity with any known change in the inner electron structure of the atom. Accordingly, it is concluded that changes with atomic number in the peripheral electron structure must play an important rôle in the production of satellites. The Hoyt equation for the shape of an x-ray line (Phys. Rev. **40**, 477 (1932)) was used in these determinations, since the equation was found to fit the $L\alpha_1$ line of Sb (51), the satellites of which are extremely faint.

78. The Determination of X-Ray Line Shapes by a Double Crystal Spectrometer. LLOYD P. SMITH, *Cornell University.*—As a result of a new mathematical analysis of the action of the double crystal spectrometer, it has been found that the instrument is capable of furnishing sufficient data to determine the initial line shape completely. These data are obtained for the most general case by taking rocking curves in the $(1,-1)$, $(2,-2)$, $(1,+1)$, $(2,+2)$ and $(1,+2)$ positions. The actual determination of the line shape and calibration of the spectrometer is considerably simplified when certain of the rocking curves such as $(1,-1)$ and $(2,-2)$ are symmetrical.

79. The *K* Series Spectrum of Thorium. J. C. HUDSON, H. G. VOGT, *Harvard University,* AND ALICE H. ARMSTRONG, *Wellesley College.*—Several lines in the K series spectrum of thorium have been photographed using a calcite crystal and the Bragg focussing arrangement. The distance from the slit serving as the source to the axis of the spectrometer is about six meters. The source of x-radiation is an air-cooled thorium target tube operated at 190 kv and 0.6 m.a. The tube is kept on the pump—a three stage mercury diffusion pump with acetone and carbon-dioxide as a refrigerant. On the photographic plate the α-lines are separated about 11 mm, the β-doublet is well separated and the γ-lines also appear as a close doublet easily distinguishable as two separate lines. A faint line appears at a wave-length just shorter than the γ-doublet which we have called the δ-line, corresponding to a similar line in the tungsten spectrum. Measurements of the wave-lengths of the lines give the following values all in X-units: $\alpha_2=137.44$, $\alpha_1=132.46$, $\beta_2=117.90$, $\beta_1=117.14$, $\gamma_2=113.69$, $\gamma_1=113.40$, $\delta=112.6$.

80. A Balanced Filter Method for Measuring the Width of the Compton Modified Line. E. O. WOLLAN, *University of Chicago.*—With the aid of a previously described (Phys. Rev. **43**, 955 (1933)) triple balanced filter, a method has been worked out for measuring the width of the modified $K\alpha$ lines of molybdenum which is applicable to scattering materials in the gaseous as well as in the solid state. The three filters are made from the oxides of zirconium, yttrium and strontium. The wave-length of the $K\alpha$ doublet of molybdenum lies between the critical absorption wave-lengths of Zr and Yt and hence is readily transmitted by the former and strongly absorbed by the latter. The wave-length of the center of the modified $K\alpha$ doublet varies with the scattering angle φ and hence it moves across the limit of the Yt filter as φ increases. With these filters one can measure the fraction of the modified line which at any scattering angle φ has passed into the region between the Yt and Sr absorption limits and from this a calculation of the width of modified line can be made. Lithium, carbon and nitrogen were used as scattering materials. The widths obtained were found to be approximately the same for all three elements and equal to about 22 X.U. for $\varphi=180°$. This is in accord with DuMond's measurements with the multicrystal spectrometer. The velocity distribution of the electrons in a nitrogen atom is calculated.

81. A Reconsideration of the Selection Rules for X-Ray Spectra. SAMUEL K. ALLISON, *University of Chicago.*—In 1928 Goudsmit showed that the Γ permanence and sum rules, which concern the spin-orbit interactions of the electrons in a given configuration and thus the multiplet separations, lead to unique results in case the J values arising are all different. He showed that this can be applied to the x-ray terms and that irrespective of the coupling between, for instance, the electrons in a p^5 configuration, two terms of $J=3/2$ and $J=1/2$ will arise, the separation of which will be governed by the same formula as is applicable to the spin-orbit interaction of a single p electron. In view of the strong probability that the coupling is different in the L shells of such widely separated atoms as, say, calcium and uranium, the assignment of Russell-Saunders term symbols to x-ray levels is logically unsound. This may also be said of the usual statement of the x-ray selection rules; $\Delta l=\pm1$, $\Delta j=\pm1$ or 0. An alternative and more general procedure is to consider the x-ray terms as odd or even in the usual way, depending on Σl_i. Thus $1s\ K$ is even; $2s\ L_{\mathrm{I}}$ is even, $2p\,{}^5L_{\mathrm{II}}L_{\mathrm{III}}$ is odd, $3d\,{}^9M_{\mathrm{IV}}M_{\mathrm{V}}$ even, etc. Then the selection rules may be stated: transitions occur between odd and even terms only, and $\Delta J=\pm1$ or 0. In such simple cases it is also known that the sum rules for intensities are independent of coupling.

82. The Crystal Lattice of Oxalic Acid Dihydrate. W. H. ZACHARIASEN, *University of Chicago.*—The crystal lattice of $H_2C_2O_4\cdot2H_2O$ was examined in order to determine the structure of the oxalate radical. The crystals are monoclinic with the following dimensions of the unit cell: $a=6.12\pm0.02$A, $b=3.61\pm0.01$A, $c=12.03\pm0.03$A, $\beta=106°\ 12'$. There are two molecules per unit cell and the space group is $P2_1/n$. All atoms are lying in the general positions of the space group. The 12 degrees of freedom for the carbon and oxygen atoms were determined accurately and uniquely from the observed intensities of reflections. Their values are:

	$2\pi x$	$2\pi y$	$2\pi z$
C	$-15°$	$15°$	$20°$
O_{I}	$32°$	$-22.5°$	$54°$
O_{II}	$-80°$	$80°$	$15°$
O_{H_2O}	$-160°$	$-135°$	$62.5°$

The oxalate radical is plane. Each carbon atom is bonded to another carbon atom (at a distance of 1.59 ± 0.07A) and to two oxygen atoms (at a distance of 1.25 ± 0.05A). The angle between the two $C-O$ bonds is 126°. These results show that there is a single bond between the two carbon atoms, while the binding between carbon and oxygen resonates between a single and a double bond. The most plausible distribution of the hydrogen atoms indicates that the compound may be considered as oxonium oxalate, $C_2O_4(H_3O)_2$, rather than as a hydrate of oxalic acid.

83. The Configuration of the Triiodide Group in Ammonium Triiodide. R. C. L. MOONEY, *Newcomb College, New Orleans.*—It is generally recognized that in groups of light atoms containing electrons not needed for binding, the configuration is angular rather than linear. Since no groups of heavy atoms of this type had been observed, the crystal structure of ammonium triiodide was undertaken. From x-ray diffraction data, it was found that the orthorhombic space group is $Pnma(V_h16)$. The dimensions of the unit cell are:

$a=6.64$A $\qquad b=9.66$A $\qquad c=10.82$

The unit cell contains four molecules. Since the iodine atoms lie in reflection planes, their positions are fixed by six parameters. These parameters were directly determined by the observed intensities, no assumptions being made other than those inherent in the theories of x-ray diffraction. Calculation of the distances between the iodine atoms fixed by these parameters shows definitely the existence of a triiodide group; further, the configuration is strictly linear. The distance between atoms belonging to the same group is 2.8A. The distance between any iodine atom and its nearest neighbors belonging to other groups is 4.22A. The ammonium atoms cannot be located by study of the diffraction data. However, the crystal symmetry reduces the possibilities to two. Neither alternative is definitely excluded by considerations of known atomic distances. Study of the isomorphous caesium salt will be used to settle the question.

	$2\pi x$	$2\pi y$	$2\pi z$
I_1	90°	125°	60°
I_2	90°	197°	140°
I_3	90°	265°	208°

84. The Dependence of Cybotactic Groups on Specific Volume. Ross D. Spangler, *University of Iowa.*—Additional x-ray diffraction data have been taken on ethyl ether in the region of the critical point (Spangler, Abstract 24, Phys. Rev. **42**, 907 (1932)). Series of diffraction curves at pressures of 39.2, 44.1, 49, and 55 kg/cm with temperatures ranging up to 235°C show, as in previous work, that the cybotactic groupings depend more on specific volume than on temperature. At each of the above pressures, the indications of groups disappear at about the critical specific volume regardless of the higher temperatures at higher pressures. The ionization currents were measured with a direct deflection amplifier employing an FP-54 tube instead of the customary electrometer. With this arrangement data could be taken much more rapidly and the fidelity of the results are, in the limit of observation, the same.

85. The Secondary Structure of X-Ray Absorption Edges from Elements in Certain Cubic Crystals. G. P. Brewington, *University of Michigan.*—The K x-ray absorption spectra of potassium, chlorine, calcium and sulfur in several different cubic crystals have been photographed. The absorption spectrum was obtained for potassium from filters prepared with KF, KCl, KBr, and KI, and the chlorine spectrum from LiCl, NaCl, KCl, RbCl. The calcium and sulfur absorption spectra were obtained from powdered calcium sulfide. A secondary structure was found on the short wave-length side of the K edges of each of these elements. The following results are not in accord with the demands of the Kronig theory for secondary structure:—The absorption spectra of two elements in the same crystal are not similar. The product of the square of the separation of each of the secondary structure components in volts and the square of the lattice space is not a constant for the crystals studied. The separation of the secondary structure lines was not found to be proportional to n^2. Some of the structure previously reported for the sulfur edge is shown to be due to the sulfur contained in goldbeater's skin which had been used to cover the slit of the x-ray tube.

86. The L Absorption Discontinuities of Bismuth. L. H. Carr, *University of Chicago.* (*Introduced by Samuel K. Allison.*)—The problem of obtaining a thin enough absorber was solved by using the bismuth in solution. Bismuth nitrate dissolved in dilute nitric acid was held in one cell, while in another like cell was put only the dilute acid. The difference in the absorption of these two cells was then due entirely to the bismuth atoms, since the absorption of the $(NO_3)_3 \cdot 5H_2O$ group added with each Bi atom almost exactly balanced that of the water and acid displaced. The cells had been balanced by trial and error, until their absorption was the same, both when they were filled with water and when they were empty. The solution was analyzed to find the amount of bismuth and the thickness of the cell was measured with a microscope, so that μ/ρ could be found. This was measured at twenty wave-lengths between 0.56 and 1.54A. By plotting these values, the equations of the four branches of the curve were obtained. $(\mu/\rho)L_{\text{I}}=2.438\lambda^{2.5}$, $(\mu/\rho)L_{\text{II}}=2.548\lambda^4$, $(\mu/\rho)L_{\text{III}}=2.251\lambda^3$, $(\mu/\rho)M=1.860\lambda^{2.715}$. The magnitudes of the discontinuities, r, where $r(\text{I, II})$ is the ratio of (μ/ρ) on the short wave-length side of L_{I} to that on the long wave-length side, are $r(\text{I, II})=1.161$; $r(\text{II, III})=1.572$; $r(\text{III, M})=2.393$; $r(\text{I, M})=4.37$.

87. A Shielded Filament X-Ray Tube. Elmer Dershem, *University of Chicago.*—Tungsten filaments as sources of electrons for x-ray tubes used with vacuum spectrographs have the disadvantages that visible light fogs the plates and a layer of tungsten is soon sputtered onto the target, thus changing the quality and quantity of x-radiation. These difficulties have been almost entirely overcome by the use of a molybdenum shield between the filament and target. The electrons are drawn through an opening in one side of the shield by means of a wire electrode charged to a potential of about 350 volts. Only a small part of the electrons strike the wire while the remainder pass on into the influence of the main field of the tube and come to a fine focus on the target. It was found: (1) That visible light is practically eliminated. (2) The intensity of an x-ray spectral line remains constant over a long period of time since the target is shielded from evaporated tungsten. (3) The tube current is more nearly constant since it depends mainly on the auxiliary potential rather than the filament heating current. (4) The life of the filament is increased, probably due to protection from positive ion bombardment.

88. Recent Developments in Commercial Production of Super-Voltage X-Ray Tubes and Generating Apparatus. Cyrus A. Poole and Wilbur S. Werner, *The Kelley-Koett Mfg. Company, Covington, Kentucky.*—Last year a preliminary report was given on the commercial production of high voltage x-ray tubes and transformer apparatus. Since then, there have been further developments in equipment of this type, the purpose of which is to produce radiations of the gamma order. Permissible voltage application has been increased, anode cooling improved, and mid-ground self-protected tubes have been produced of still higher voltage rating. Oil diffusion vacuum pumps that do not require liquid air traps, have been developed and are now a part of a high voltage x-ray system. Cascaded transforming and rectifying systems have been developed for either mid-ground or end-ground type circuits in both constant direct voltage and impulsing voltage. The designs include potentials of 1,200,000 volts. Improvement of the means of ray-proofing the room in which the x-ray emitting portion of the x-ray tube is projected has been made. Ray protection by metallic lead has been replaced by concrete or combination of concrete and lead. Valuable help has been rendered in this work by other men to which due credit is to be given.

89. Tension Coefficient of Resistance of the Single Hexagonal Crystals, Zinc and Cadmium. MILDRED ALLEN, *Mount Holyoke College*.—The work on the tension coefficient of electrical resistance of single metal crystals which was begun with the trigonal crystals bismuth and antimony (Phys. Rev. **42**, 848 (1932), **43**, 569 (1933)) has been extended to the hexagonal crystals zinc and cadmium. Experimentally they were somewhat more difficult to work with because of their lower specific resistance, smaller tension coefficient and lower elastic limit. According to Professor Bridgman's theory of the effect (Phys. Rev. **42**, 858 (1932)), hexagonal crystals may be considered as a degenerate case of trigonal crystals in which the constant which determines the variation of the tension coefficient with the orientation of the secondary cleavage planes becomes zero. Hence the tension coefficient of these hexagonal crystals should depend only on the orientation of the primary cleavage planes with respect to the direction of the current and the tension; this has been verified experimentally.

90. The Absorption of Water for Wave-Lengths from 4400 to 2000A. L. H. DAWSON AND E. O. HULBURT, *Naval Research Laboratory*.—The absorption coefficient of chemically pure fairly dust free water was measured by photographic photometry using tubes of water up to 272 cm long. γ, defined by $i=i_0e^{-\gamma x}$, where x is in cm, was 0.8, 1.4, 2.2, 4.3, 7.7, 13.5 and 80×10^{-3} at wave-lengths 4400, 4000, 3600, 3200, 2800, 2400 and 2000A, respectively. The values were more than 15 times those calculated from molecular scattering.

91. Infrared Absorption Spectrum of Heavy Water. JOSEPH W. ELLIS AND BARTHOLD W. SORGE, *University of California at Los Angeles*.—Water rated as 99.5 percent pure with respect to deuterium oxide, when studied with a Hilger rocksalt spectrometer and a quartz recording spectrograph, yielded the following bands which we assign to H^2OH^2: 8.20μ, 6.85, 4.00, 2.96, 2.040, 2.015, 1.657, 1.564, 1.355, 1.308 and 1.19. Water 60 percent pure with respect to H^2 showed, in addition to a slight displacement of some of the above bands, absorption maxima at 6.76, 2.455 and 1.915, which we assign to H^1OH^2. In addition, bands appeared at 6.20, 1.945 and 1.413 which are doubtless due to the presence of H^1OH^1. Using known bands of H^1OH^1 at 2.80, 2.92 and 6.20 as $\nu(\sigma)$, $\nu(\pi)$ and $\delta(\pi)$ respectively, we find by calculation the following corresponding fundamentals for the two triangular models, namely 3.78, 4.08, 8.40 for H^2OH^2 and 2.84, 3.98 and 7.10 for H^1OH^2. Our observed values (H^2OH^2 : 4.00$\nu(\sigma)$ and $\nu(\pi)$ unresolved, 8.20$\delta(\pi)$; H^1OH^2 : 3.05$\nu(\sigma)$ not resolved from H^1OH^1 bands, 3.95$\nu(\pi)$ and 6.76) agree within 5 percent with these, but we find that to identify all of the other bands as overtones or combinations, a fourth fundamental $\nu(p)$ at 6.85 (corresponding to 4.70 in H^1OH^1 and doubtless due to polymers) must be chosen. That the triangular shape of the vapor molecule is not greatly distorted when polymers are formed in the liquid is indicated not only by the close agreement between calculation and observation but also by the fact that $\nu(p)$ enters into combination with other fundamentals.

92. New Band System in Nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles*.—The measurements of the new band system of nitrogen, which was first reported in a recent note (Phys. Rev. **44**, 947 (1934)), have been revised, and the revised values are shown in Table I. This band system corresponds with members of the ϵ-system observed by Vegard in the luminescence of solid nitrogen. The revision was made possible by the successful photography of these bands on a spectrograph of larger dispersion than the one first used. The agreement between the lower state of these bands and the normal $X\ {}^1\Sigma$ state of N_2 is very good, but there is no agreement between the upper state and the well-known metastable $A\ {}^3\Sigma$ state. The upper state, or the initial state in emission, corresponds to a new level of N_2, probably the ${}^3\Sigma$ level which is produced from two ${}^4S$ atoms. No such level has been observed heretofore although it has often been identified with the $A\ {}^3\Sigma$ state. The $A\ {}^3\Sigma$ state dissociates into a ${}^4S$ and a ${}^2D$ atom, and hence it cannot be the ${}^3\Sigma$ state under discussion. The bands of this system can be represented by the equation

$$\nu=49766+(1460v'-21v'^2)-(2345.16v''-14.445v''^2).$$

TABLE I.

v' \ v''	3	4	5	6	7	8	9	10
0	2332.8 42866	2461.6 40627	2603.8 38405	2760.6 36224	2935.7 34063			
1		2377.5 42066	2509.8 39844	2655.5 37658		2997.0 33366	3197.5 31274	3424.6 29205
2			2424.2 41242	2560.1 39061	2710.1 36898			

93. The Effect of Latitude on Cosmic-Ray Intensities Both at Sea Level and at Very High Altitudes. R. A. MILLIKAN AND VICTOR NEHER, *California Institute of Technology*.—Self-recording electroscopes sent around the world and across the equator have now increased the accuracy of our sea-level surveys. The results show an equatorial dip intermediate between that formerly obtained by us and that reported by Clay and Compton. Our very high altitude survey extended into the stratosphere yields data having important bearing on the theory of cosmic rays.

94. A Precision Recording Cosmic-Ray Meter. A. H. COMPTON,[1] E. O. WOLLAN,[1] R. D. BENNETT,[2] A. W. SIMON.[1]—A cosmic-ray meter has been built and others are under construction for the Carnegie Institution, designed for obtaining continuous records over long periods of time at fixed stations. The 20 liter spherical ionization chamber is filled with pure argon at 50 atmospheres pressure. The average cosmic-ray ionization is balanced by that in a small chamber produced by beta-rays from metallic uranium, so that only changes in the cosmic rays are recorded. The ionization current is measured by a Lindemann electrometer, and recorded on a roll of 60 mm photographic paper, moving normally at 2.0 cm per hour. At a convenient sensitivity a 5 percent change in cosmic-ray intensity is sufficient to produce a full scale deflection in an interval of 1 hour. The sensitivity is adequate to record Steinke bursts. All first order effects due to changes in battery voltage, and in the temperature or pressure of the ionized gas are eliminated. Local radiation is absorbed by a layer of lead shot and steel walls equivalent in all to a thickness of 12 cm of lead. Barometer to 0.1 mm, external temperature, and meter temperature are recorded in addition to the changes of the cosmic rays.

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[2] Massachusetts Institute of Technology.

95. Ionization Spurts Resulting from Cosmic-Ray Entities. W. F. G. SWANN AND W. E. RAMSEY, *Bartol Research Foundation.*—The apparatus formerly used for studying the ionization per cm of path by secondary cosmic rays has been modified for the purpose of examining large groups of ions of relatively rare occurrence. The arrangement provided for recording on the same film spurts of ions and the discharge of counters placed above and below the ionization chamber. To increase the number of such spurts, varying quantities of aluminum and paraffin and 900 lbs. of copper were placed immediately above the chamber. A coincident spurt of the order of magnitude of 10^5 ions was observed on the average of once every 4.6 hours. This would correspond to 80 β-particles travelling 4 cm, or the average path length, in the vessel. An investigation was also made of the distribution functions for these large spurts, with and without the material above the ionization chamber. This analysis indicates that from the aluminum and paraffin there arise a few entities which are the equivalent in ionizing capacity of from two to four or more α-particles.

96. Barometer Effect of Shower-Producing and of Vertical Cosmic Rays. E. C. STEVENSON AND THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—By counting coincidences of three G.M. counters in triangular arrangement, covered with a 1 cm thick lead plate, shower intensities have been studied as a function of barometric pressure. Close and wide separations of the counters gave, within probable errors, the same coefficient 0.54 ± 0.027 percent per mm Hg. Three counters vertically in line gave a coefficient 0.38 ± 0.044 percent per mm Hg and the ratios of shower to vertical intensities, calculated from hourly readings, had a coefficient 0.19 percent per mm Hg. The effective absorption coefficient per meter of water for shower producing rays is, therefore, 0.41 ± 0.08 and for the vertical rays, 0.31. The results accord with the finding by one of us of a seven-fold increase in shower intensity from sea level to 14,500 ft., and the coefficient of the vertical rays agrees with the value predicted from the absorption curve analysis of Bowen, Millikan and Neher. No evidence has been found for barometer coefficients of the order of 5 percent per mm Hg reported by Steinke, Gastell and Nie for small bursts in an ionization vessel.

97. What Fraction of the Primary Cosmic Radiation is Positive? THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—Analysis of the asymmetry measurements by the theory of Lemaitre and Vallarta results in an expression representing the intensity due to positive primaries per unit range of parameter, x. Integration over the observable range, $x=0.2$ to 0.75, gives a lower limit of the intensity of the positive component at high latitudes where none of these rays are excluded by the field. At sea level the calculation shows that 37 percent of the vertical rays and 13 percent of the rays averaged over all zenith-angles are due to positive primaries. At 14,000 ft. elevation 58 percent of the vertical rays and 33 percent of the average rays are of the same character. The absorption coefficient of the intensity resulting from positive primaries has been determined to agree with (a) the variation of asymmetry with zenith-angle, (b) the variation of asymmetry with elevation and (c) the variation of latitude effect with elevation. The most probable value, 0.52 per meter of water, as well as the great intensity at high latitudes associates the positive rays with the intense, soft band, deduced from absorption measurements, which contains more than 90 percent of the total intensity at the top of the atmosphere. The above coefficient for rays of these energies is explained by shower production.

98. A Wilson Cloud Chamber with an Increased Time of Sensitivity. J. A. BEARDEN, *The Johns Hopkins University.*—A sylphon bellows type expansion chamber has been developed which is operated by a cam. The gas in the chamber is compressed above atmospheric pressure and then allowed to expand. The expansion was slowed down by a damping arrangement such that it required about 0.02 second to complete the expansion. The bellows was filled with water up to the glass ring. With the water acting as the floor of the chamber, it was found that after the chamber had been opened, only four or five expansions were necessary to clear the chamber of all dust particles. The adjustment of the chamber to show β-rays is very easily made and the chamber remains in adjustment indefinitely. An arrangement was set up such that a large number of photographs could be made of a single expansion. These photographs showed that new β-ray tracks continued to appear in the chamber for more than one second after the expansion took place. They also showed that the tracks formed soon after the expansion remained practically undistorted for about one to one and one-half seconds.

99. Ionization Potentials of Ge V, As VI, Se VII and Sb VI, Te VII. P. GERALD KRUGER AND W. E. SHOUPP, *University of Illinois.*—With the use of a twenty-one foot grazing incidence vacuum spectrograph the radiations represented by $d^{10}\ {}^1S_0 - d^9p\ {}^3P_1{}^0,\ {}^1P_1{}^0,\ {}^3D_1{}^0$ have been found in Ge V, As VI, Se VIII, Sb VI and Te VII. By extrapolating the curve for the $d^9p\ {}^1P_1{}^0$ levels in the first elements of the isoelectronic sequence and assuming it to be a straight line, it is possible to determine the term value of the $d^{10}\ {}^1S_0$ terms. Table I gives these term values and the respective ionization potentials.

TABLE I.

Element	Term value of $d^{10}\ {}^1S_0$ (cm^{-1})	Ionization potential (volts)
Ge V	753,775	93
As VI	1,028,825	127
Se VII	1,341,900	166
Sb VI	868,125	107
Te VII	1,106,863	137

100. Mean Life of the 7 ${}^3S_1$ State of Mercury from Polarization Measurements on the Visible Triplet. ALLAN C. G. MITCHELL AND EDGAR J. MURPHY, *New York University, University Heights.*—Fluorescence of the visible triplet lines of mercury (4047, 4358, 5461) was obtained by exciting a mixture of mercury vapor and a small amount of nitrogen by radiation from a quartz mercury arc. The fluorescence was observed at right angles to the exciting light beam and the polarization of each line, isolated by suitable filters, was measured by the method of crossed Wollaston prisms. Measurements in zero magnetic field (polarized excitation) gave 88.2 percent for 4047, -65.5 for 4358, and 14.55 for 5461, compared to theoretical values (broad line excitation) of 84.7, -67.0, and 8.7 percent, respectively. Measurements were then made of the polarization as a function of a magnetic field applied in the observation direction and the mean life of the 7 ${}^3S_1$ state calculated from the data. The mean life of this state as measured by 4047 and 4358 was $0.8 \pm 0.1 \times 10^{-8}$ sec. at about 3.0 mm nitrogen pressure. The mean life as measured by the line 5461 was about $0.6 \pm 0.1 \times 10^{-8}$ sec. The collision cross section for the 7 ${}^3S_1$ state against nitrogen was measured by measuring the polarization of 4358 at a field of 3 gauss and varying nitrogen pressures, giving the result $\sigma_q{}^2 = 1.3 \times 10^{-16}$ cm^{-2}. The results for the measurement of the mean life of the 7 ${}^3S_1$ state are not in agreement with those of Randall but approximate more closely the theoretical expectations.

101. The Influence of the Stark Effect on the Fine Structure of the Balmer Lines. N. P. HEYDENBURG, *National Research Fellow, New York University.*—Houston and Hsieh have recently made determinations on the doublet separations of the Balmer lines of hydrogen finding a disagreement with the theoretical values. Their method requires that the two components should be symmetrical. Calculations have been made to determine the effect of the presence of an electric field on the shape of these components. A field of 200 volts/cm is sufficient to produce an asymmetry in the weaker component which will account for a considerable part of the observed discrepancy. A field of this order might well be present due to ions in the discharge tube. The effect of the field decreases as one goes to the higher terms as does the observed discrepancy. In the case of $H\epsilon$ it is not possible to account for all the discrepancy even with higher fields, for 200 volts/cm a difference of about 0.007 cm^{-1} remains for both $H\beta$ and $H\epsilon$ indicating that perhaps some other effect the same for all the lines is also present. The Stark effect does not produce an appreciable change on the intensity ratio of the doublet components.

102. Relative Multiplet Transition Probabilities from Spectroscopic Stability. C. W. UFFORD AND F. M. MILLER, *Allegheny College.*—With the method based on the principle of spectroscopic stability, the relative transition probabilities of different multiplets in Russell-Saunders coupling have been calculated for the transitions $d^3p - d^4$, $dp^2 - pd^2$, $d^2p^2 - d^3p$, and $d^2sp - d^3s$. It can be shown that Kronig's formulas for the relative transition probabilities of different multiplets in Russell-Saunders coupling hold for all transitions between pairs of electron configurations where a definite group of electrons, either in the initial or final state, remains fixed. This means that none of the electrons in this group takes part in any of the transitions between the two configurations in question. Thus the formulas hold for all transitions in which the jumping electron is equivalent to not more than one other electron, either in the initial or final state but not in both states. Thus $s^2p - sp^2$ and $dp^2 - pd^2$ are the simplest type of transition for which Kronig's formulas do not hold. The transitions involving only s and p electrons have been calculated previously. The transitions given here, together with those previously calculated, complete all transitions for d electron configurations containing four or less than four electrons outside closed shells occurring in the spectra which we have found analyzed.

103. The Extreme Ultraviolet Spectrum of Neon. J. C. BOYCE, *Massachusetts Institute of Technology.*—With the two meter focus normal incidence broad range vacuum spectrograph previously described (Compton and Boyce, Phys. Rev. **40**, 1038 (1932)), the extreme ultraviolet spectra of the inert gases are being investigated. The much greater dispersion of the present instrument makes possible more accurate measurements and its higher resolving power permits the separation of groups of lines previously observed blended. The electrodeless discharge used as a source does not favor the strong excitation of Ne I, but more than a dozen of its strongest lines have been measured. The number of known lines of Ne II below λ500 has been doubled. In Ne III revised values of certain lines, λ379.308 and λ427.840, confirm the identification of the nebular line λ3342 as due to the forbidden $^1D_2-^1S_0$ transition in Ne III. Similarly, revised values in Ne IV, λ469.842 and λ521.771, agree much more closely than their earlier values with the assignment of the nebular line λ4725 to the forbidden $^2D^0-^2P^0$ transition of that stage of ionization of neon.

104. Automatic Comparator and Wave-Length Reducer for Spectrograms. George R. Harrison, *Massachusetts Institute of Technology.*—Applications of the interval sorter (Harrison, R.S.I. **4**, 581 (1933)) to rare earth spectra indicate the need for more accurate wave-length measurements. An automatic comparator-reducer has been designed to issue a wave-length-intensity list by interpolation between iron standards. First tests indicate much saving in time and labor in measurement and reduction of spectrograms, with increased comparator accuracy due to more precise setting and smaller temperature fluctuations. Light traverses the plate, suffers 3000 cycle interruption, and through a photocell-amplifier combination has its intensity recorded magnetically in a steel tape moving one meter per second at four meters per cm of plate. Line positions and intensities are determined in the reducing machine with a rotating coil-amplifier-meter combination. Its tape drum and wave-length dial shafts are connected through dispersion gears and a differential for nonlinear interpolation. The tape is first traversed for known iron lines, the differential point for each being quickly recorded on a correction drum. It is then rapidly traversed again with the differential pointer following the plotted correction curve. At each line maximum a light flash photographs the wave-length and intensity readings.

105. The Dispersion of the Electro-Optical Kerr Effect in CO_2 in the Visible Region. Gilford G. Quarles, *University of Virginia.*—The Kerr effect in CO_2 has been measured for a series of wave-lengths from 4000A to 7000A at a temperature of 35°C and densities between 0.1 and 0.2 g/cc. Improvements have been made in the method developed by Beams and Stevenson (Phys. Rev. **38**, 133 (1931)) and used by Bruce (Phys. Rev. **44**, 683 (1933)). The precision of the values of the Kerr constant B for the individual wave-lengths is about 1 percent. The plot of B as a function of λ agrees well with the prediction of the Langevin-Born theory [with values of the index of refraction from Phillips, Proc. Roy. Soc. **A97**, 225 (1920), and Fuchs, Zeits. f. Physik **46**, 519 (1927–28)], the average deviation of the points from the curve being 0.6 percent.

106. The Effect of Pressure on the Refractive Index of Aqueous Solutions of Ethyl Alcohol. Franklin E. Poindexter and Joseph S. Rosen, *St. Louis University.*—The refractive indices of mixtures of water and ethyl alcohol were measured over the pressure range from 1 atmosphere to 1800 kg per cm² by means of a confined liquid prism of 51° angle. Our results may be found by means of the equation $n=a+bp+cp^2+dp^3$, the coefficients of which are tabulated. The percentages given are by weight. The source of light was a Hg arc lamp giving the lines $\lambda_y=5790$A, $\lambda_g=5460$A, $\lambda_B=4360$A and $\lambda_v=4060$A. (See table.)

Coef.	Wave-length	100% alc. ($t=23°$)	90.74% ($t=25°$)	81.30 ($t=24°$)	60.80 ($t=17°$)	40.04 ($t=23°$)	19.80 ($t=22°$)	Water ($t=25°$C)
a	λ_y	1.3606	1.3633	1.3640	1.3650	1.3578	1.3469	1.3331
	λ_G	1.3616	1.3647	1.3651	1.3662	1.3593	1.3482	1.3342
	λ_B	1.3676	1.3707	1.3713	1.3724	1.3651	1.3537	1.3399
	λ_V	1.3703	1.3732	1.3739	1.3747	1.3677	1.3566	1.3424
$b\times10^5$	λ_Y	3.837	3.420	2.734	2.077	1.600	1.353	1.410
	λ_G	4.133	3.450	2.770	2.063	1.533	1.337	1.427
	λ_B	4.107	3.660	2.744	2.127	1.603	1.437	1.417
	λ_V	4.150	3.763	2.920	2.163	1.590	1.343	1.454
$c\times10^9$	λ_Y	−11.80	−12.12	−4.535	−2.867	−2.000	−1.333	−1.400
	λ_G	−16.20	−12.57	−4.600	−2.732	−1.733	−1.267	−1.466
	λ_B	−15.60	−15.82	−4.335	−3.068	−1.934	−1.667	−1.266
	λ_V	−15.60	−17.09	−5.500	−3.125	−1.800	−1.133	−1.490
$d\times10^{12}$	λ_Y	2.132	2.910					
	λ_G	3.867	3.190					
	λ_B	3.733	4.445					
	λ_V	3.600	4.835					

107. Scattering of Hydrogen and Helium Beams in Mercury Vapor. R. M. Zabel, *National Research Fellow, Massachusetts Institute of Technology.*—The scattering of beams of hydrogen molecules and helium atoms in mercury vapor has been investigated in the angular region from 5° to 65° at beam temperatures of 115°, 300° and 590°K. The results are expressed in terms of the number of molecules scattered per incident molecule, per cm path, per 10^{-3} mm of mercury at 0°C per unit solid angle in the direction θ to the original beam. The general shape of the helium scattering curves and the change in shape with change in beam temperature is in good qualitative and moderately good quantitative agreement with the quantum theory of scattering of rigid spheres as developed by Massey and Mohr. The scattering of hydrogen molecules, especially at low temperatures, shows some deviation from the results predicted by the same theory. In the case of both hydrogen and helium it is necessary to assume collision radii larger than the corresponding kinetic theory values in order to obtain the best agreement between the calculated and observed curves.

108. The Nuclear Spin of Deuterium. G. M. MURPHY AND HELEN JOHNSTON, *Columbia University.*—The relative intensities of 29 lines have been measured in the α-bands of the molecular spectrum of deuterium. The bands lie between 5939 and 6291A and were photographed in the second order of a 21 foot grating by using a sample of gas containing more than 90 percent deuterium. The latter was kindly furnished by Professor H. C. Urey and the analysis of the bands by Professor G. H. Dieke. A tungsten filament lamp and a set of 8 neutral wire screens were used for putting density marks on each plate. They were put on the same plate with the molecular spectrum using the same exposure time for each. The usual type of photographic density curves were plotted and from them the intensities of the molecular lines determined. The values of g_s and g_a, the statistical weight due to nuclear spin for the symmetric and antisymmetric levels were obtained for each branch by a least squares solution of the equation, $\ln I/i = \ln Cg - BJ(J+1)/kT$ where I is the measured intensity of the line, i is the transition probability, g is the statistical weight for the nucleus, C is a constant and the other quantities have their usual significance. The results for Q and R branches of the (0,0), (1,1), (2,2) and (3,3) bands using 2 different plates gave 1.95 ± 0.06 and 2.02 ± 0.04 as the ratio of g_s/g_a. Since the symmetric levels are more intense, the nucleus obeys Bose-Einstein statistics and the nuclear spin is 1.

109. Magnetic Moment of the Deuton. I. ESTERMANN AND O. STERN, *Carnegie Institute of Technology.*—Molecular rays of heavy hydrogen molecules were deflected in the Stern-Gerlach experiment. From these experiments we derived the magnetic moment of the deuton in the same way as the magnetic moment of the proton in our previous work with ordinary hydrogen. Our preliminary results suggest a value between 0.5 and 1.0 nuclear magnetons for the magnetic moment of the deuton. The result of our previous work is 2.5 nuclear magnetons for the proton. If we assume the deuton to be composed of one proton and one neutron, and if we simply assume addition of the magnetic moments, we would get a value between -1.5 and -2 nuclear magnetons for the magnetic moment of the neutron.

110. The Magnetic Moment of the Proton. I. I. RABI, J. M. B. KELLOGG AND J. R. ZACHARIAS, *Columbia University.*—The recent experiments of Stern, Estermann, and Frisch on the deflection of hydrogen molecules in inhomogeneous magnetic fields indicate that the magnetic moment of the proton has the unexpected value of 2.5. (The unit is taken as the Bohr magneton divided by 1840.) A completely independent method of measuring nuclear magnetic moments and spins is by the deflection of atoms in known weak magnetic fields of sufficient inhomogeneity. The value of the field for measuring nuclear magnetic moments must be such that the spin of the nucleus and of the extra nuclear configuration are only partially decoupled. We have succeeded in performing this experiment with a long narrow beam of hydrogen atoms from a Wood discharge tube. Detection was effected on a molybdenum oxide coated plate and the results evaluated by the measurement of the width and separation of the traces produced by the reduction of the oxide by the hydrogen atoms. Our results are most consistent with a value of the proton moment of 3.15 ± 0.3 units. Further experiments are in progress.

111. On the Relative Abundance of the Silicon Isotopes. ANDREW MCKELLAR, *National Research Fellow, Massachusetts Institute of Technology.*—A photometric investigation of the violet bands of SiN permits a determination of the relative abundance of the isotopes of silicon. The bands as excited by introducing silicon tetrachloride vapor into active nitrogen, were photographed in the first and second orders of the 21 ft. concave grating. The plates were calibrated, by using the band source, by placing a step weakener directly in front of the plate. They were also calibrated on a Hilger E1 spectrograph employing a standard lamp in conjunction with step weakeners and with a step slit. Measurements on the main and isotopic unresolved band heads formed by the Q branches of the 3,3 4,4 and 5,5 bands indicate tentatively an abundance ratio $Si^{28} : Si^{29} : Si^{30} = 89.6 : 6.2 : 4.2$. These figures are subject to a small correction factor upon the determination of the form of the excitation function for SiN as excited by active nitrogen. This work is now under way. The present intensity ratio corresponds to a slightly higher abundance of the rarer isotopes relative to Si^{28} than that estimated by Aston from mass-spectrograph data. In keeping with previous determinations of iostopic abundances by measuring intensities in band spectra, an atomic weight definitely higher than the accepted chemical value is here obtained.

112. An Automatic Recording Mass-Spectrograph. P. T. SMITH, *National Research Fellow,* W. WALLACE LOZIER AND WALKER BLEAKNEY, *Princeton University.*—A mass-spectrograph of the modified Dempster type (Bleakney, Phys. Rev. **40**, 496 (1932)) has been built. While retaining the advantages of the former one this new apparatus has several improvements. A novel feature is the incorporation of a 90° analyzer in addition to the customary 180° analyzer. Both of these are housed in the same vacuum tube and share the same electron current as an ion source. The 90° analyzer possesses wide slits and gives high intensity with sufficient resolving power to study the lighter atoms and molecules. The 180° analyzer possesses narrower slits and consequently better resolving power at a corresponding sacrifice of intensity. Another important feature of this apparatus is the use of an automatic recorder. By means of a revolving wire-wound drum potentiometer and a synchronized vertically moving photographic plate carrier, the experimental records of current against voltage or time are recorded automatically. The analyzed ion currents are measured with a vacuum tube amplifier. Because of the increased sensitivity of this device and the greater slit dimensions, this apparatus is considerably more sensitive than the previous one, making it well adapted for the study of isotope abundance of the light elements.

113. The Change of the Vapor Pressures of the Hydrogen Isotopes with Time. R. B. Scott, F. G. Brickwedde, H. C. Urey and M. H. Wahl, *Bureau of Standards, Washington, D. C., and Columbia University.*—The changes in the vapor pressures of protium and deuterium condensed in glass capsules immersed in liquid hydrogen were measured with mercury manometers. Temperatures were determined with a platinum resistance thermometer. (A) The vapor pressure of liquid protium at 20.38°K increased 7.5 mm in 50 hours. The velocity constant of the conversion of liquid ortho- to para-protium as determined from the rate of increase of the vapor pressure is in good agreement with the value determined by Cremer and Polanyi by using the thermal conductivity method of analysis. Small amounts of an oxygen impurity in protium increased the rate of conversion markedly, about 300 percent for 0.01 percent impurity. (B) A slight decrease, 0.03 mm in 100 hours, in the vapor pressure of deuterium at 20.38°K was observed. This small decrease indicates either that the rate of conversion of liquid para- to liquid ortho-deuterium is very slow or that the vapor pressures of the two varieties are very nearly the same. (C) From these data it appears that deuterium is more suitable than protium for fixed points in thermometry.

114. Some Properties of the Hydrogen Isotopes as Revealed by the Mass-Spectrograph. Walker Bleakney, *Princeton University.*—A mass-spectrograph capable of dealing with gases at very low pressure not only enables one to determine the relative abundance of the isotopes in a sample of hydrogen but also reveals the distribution of these isotopes among the several types of possible molecules. Hence this instrument is particularly suitable for studying various exchange phenomena and the variation of the equilibrium constant with temperature. Tests have revealed that no exchange takes place nor is equilibrium established when a non-equilibrium mixture is put in the presence of water, mercury, soft glass, Pyrex, or stopcock grease; and the apparatus itself produces a negligible change during the analysis. Certain catalysts, however, such as Ni and Cr_2O_3, establish equilibrium at temperatures as low as liquid air. The results check the theoretical curve obtained by Urey and Rittenberg assuming Bose-Einstein statistics and a spin of unity for the deuton.

115. Ionization of Liquid Carbon Disulphide by X-Rays. F. L. Mohler and L. S. Taylor, *Bureau of Standards.*—The ionization current produced by x-rays in an ionization chamber containing an insulating liquid has the characteristics found in gases at high pressure. With increasing field strength the current does not saturate because of the "columnar effect" and published measurements with fields less than 5000 volts per cm give no indication of the actual rate of production of ions. We have used carbon disulphide between aluminum disks 1 and 0.3 mm apart. Above a few thousand volts per cm the current is proportional to the intensity of the radiation. The current continues to increase but at a decreasing rate up to 60,000 volts per cm. A plot of the reciprocals of current *versus* voltage becomes linear at high voltage and can be extrapolated to infinite voltage. The form of curve is consistent with Jaffe's theory of columnar recombination. The saturated current is 2440 times the current in an equal volume of air as measured by a roentgenometer. The ratio of absorption coefficients is 2050 for the radiation used which indicates that the energy expended to produce an ion pair in the liquid is 0.84 times the value for air.

116. An Integrating α-Ray Photometer for X-Ray Crystal Analysis. George J. Mueller, *Cornell University. (Introduced by Carleton C. Murdock.)*—In 1927, Astbury described an integrating microphotometer in which the density of the negative is not measured, but, by using the "stopping power" for α-rays of a carbon tissue positive, ionization in an α-ray electroscope is produced in direct proportion to the original x-ray intensity which formed the negative. In the new instrument here described, a Geiger-Müller point counter is employed in conjunction with a thyratron recording circuit to measure the ionization produced. It might be noted that, contrary to the general belief, carbon tissue manipulation is simple and requires no expensive or complicated apparatus. The results show that with such an integrating photometer, inexpensive to construct and operate, direct proportionality between the x-ray intensities used to make the negative and the α-ray ionization is readily obtained over a wide range.

117. The Perfection of Quartz Crystals. F. E. Haworth and R. M. Bozorth, *Bell Telephone Laboratories.*—The perfection of quartz crystals has been investigated using an x-ray double crystal spectrometer. Crystal plates etched 100 hours give rocking curves 2.6 seconds wide at half maximum (Mo $K\alpha$ radiation, $(11\bar{2}0)$ face), and have a resolving power about twice that of a calcite cleavage face. They may be classed as "perfect" crystals. The rocking curve widths and the thickness of crystals cut and ground with various abrasives parallel to $(10\bar{1}0)$ were determined after various times of etching and found to depend upon the abrasive and the time of etching. With 100 carborundum as abrasive, the initial rate of etching was about thirty times the final rate which was attained only after about 100 hours etching; the initial width of the rocking curve was 40 seconds, decreasing to 11 seconds after only 2 minutes of etching. The results indicate that the irregularities in the contour of the surface due to grinding are about equal to the diameter of the abrasive particles, but that the lattice imperfections are much more superficial, penetrating only about a hundred atom diameters.

118. Relation Between Amorphous and Crystalline Scattering and Its Application to Crystal Analysis. N. S. Gingrich and B. E. Warren, *Massachusetts Institute of Technology.*—The expression for the intensity of x-ray scattering from an amorphous substance must also be applicable to a crystal. From this consideration, an expression is obtained for the average radial distribution of atoms about any one atom, expressed as a series over the number of lines in the powder pattern. The coefficients in the series are given directly by the integrated *intensities* of the different powder pattern lines. As the coefficients are determined by *intensities* and not amplitudes, there is no ambiguity due to phase, and one obtains directly from the powder pattern an average radial distribution function. For a crystal containing only one kind of element, the series takes a particularly simple form

$$\rho(r)=\sum_{hkl}K_{hkl}\frac{\sin sr}{sr}-\frac{e^{-r^2/4B}}{8\pi^{3/2}B^{3/2}};\quad s=\frac{4\pi\sin\theta}{\lambda}.$$

K_{hkl} is given by the integrated intensities of the lines, and B is proportional to the Debye temperature factor. The second term can be neglected except at very small r. The series has been applied to several crystals with known structures. By this method one obtains directly interatomic distances without necessarily determining a complete structure.

119. A Fourier Series Representation of the Average Distribution of Scattering Power in Crystals. A. L. Patterson, *Massachusetts Institute of Technology.*—The result obtained by Gingrich and Warren (see preceding abstract) is discussed in terms of the three dimensional Fourier series representing the density of scattering power in the crystal. The coefficients in this series are proportional to the amplitudes of the rays diffracted by the crystal. A related series is set up in which the coefficients are proportional to the intensities of the diffracted rays, i.e., the squares of the absolute values of the previous coefficients. It is shown that this new series represents an average three dimensional distribution in the crystal which is strictly analogous to the radial distribution discussed by Gingrich and Warren except that it takes into account the variation in this average distribution with direction in the crystal. Similar results are obtained for a plane projection of the density and for the density normal to a crystal plane. The use of these results in obtaining values for the components of interatomic distances is discussed in terms of simple examples.

120. X-Ray Diffraction Study of Carbon Black. B. E. Warren, *Massachusetts Institute of Technology.*—X-ray diffraction patterns have been made of carbon black by using a vacuum camera and Cu radiation monochromatized by crystal reflexion. The patterns show three diffuse rings at $\sin\theta/\lambda=0.129$, 0.234 and 0.407. These rings have roughly the position of the strongest lines in the pattern of graphite, but this does not justify the conclusions of other workers that carbon black is simply finely divided graphite. A Fourier integral analysis of the pattern gives directly the radial distribution function $4\pi r^2\rho(r)$. The curve shows peaks at $r=1.4$A, 2.6A, 4.0A, etc., and with appropriate areas to indicate the atomic arrangement of a *single* graphite layer. A broad flat peak starting at about 3.7A indicates other such single graphite layers roughly parallel to the first one. If these neighboring layers have definite orientation and position with respect to the first layer the configuration is that of graphite, if they do not, the material is meso-morphic (regular arrangement in two directions only). The x-ray diffraction pattern of carbon black definitely does not distinguish between these two possibilities.

121. The "Most Probable" Locations of the Valence Electrons in the Carbon Atom. Wheeler P. Davey, *The Pennsylvania State College.*—Diamond has eight carbon atoms per unit-cube, and therefore 32 valence electrons per unit-cube. The theory of space-groups shows that there is one and only one way in which 32 points can be arranged in space with the symmetry (Wyckoff's cubic 8*f*) of diamond, and still account for the well-known diamond type of diffraction pattern. The 32 points must lie on Wyckoff's cubic 32(*b*). This gives tetrahedra placed corner to corner so that adjacent corners lie on a line joining the centers of the two tetrahedra. This may be interpreted as meaning that the "most probable" positions of the various valence electrons are such as to give tetrahedral carbon atoms. The configuration of *pairs* of electrons at adjacent corners conforms to G. N. Lewis' theory of chemical combination. Chemical considerations enable the organic chemist to say that carbon atoms *may be* tetrahedral in shape. If we are willing to talk in terms of the "most probable" positions of valence electrons, we can now say that carbon atoms *must* be tetrahedral in shape. This conclusion is consistent with that drawn from the crystal structures of carbon compounds and from the well-known nonpolar nature of symmetrical carbon compounds like CCl_4.

122. Secondary Emission of Electrons from Gold and Aluminum. J. C. Turnbull and Paul L. Copeland, *Massachusetts Institute of Technology.*—The total secondary emission of electrons from both gold and aluminum has been examined for primary electron energies from 50 to 3500 volts. Distribution in energy of the secondaries has also been determined by the retarding potential method. Curves showing the number of secondaries per primary as a function of the primary energy are of the familiar form. For aluminum our results show a maximum of 1.75 secondaries per primary at about 350 volts primary energy. The decline of the secondary emission at higher energies is quite sharp and correlates with the results of one of us involving a comparative study of numerous targets (Copeland, Phys. Rev. **40**, 122 (1932)). Our findings for gold stand in sharp contrast with previously published values. We obtain a maximum of 1.71 secondaries per primary at 900 volts primary energy. The shape of the curve correlates with the comparative studies cited.

123. Secondary Emission of Electrons from Complex Targets. Paul L. Copeland, *Massachusetts Institute of Technology.*—Previous work of the writer has shown a correlation to exist between the atomic number of the element used as a target for electron bombardment and the relative decrease in secondary emission with increased primary energy. (Thesis presented at the State University of Iowa, July, 1931.) Now the work has been extended to complex targets formed by the evaporation of one element on another. If a very light substance be evaporated on a very heavy one, two maxima may appear when the secondary emission is plotted as a function of the primary energy. The maximum occurring at the lower primary energy is that characteristic of the element in the thin evaporated film, while the maximum occurring at the higher energy is that due to the heavy metallic base. Conversely results have been obtained by the evaporation of a heavy element on a light one. It has been found that at low primary energies the shape of the secondary emission curve is characteristic of the evaporated film, but that at some primary energy (which increases with the thickness of the evaporated film) the secondary emission curve breaks and declines at a rate characteristic of the underlying element. These results suggest the relation to secondary emission (1) of the primary electron penetration, (2) of the random diffusion of the secondaries, and (3) of a sharing of energy by the diffusing electrons.

124. Inelastic Scattering of Electrons from Metals. Erik Rudberg, *Massachusetts Institute of Technology.*—Targets of copper, silver and gold, freshly prepared by evaporation, have been bombarded with a homogeneous beam of electrons and the energy distribution of the scattered electrons determined using a magnetic deflection method. The distribution curves give the relative probability of different energy losses by an electron upon impact, the origin of the scale of energy loss being determined by the position of the sharp peak due to elastic scattering. Such energy loss curves exhibit a definite structure in the region of small energy losses, which is characteristic of the target material and independent of the primary voltage in the range 50–400 volts. Of the metals studied, silver has the most conspicuous curve with a sharp maximum for an energy loss of 3.9 volts and a broader maximum at twice that value. The position of the 3.9 volt peak suggests that the excitation process involved is connected with the transitions responsible for the steep absorption edge in solid silver for radiation quanta of the same energy, and with the weak emission of radiation in this region from silver under electron bombardment, which has been reported by Mohler and Boeckner.

125. Electron Microscope. C. J. Calbick and C. J. Davisson, *Bell Telephone Laboratories, Inc.*—As previously reported (Phys. Rev. **38**, 585 (1931); **42**, 580 (1932)), a circular hole in a charged plate constitutes for charged particles passing through it a spherical lens of focal length $4V/(G_2-G_1)$, where V is the energy of the particles in volts and G_1, G_2 are the gradients, in the direction of motion of the particles, on the incidence and emergence sides respectively. Calculations are made for a two-lens electron microscope used to cast images of ribbon filaments upon a fluorescent screen. The electrons are thermionically emitted and have small initial velocities; this fact is taken into consideration in the calculations. The image is photographed and the focussing conditions and magnification determined and compared with those calculated. The images reveal the crystal structure of the emitting surface. Activation and deactivation effects also are observed.

126. Some Observations on the Radiation Characteristics of Oxide Cathodes. W. T. Millis and E. F. Lowry, *Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania.*—Since we are dealing here with a composite surface of such a character that part of the radiation may come from the underlying metal, the effect of oxide layers of various thicknesses has been investigated. An approximate linear relation has been established between radiance and coating thickness within certain limits, defined, for thin coatings by the amount of oxidation of the core metal and for thick coatings by the extent of the cracks which develop in the coating. The major part of this investigation, however, has to do with the radiance from folded or slotted surfaces. Curves are shown of the radiance at operating temperatures (900°C) for these slotted cathodes as a function of three parameters; that is, (a) width of ribbon, (b) width of slot, and (c) depth of slot. An effort has furthermore been made to correlate these effects in terms of area of envelope.

127. The Effect of a Current Through the Emitter upon the Energy Distribution of Field Current Electrons. Jos. E. Henderson and R. K. Dahlstrom, *University of Washington, Seattle.*—With a method previously described (Henderson, Dahlstrom, Abbott, Phys. Rev. **41**, 2, 261 (1932)) the distribution of energy of the electrons emitted from a tungsten filament has been obtained under varying conditions of the emitter. At room temperature with no current through the filament the energy is distributed among the electrons in such a manner that the energy distribution curve shows a sharp maximum very near to the greatest energy observed. When a current is sent through the filament, there is an increase in the magnitude of the field current emission even though the rise in temperature is far too little to produce a measurable thermionic emission. Accompanying this increase in emission is a change in the energy distribution. With small currents through the filament this change appears as a second maximum in the distribution curve. This maximum changes both in position and magnitude as the current through the filament is increased. With relatively small field currents this second maximum becomes predominant as thermionic temperatures are approached. Preliminary study of the emission indicates that this effect is due mainly to the increase in temperature caused by the current rather than to the existence of the current itself.

128. The Emission of Electricity from Columbium. H. B. Wahlin and L. O. Sordahl, *University of Wisconsin.*—The electron and positive ion emission from columbium has been studied as a function of temperature, and the work functions for the electrons and ions have been determined. The electron work function has been found to be 3.96 volts, and that for the positive ions 5.52 volts. The effect of alkaline impurities condensed on the tube is in general such as to increase the work function for the positive ions.

129. The Effect of Temperature on Electron Field Currents from Thoriated Tungsten. A. J. Ahearn, *Bell Telephone Laboratories, Inc.*—Measurements, similar to those on clean surfaces (Phys. Rev. **44**, 277 (1933)), have been made on the effect of temperature on electron field currents from thoriated tungsten. Measurements were made with different amounts of thorium on the surface. The observed currents at high fields (from 4×10^5 to 9×10^5 v/cm) were independent of temperature to about 5 percent from 300°K to about 1100°K, when the thermionic activity was only slightly greater than that for clean tungsten. When the thermionic activity was increased to approximately that of fully thoriated tungsten this independence of measured current extended only to about 900°K. Above these temperatures current values obtained by subtracting the room temperature current from those at higher temperatures satisfied the Richardson thermionic emission law as well as direct measurements thereof. All the data have now shown that there is no evidence of any temperature effect on field currents from clean molybdenum and tungsten surfaces and from tungsten contaminated with thorium. The measurements are consistent with the assumption that the field currents are constant and independent of temperature and that the thermionic emission accounts for all of the observed variations with temperature.

130. Electron Emission from Thoriated Tungsten. W. B. Nottingham, *Massachusetts Institute of Technology*.—The electron emission from carbon free thoriated tungsten has been measured as a function of the temperature and the electric field with different amounts of surface coverage from zero to approximately a single layer. The filament was heated by 200 cycle pulsating current when desired. The principal results were: (1) High velocity electrons have a Maxwellian distribution; (2) A selective transmission at the surface barrier results in a deficiency in the number of electrons with energy less than 0.5 volt; (3) The transmission properties of the surface are independent of the amount of thorium on the surface. This effect with pure tungsten has escaped detection since it is clearly observable only at temperatures less than 1400°K. (4) Unless the partial pressure of gas which may react with the filament is less than approximately 10^{-14} mm a double layer composite surface is formed which has a lower work function and a lower transmission efficiency for low velocity electrons (Phys. Rev. **41**, 793 (1932)). (5) The observed lack of "saturation" for *partially* activated surfaces results from surface fields set up between covered and noncovered areas. At 1160°K the enlargement of patches due to thorium migration is observable, thus indicating that the long range forces between thorium atoms are repulsive while the short range forces are attractive.

131. Thermionic Work Function of Thoriated Tungsten at Zero Field. N. B. Reynolds and W. B. Nottingham, *Massachusetts Institute of Technology*.—The work function of thoriated tungsten has been determined at zero field by the T^2 formula. At the same time the effective transmission coefficient and the temperature coefficient of the work function were determined from the energy distribution and the contact potential shift. The observed results are accurately represented by the formula $I=ADT^2 \exp\{-(e\phi_0+\alpha kT)/kT\}$ where $A=120$ amp. per cm² per deg.² as given by theory, $D=0.36$, $\phi_0=2.83$ electron-volts, and $\alpha=2.0$. These values must be taken as provisional since they apply to only one filament. Measurements of emission at zero field and at 6000 volts per cm (100 volts applied) as a function of the time of activation at 1920°K, showed that the emission reaches a maximum with the high field at almost exactly two-thirds of the time required to obtain a maximum emission at zero field. This seems to indicate that the maximum average dipole moment per unit area is found with a complete monomolecular film while 67 percent coverage gives the maximum emission with moderate accelerating fields, as was found by Langmuir and Taylor for caesium.

132. Electric Energy and Waves. F. W. Warburton, *University of Kentucky*.—The viewpoint that magnetic energy may be treated simply as potential energy of moving charges, leads to an equation of energy of two charges,

$$\psi=(ee'/r)\{1+\dot{r}^2/2c^2+\cdots\},$$

similar to Weber's energy with sign reversed. When substituted in Lagrange's formula, this gives the expressions derived by Weber and Bush for the force exerted by moving charges, and thus results in Ampere's expression for elements of currents and the classical magnetic force for closed circuits as well as induced currents. Replacing Maxwell's displacement current by the recognition that an induced electric field is the force on electrons $-e$ alone due to the combined effect of the electrons $-e'$ and the positive charges $+e'$ in the source, a simple derivation yields an equation of a homogeneous rectilinear wave propagation of potential A with a speed c. The energy equation conforms, like the classical mechanics, to a Galilean transformation, but appears, in contrast to classical electromagnetic theory, to be amenable to the demands of both relativity and the quantum theory.

133. A Proposed Experiment for Determining Simultaneously the Altitude, Azimuth, and Magnitude, of an Ether Drift Velocity. Preston B. Carwile, *Lehigh University*.—Suppose an equal-arm Michelson interferometer is tilted so that one arm has an altitude of, say 45°, while the other remains horizontal. If now the whole interferometer be rotated slowly about a *vertical* axis with a constant angular velocity, all mechanical strains due to the rotation will be small and constant. If there is a fringe displacement d proportional to the difference between the squares of the projections of an ether velocity v (of altitude α and azimuth 0°) on the two interferometer arms, we find

$$d=(Dv^2/\lambda c^2)[\sin\alpha\cos\alpha\cos\theta+0.75\cos^2\alpha\cos 2\theta +0.5-0.75\cos^2\alpha],$$

where D is the length of arm and θ the azimuth of the tilted arm. Assuming α and v constant over a small fraction of a day, the equation shows the ratio of the amplitude of the fundamental to that of the harmonic to be 1.33 tan α. Hence a harmonic analysis of observed values of d and θ would give α. By substitution v could be found. Thus an investigation could be made for possible diurnal variations in the magnitude and *sidereal* direction of v, both of which Miller implicitly assumed to be constant throughout a day (Rev. Mod. Phys. 5, July, 1933).

134. Collision of Two Quanta. G. BREIT AND JOHN A. WHEELER, *National Research Fellow, New York University.*—The probability of the collision of two light quanta to form a positron electron pair has been calculated with the Dirac equation. The collision cross section for unpolarized quanta of the same energy γmc^2 meeting head on is

$$\sigma(\gamma)=4\pi(e^2/mc^2)^2(2\theta\gamma^{-2}+2\theta\gamma^{-4}-\theta\gamma^{-6}-s\gamma^{-3}-s\gamma^{-5}),$$

where $\gamma=\cosh\theta$ and $s=\sinh\theta$. When the quanta have different energies $\gamma_1 mc^2$ and $\gamma_2 mc^2$ and meet at an angle differing by φ from head on, the cross section is $\sigma'=\sin^2\frac{1}{2}\varphi\sigma(\gamma)$, where $\gamma^2=\gamma_1\gamma_2\sin^2\frac{1}{2}\varphi$. With this relation one may calculate the probability that a high energy quantum passing through a region in space containing temperature radiation will collide with one of the low energy quanta to form a positron electron pair. The coefficient of absorption of high energy quanta in such processes is found to be approximately $1.5\times10^6\gamma^{-3}(\gamma T/5.92\times10^9)^{5/2}\exp(-5.92\times10^9/\gamma T)(\mathrm{cm}^{-1})$. Here T is in degrees absolute and γmc^2 is the energy of the high frequency quantum. The absorption is too small to be of any importance for the theory of cosmic radiation or the internal constitution of the stars.

135. Vibrations and Internal Rotation of a Chain of Four Atoms. LOUIS S. KASSEL AND C. W. MONTGOMERY, *Pittsburgh Experiment Station, U. S. Bureau of Mines.*—In an attempt to classify more satisfactorily the infrared and Raman spectra of the higher hydrocarbons, the dynamical behavior of a chain of four equal atoms with tetrahedral bond angles has been studied. The configuration of such a chain is determined by three distances, two bond angles, and one angle φ measuring the internal rotation. For an artificially maintained value of φ the kinetic energy is a quadratic form, and five normal frequencies may be found; the three valence frequencies are nearly independent of φ, but the two deformation frequencies vary greatly with φ. It seems likely that this will result in a pseudo-potential energy hindering free rotation, and this conclusion is supported by an approximate treatment of the wave equation including φ as a variable. Even the zero-point energy of the deformation vibrations is probably sufficient to produce a considerable barrier against free rotation. These calculations seem to offer an explanation for extra Raman lines observed in many cases by Kohlrausch, and for the tendency of long chain hydrocarbons to exist in the linear form.

136. Vibration Frequencies of Symmetrical Pentatomic Molecules. JENNY E. ROSENTHAL, *Harvard College Observatory.*—The observed frequencies of symmetrical pentatomic molecules are compared with theoretical expressions in order to test the validity of various assumptions concerning intramolecular forces. For the valence force case, we obtain the following relation between the inactive frequencies ω_1, ω_2 and the active frequencies ω_3, ω_4:

$$\omega_1\omega_2/\omega_3\omega_4=[3M/(2M+8m)]^{\frac{1}{2}},$$

where M is the mass of the central atom and m that of each end atom. This relation is true for CH_4 where the agreement between calculated and observed frequencies is within 3 percent. Other molecules require four force constants to account for the observed frequencies. For each molecule there are two mathematically possible sets of force constants; one of them may usually be discarded as not being consistent with physical ideas. The ambiguity is completely removed wherever there are observable isotopic shifts. Assuming valence forces and assuming that force constants are at least roughly the same for YX_2 and YX_4, we obtain:

$$[\omega_1(YX_4)/\omega_1(YX_2)][\omega_2(YX_4)/\omega_2(YX_2)]=[3M/(2M+4m)]^{\frac{1}{2}},$$

where $\omega_1(YX_2)$ and $\omega_2(YX_2)$ are the "parallel" frequencies of YX_2.

137. Transport Phenomena in Einstein-Bose and Fermi-Dirac Gases. II. E. A. UEHLING, *Camden, N. J.*—The formal theory of viscosity and heat conductivity in a simple gas valid in all statistics is extended to yield final numerical results in the Einstein-Bose statistics for the gas coefficients of helium and hydrogen assuming these molecules to act as rigid elastic spheres. The result of this quantum-theoretical treatment of the general problem in transport phenomena is twofold: (1) A modification in the temperature dependence as predicted by the classical theory which is of importance at ordinary temperatures and which increases in magnitude as the temperature is reduced; (2) The introduction of a correction term dependent on density as well as temperature which is of importance at low temperatures only. For temperatures which are sufficiently low the magnitude of this correction term is considerably greater than and its sign opposite to the density dependence term of the classical statistics as determined by Enskog. In the range of densities to which this theory is restricted this correction term is small, but appears to be of sufficient magnitude below 15°A to render possible an experimental verification of the theory and thus a test of the Einstein-Bose statistics.

138. Electronic Energy Bands in Metals. J. C. SLATER, *Massachusetts Institute of Technology.*—The method of Wigner and Seitz (Phys. Rev. **43**, 804 (1933)) has been extended to the computation of the excited bands of electrons in a metal, with particular applications to sodium. Instead of using simply one s wave function, as Wigner and Seitz do, a combination of eight separate functions is used, one s, three p, three d, and one f. Boundary conditions for an arbitrary electron momentum are satisfied at the midpoints of the lines connecting an atom with its eight nearest neighbors. Energy levels and wave functions are determined as functions of internuclear distance, leading to the following qualitative results: At the observed distance of separation, energy levels are given with remarkable accuracy by the Fermi-Sommerfeld theory, the gaps fall approximately where they should as computed from de Broglie waves, and the wave functions act accurately like plane waves in the region between atoms, but fluctuate violently, like s, p, $\cdots$ functions, near the nuclei. Gaps in energy are precisely filled up, though in each definite direction of propagation there are gaps. As the internuclear distance increases, gaps in energy appear at definite points, the allowed regions shrinking to zero breadth about the atomic energy levels at infinite separation.

139. Some Important Statistical Relations. W. EDWARDS DEMING, *Bureau of Chemistry and Soils, Washington*, AND RAYMOND T. BIRGE, *University of California, Berkeley.*—Let $\bar{x}$ and s denote the mean and standard deviation (the r.m.s. residual) of a set of n equally reliable observations. Let u denote the true error of $\bar{x}$ and r the *probable error* of $\bar{x}$. In practice u and r are unknown. The n observations can be considered as a sample drawn from an infinite parent population having mean μ and standard deviation σ (both unknown in practice). The standard deviation of samples of n drawn from a "normal" parent population fluctuate from 0 to ∞ (an infinite value of s is precluded by the discontinuous nature of measurement) according to the sampling distribution curve derived by Helmert in 1876. The median on this curve can be denoted by σ/f, and f will decrease monotonically to unity as n increases. For any random set of n observations drawn from the normal parent population it is an even bet that $|u|<r$, $\phi s<r$, $|u/s|<\zeta$, $|u|<\zeta s$, where $\phi=0.674\cdots f/\sqrt{n}$ and ζ is the quartile deviation in Student's distribution of $z=u/s$. These relations are illustrated with 100 samples of 4, drawn from a normal parent population (W. A. Shewhart, *The Economic Control of Quality* Table D) whose mean μ and standard deviation σ are known. The above inequalities are found to be satisfied by approximately half the samples, but the fluctuations in $\bar{x}$ and s disclose clearly the danger of trying to draw conclusions from a small set of observations.

140. The Electrostatic Interaction in Atoms. R. F. BACHER AND S. GOUDSMIT, *University of Michigan.*—If the electrostatic interaction between the electrons of an atom is considered as a perturbation, the first order change in the energy is proportional to the nuclear charge Z, the second order is independent of Z, the nth order proportional to $1/Z^{n-2}$. Where low electron configurations are considered of which all outer electrons have the same principal quantum number, it seems that the first two orders are far more important than the higher ones. As a result the energy change due to electrostatic interaction in isoelectronic spectra is approximately a linear function of Z for such configurations. This can be used to extrapolate absolute term values in an isoelectronic sequence with greater accuracy than has been possible before. It also explains why the so called "irregular doublet law" holds for many electron spectra.

141. Sorption in an Ideal Soil. W. O. SMITH, *Pittsburgh, Pennsylvania.*—Vapor sorbed by an ideal soil is distributed in two ways; first as capillary condensed masses enmeshed in grain configurations, and second, in adsorbed layers on the parts of the grain surfaces not covered by capillary masses. During hydration, the condensed liquid exists, when the vapor pressure is small, in the form of rings around contact points of each pair of grains—a pendular region; when the vapor pressures become moderate the rings coalesce to form more complicated masses—a funicular region; and finally, all liquid bodies merge completely and the packing is, at larger vapor pressures, saturated. The quantity of liquid absorbed in a small sample subject to constant vapor pressure is also determined. It is shown that, during dehydration, saturation can exist at a smaller vapor pressure than that which prevails when the soil is hydrated. The process of hydration is followed from a state of complete dryness to one of saturation and, likewise, that of dehydration in the reverse order. Hysteresis is found to be a property of the absorption cycle. The intersections of the curves of hydration and dehydration are determined. The effect of surface adsorption is discussed; it is important only when the grains of the packing approach colloidal size.

142. Some Observations on the Induced Radioactivity which Follows Bombardment of Targets by Deuterium Ions. L. R. HAFSTAD AND M. A. TUVE, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—Having been disturbed by certain transient effects of a quite different nature produced in some targets by deuton bombardment, which have so far eluded our efforts to produce them systematically, we were much interested in the announcement of Curie and Joliot, of the delayed emission of positrons and gamma-rays after alpha-particle bombardment of certain targets. We have carried out some similar experiments using deuton bombardment, detecting the resultant delayed effects in a series of targets by Geiger and Geiger-Mueller counters. Our preliminary figures have not been checked as yet by duplicate observations, but the similarity of the results using targets of different materials indicates either a very special process or else a contamination as responsible for the effects we observe. Such a contamination might even be hydrogen itself, driven into the target by the beam and occluded there. With ten minutes exposure to 0.02 to 0.10μA of the $2H$ spot at 1200 kilovolts (mostly deutons) the gamma-ray emission from our targets five minutes after the end of the exposure is equivalent to about 1/10 microgram of radium as measured by direct comparison on a Geiger-Mueller counter without lead shielding. The decay-periods are also similar, dropping to half-value in from ten to fifteen minutes. Although we have often looked for such effects, we have never observed the delayed emission of protons, alpha-particles or neutrons from any of the six targets, Be, C, SiO_2, CaF_2, Al and Ag, in numbers as great as 0.2 counts per second in our ionization-chamber, which subtends under different conditions 1/200 to 1/700 of the total solid angle. Such observations have been made in general within 30 seconds after the end of bombardment for indefinite periods by as much as 2μA of protons or one μA of deutons at 1200 kilovolts.

143. The Technique of Focussed Ion-Beams with Cascade-Tubes and Electrostatic Generators. M. A. TUVE, L. R. HAFSTAD AND O. DAHL, *Carnegie Institution of Washington, Department of Terrestrial Magnetism.*—A Van de Graaff generator with concentric two-meter and one-meter shells installed in a room with a minimum clearance of eight feet has given potentials up to a maximum steady voltage of 1300 kilovolts as measured by accelerated particle-ranges and checked by magnetic deflection. A 16-inch paper belt driven at 120 feet per second gives a charging current of 600μA. Higher currents could be obtained but have been found unnecessary for the ion-sources thus far used. Much effort spent in testing various modifications of low-power low-voltage arcs has failed to produce really intense ion-beams. A current-density from the hole in the probe of about 30 microamperes per square mm has been the approximate value obtained in all cases. Very sharp focussing has been obtained by providing a variable voltage (by movable corona-points) on the first sections of the tube, thus providing adjustable lenses by which a spot (of mixed ions) as small as 2 mm in diameter can be obtained on a screen 15 feet from the source. After magnetic resolution the spots of mass 1, 2 and 3 are separated by distances of about 2 cm.

144. The *K* X-Ray Absorption of Light Elements. ELMER DERSHEM, *University of Chicago.*—Through the use of the shielded filament x-ray tube described in another abstract it has been possible to make photographic measures of the absorption of the $L\alpha_{12}$ lines of copper, nickel and iron ($\lambda = 13.3$, 14.6 and 17.6A, respectively) in carbon dioxide, nitrogen, oxygen and neon with a probable error for a single observation of one to two percent. Since fifteen or more independent measures were taken in each case the probable error in the absorption coefficient thus determined was in each case less than one percent. Curves drawn by plotting the logarithm of the atomic absorption coefficient against the logarithm of the wave-length and also the logarithm of the atomic number show that in the equation $\tau_a = C\lambda^n Z^p$, n decreases with increase of λ as has been previously well known. However, p is shown to decrease with increase of Z. From $\lambda = 13.3$A to $\lambda = 17.6$A the average value of n decreases from 2.43 to 2.21, while from $Z = 6$ to $Z = 10$ the average value of p changes from 4.6 to 4.

145. A Two-Stage Oil Diffusion Pump. JOS. E. HENDERSON, *University of Washington, Seattle.*—A simple two-stage oil diffusion pump has been designed and tested which embodies the following characteristics. It may be used satisfactorily with a coarse vacuum of 0.2 mm or worse. This makes possible the realization of oil diffusion pump advantages without the necessity of having a particularly good coarse pump or the utilization of auxiliary drying agents. This is accomplished by using a readily adjustable, small clearance nozzle on the first stage so arranged that droplets of oil cannot collect to block it. The pump operates well at the comparatively low oil vapor pressure of 5 to 10 mm, thereby avoiding undue decomposition of the oil. Using Apiezon oil "B" under these conditions a vacuum of 10^{-7} mm of mercury is readily obtained. Utilizing a charcoal trap as described by Becker and Jaycox, a vacuum of 2×10^{-8} mm of mercury has been obtained. The time required to construct the pump is about four hours.

146. Recent Actions of the International Electrotechnical Commission in Reference to Electrical Units. A. E. KENNELLY, *Harvard University.*

147. Reversal Nuclei in Magnetic Propagation. K. SIXTUS, *General Electric Company.*—The propagation of a magnetic discontinuity along a NiFe wire in a field H greater than the critical field H_0 can be initiated by application of a local adding field. If the adding field was applied only for a short time interval, no spontaneous propagation occurred, but an artificial reversal nucleus had been created which reduced the starting field H_s for the wire. The surface pole distribution of such a nucleus was measured by an exploring coil. On repeated application of field pulses the nucleus grew at a greater rate in the direction of the axis than perpendicular to it, until it was large enough to cause spontaneous propagation. To every value of main field there belonged a critical nucleus size which would just start propagation. The demagnetizing field of a nucleus in this condition was calculated under simplifying assumptions and was found to be approximately equal to the excess field $H - H_0$. Thus, as soon as the total field, which is the algebraic sum of main field and demagnetizing field, in the nucleus region exceeds the value H_0, the propagation will start. The analogy of critical size magnetic nuclei in anti-saturated material with critical size droplets in supersaturated vapor suggests itself.

148. The Scattering of Neutrons by $H^1{}_2O$, $H^2{}_2O$, Paraffin, Li, B and C and the Production of Radioactive Nuclei by Neutrons found by Fermi. J. R. DUNNING AND G. B. PEGRAM, *Columbia University.*—The scattering of Be-radon neutrons from cylindrical forms of these light elements, 2.5 cm diameter and 3 or 4 cm long, has been determined from relative transmission measurements with a nearly parallel neutron beam. Since the transmission through $H^1{}_2O$ and $H^2{}_2O$ is the same, within the experimental error of perhaps 2 percent, the collision cross section for the proton and the deuton, which may be a combination of a proton and a neutron, is nearly the same. The scattering by $H^1{}_2O$, $H^2{}_2O$, paraffin, Li, B and C shows that the cross section for neutron-nucleus collision does not, for light nuclei, in contrast to heavy nuclei, vary much with the nuclear charge or the nuclear mass. Elastic collisions can account for most of the "absorption" and scattering of neutrons (Phys. Rev. **43**, 497 (1933), **44**, 317 (1933), **45**, 586 (1934)), although it has been known that inelastic collisions, as with the nitrogen nucleus, also occur, and the recent work of Fermi (Ricerca Scientifica, March 15, 1934) on the production of artificial radioactive nuclei by neutron bombardment emphasizes the importance of inelastic collisions. We have repeated Fermi's subjection of Al and F to neutrons from a Be-radon source and confirm his half-life periods of about 10 seconds for the radioactive substance from F and about 12 minutes for that from Al. Mg gives a radioactive substance of period about 3 hours. An Al foil of 0.4 mm thickness stops few of the particles from the irradiated Al. Further measurements will be required to arrive at the ratio of inelastic to elastic collisions.

149. The Production of H^3 by a Canal-Ray Discharge in Deuterium. G. P. HARNWELL, H. D. SMYTH, S. N. VAN VOORHIS AND J. B. H. KUPER, *Princeton University.*—We have been running a high voltage discharge in deuterium at low pressure and passing the canal rays from it into deuterium at a higher pressure, hoping in this way to accumulate an appreciable amount of $_1H^3$. We believe we have succeeded in doing so. According to an analysis with a mass-spectrograph by Smith, Lozier and Bleakney, the deuterium with which we started contained about one part of $_1H^3$ to 200,000 of $_1D^2$. Three samples of the same gas which had been circulated through our canal-ray apparatus for about an hour each were analyzed in the same mass-spectrograph by the same procedure. They showed about one part of $_1H^3$ to 5000 of $_1D^2$ in each case. Attempts to get samples treated for a longer period have hitherto been balked by technical difficulties of the usual sort and also by the increasing proportion of ordinary hydrogen coming from the walls and electrodes of the discharge tube.

150. The Magnetic Moment of the Deuton. I. I. RABI, J. M. B. KELLOGG AND J. R. ZACHARIAS, *Columbia University.*—We have performed a magnetic deflection experiment on deuterium atoms (H^2) from a Wood discharge tube under conditions similar to our experiments on hydrogen (H^1) atoms. (Bull. Am. Phys. Soc. **9**, A110 (1934).) With a value of 1 for the spin of the deuton, our measurements yield a value for the magnetic moment of 0.75 ± 0.2 in units of $\mu_0/1840$. Because of this small moment it was found advantageous to use magnetic fields as low as 100 gauss. The principal experimental error is a possible contamination by ordinary hydrogen in the discharge tube in spite of prolonged flushing with helium and highly concentrated deuterium. These experiments do not fix the sign of the magnetic moment of either the deuton or the proton. However, if we assume the deuton to consist of a neutron and a proton, and that in combining these particles preserve their identity and have no orbital angular momentum, then the magnetic moment of the neutron is ±2.5 or ±4. We wish to thank Dr. H. C. Urey for kindly furnishing the deuterium used in these experiments.

151. Aluminizing Process for Coating Telescope Mirrors. JOHN STRONG, *California Institute of Technology.*—A steel bell jar 40″ in diameter is evacuated by apiezon oil diffusion pumps and a Hypervac pump to 10^{-4} mm of mercury pressure. Aluminum is distilled from twelve tungsten coils to form a uniform film $1/10\mu$ in thickness on the surface of the telescope mirror. The mirror surface is made clean for the coating process by an electrical discharge as the bell jar is being evacuated. The evaporated aluminum coat is immune to tarnish, adheres tenaciously to the glass and is not easily scratched once the oxide film which forms on it is established. The reflectivity is 89 percent in the visible dropping gradually to 80 percent at 2500A. Measurements at Lick Observatory show the reflectivity for photographic light exceeds silver by approximately 50 percent. Stellar spectra to 3000A have been obtained.

152. Pure Rotation Spectrum of the HCl Flame. JOHN STRONG (*National Research Fellow*), *California Institute of Technology.*—Pure rotation lines for $j=17$ to 33 of the emission spectrum of the HCl flame are measured with a KBr prism. The following empirical formulae are determined to represent two series of lines measured corresponding to pure rotation in the two lowest oscillation states,

$$N=0, \qquad \nu=20.9j-0.00185j^3$$
$$N=1, \qquad \nu=20.2j-0.00163j^3.$$

The linear coefficients agree satisfactorily with values calculated from the empirical oscillation-rotation formula. Theoretically the two cubic coefficients should be equal. High values of j allow considerable accuracy to be ascribed to these cubic coefficients so the discrepancy is not regarded as accountable by experimental error.

153. Dirac Equations in Projective Relativity. O. VEBLEN, J. VON NEUMANN AND A. H. TAUB, *Princeton, New Jersey.*—The extension of the Dirac equation to general relativity is discussed by the method of projective relativity. The class of equations of the Dirac type obtained include the previously proposed generalizations. Of this class, there is one which reduces exactly to the Dirac equation of a charged particle in special relativity.

AUTHOR INDEX TO ABSTRACTS OF THE WASHINGTON MEETING