Proceedings of the American Physical Society

MINUTES OF THE CHICAGO, ILLINOIS MEETING, NOVEMBER 26–27, 1937

THE 216th regular meeting of the American Physical Society was held at Chicago, Illinois on Friday and Saturday, November 26 and 27, 1937 at the University of Chicago in Eckhart Hall. The contributed papers, thirty-two in number were read in four sessions, one session on each of the four half-days. The presiding officers were Lyman J. Briggs, vice president of the Society, and John T. Tate. The headquarters of the Society was the Windermere Hotel. The attendance at the meeting was about three hundred.

On Friday evening the Society joined with the Chicago Physics Club at dinner in the autitorium of the International House on the university campus. The president of the Physics Club, Dr. K. W. Miller, presided and introduced the speaker of the evening, Dr. Paul D. Foote, vice president of the Gulf Refining Company, who spoke on *Physics and Petroleum Research.* The address was copiously illustrated with excellent lantern slides.

Meeting of the Council. At the meeting of the Council held on Friday, November 26, 1937 the deaths of one honorary member (Lord Rutherford), two fellows (Edward L. Nichols and Charles B. Thwing) and four members (Leslie V. Case, Ronold Curry, John B. Dutcher, and Bailey Townshend) were reported. The Council asked Editor John T. Tate to correspond with Professor Ernest Merritt and prepare a suitable memorial on the death of Professor Nichols to appear in an early issue of the *Physical Review.* Three candidates were transferred from membership to fellowship and one hundred and thirty-four candidates were elected to membership. *Transferred from membership to fellowship:* F. Woodbridge Constant, H. Richard Crane and J. Stuart Foster. *Elected to membership:* Julius G. Adashko, Paul C. Aebersold, Bruno E. K. Alter, Jr., Scott Anderson, LeRoy W. Apker, Henry S. Bamford, Paul F. Bartunek, Samuel B. Batdorf, D. S. Bayley, David F. Bender, E. T. Booth, Louis Philippe Bouckaert, Woodford E. Bowls, William M. Brobeck, Frederick W. Brown, Richard L. Burling, Glenn R. Carley, Mary Louise Carll, Hugh Carmichael, Kenneth G. Carroll, Chang-Ning Chou, Joe S. Clark, Francis F. Coleman, Nathan J. Cornfeld, Robert Cornog, J. Hollie Cross, Munsey E. Crost, Edward N. Cunningham, Mark L. Dannis, Philip W. Davies, Henry M. Davis, Jules de Launay, Richard R. Dempster, Martin Deutsch, Joe R. Dietrich, Thomas J. Dietz, Kamal Djanab, Richard E. Downing, Durward L. Eaton, Alfred W. Einarsson, Alfred G. Emslie, Theodore Enns, Howard J. Evans, Robert D. Fowler, John E. Freehafer, Arthur S. Fry, Alvin C. Graves, G. K. Green, M. Mendel Greenberg, Theodore J. Hanwick, William E. Harper, Preston M. Harris, R. J. Havens, Arthur Hemmendinger, Wm. James Henderson, Victor Hicks, Jerald E. Hill, Chas. Hire, Laurence Hoisington, John H. Hollomon, William J. Horvath, Charles E. Houston, Colin M. Hudson, Emmett Hudspeth, Henry R. Hulme, Hillard B. Huntington, Vivian A. Johnson, Helen Jupnik, Sydney Kalmbach, T. C. Keeley, H. Kuhn, I. C. Kuo, Vernon W. Lemmon, Humboldt W. Leverenz, Josef Lichtschein, Harold Lifschutz, Robert S. Livingston, Dwight L. Loughborough, Emmeth A. Luebke, E. G. Lunn, Basile J. Luyet, James W. McGrath, Leonidas D. Marinelli, Emery P. Miller, George E. Moore, Ted J. Morgan, LeRoy L. Newman, Jr., Sikizi Onda, Robert H. Osborn, W. K. H. Panofsky, William L. Parker, David B. Parkinson, Howard S. Pattin, Gene T. Pelsor, L. W. Phillips, Herbert C. Pollock, Richard W. Quarles, Arthur H. Redmond, Arthur Roberts, Pauline Rolf, Frederick D. Rossini, Arthur G. Rouse, Arthur J. Ruhlig, Howard S. Seifert, Durnford Smith, Adam H. Spees, Raymond G. Spencer, Louis A. Strait, Robert E. Street, Gerald F. Tape, Gereld L. Tawney, Owen L. Tekippe, Charles D. Thomas, D. Boyd Thomas, Frank H. Trimble, A. Francis Turner, A. van der Tiel, Albert L. Vitter, John E. Walter, Newton

E. Ward, Norman A. Watson, V. F. Weisskopf, Milo M. Wells, Hans Weltin, Raymond C. Westphal, Milton G. White, Enos R. Wicher, Lauriston P. Winsor, Clifford M. Witcher, Robert A. Woodson, John R. Woodyard, Chien-Shiung Wu, Allan C. Young and John Youngblood.

The regular scientific program of the Society consisted of thirty-two contributed papers (abstract number fifteen was withdrawn). 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. Solubility at the Grain Boundaries of Solid Solution. GEORGE R. DEAN, *The Pennsylvania State College. (Introduced by Wheeler P. Davey.)*—(1) A technique has been developed for obtaining, in a form suitable for spectrographic chemical analysis, specimens of material representing primarily crystal-boundary material which may be compared with other specimens of material from the body of the crystals themselves. Specialized equipment, developed for this purpose, will be shown by means of diagrams. (2) By spectrographic chemical analysis it has been shown that the concentration of solute in a solid solution is different at the intercrystalline boundaries than it is in the body of the crystals. (3) It has been shown specifically that Cu is more soluble in the body of the crystals of solid solutions of Cu in Zn than in the intercrystalline boundaries of those same solid solutions.

2. The Packing Fractions of Titanium, Iron, Copper, Silver, Gold and Platinum. A. J. DEMPSTER, *University of Chicago.*—By comparisons with oxygen, the packing fraction ($\times 10^4$) for titanium[48] has been found to be -7.2 ± 0.1, and the mean of the fractions for the two copper isotopes -6.9 ± 0.2. The value for titanium has been confirmed by a comparison with carbon. By comparing with nitrogen, the fraction for iron[56] has been determined as -7.0 ± 0.4. Silver has been compared with aluminium giving -4.9 ± 0.5 for the mean of the fractions for the silver isotopes, assuming -3.7 ± 0.3 for aluminium. Gold[197] and platinum[195] isotopes have been compared with copper[65] giving values of 2.0 ± 0.4 and 2.0 ± 0.3 for their packing fractions. Comparisons that serve to confirm the values given above have also been made between gold and titanium[49], and between silver and iron[54]. A packing fraction curve drawn through these values lies about 2.0 units above Dr. Aston's packing fraction curve. A probable packing fraction curve will be presented, and the agreement with a series of other mass comparisons will be illustrated.

3. X-Ray Diffraction in Ionic Solutions. G. W. STEWART, *University of Iowa.*—For very dilute aqueous solutions of light ions, the alteration in the diffraction curve from that of pure water may be regarded as caused largely by the change in the structure of the water itself. Careful measurements were made of the diffraction curves of dilute aqueous solutions of LiCl, NaCl, KCl, NH_4Cl, and $MgCl_2$. When the change in positions of the major and minor diffraction peaks and the relative heights of the latter in the diffraction curves are considered, it is observed: (1) that the two peak positions approach each other with increasing concentration, (2) that the relative height of the minor peak and sharpness of the major peak decrease. There is an interesting relationship between the rate of change of height of the minor peak and the rate of change of apparent volume per mole of the solute. Thus the latter may be explained in part by the change in structure of the solvent.

4. Radiography of Thin Microtome Sections by Means of Fluorescence X-Radiation. ELMER DERSHEM, *University of Chicago.*—Heretofore radiographs of thin microtome sections have been made with the use of soft x-rays from grenz ray tubes. However, it can be shown that much greater contrast may be secured by using x-rays of moderate voltage to excite fluorescence radiation in an element the K radiation of which is selectively absorbed by some element whose distribution in the microtome section it is desired to study. Some of the more interesting problems in this field relate to the distribution of calcium. In this case, x-rays just shorter than 3.06A are selectively absorbed; hence scandium whose K emission lines have a weighted mean wave-length of 3.02A is the proper element to use as radiator. Extrapolation from data on fluorescence yield obtained by A. H. Compton and his collaborators indicates that more than 90 percent of the secondary radiation from scandium consists of these characteristic wavelengths, provided the x-ray tube voltage is below 15 kv. Other elements may be selectively photographed by the use of the proper radiator. Slides will be shown illustrating the selective detail with which the calcium content of thin sections of bone may be photographed with the use of fluorescence radiation from scandium oxide.

5. The Crystal Structure of Potassium Acid Dihydronium Pentaborate, $KH_2(H_3O)_2B_5O_{10}$. W. H. ZACHARIASEN, *University of Chicago.*—In connection with studies on the constitution of the borates the crystal structure of "potassium pentaborate tetrahydrate" has been completely determined. Crystals of this compound are orthorhombic, $a=11.08$A; $b=11.14$A; $c=8.97$A. The unit cell contains four molecules and the space group is $Aba(C_{2v}^{17})$. The four potassium atoms and four of the boron atoms are lying on the twofold axes and all the remaining atoms in general

positions. The 25 parameters (disregarding the hydrogen atoms) were determined. The results show that it is incorrect to consider the compound as a hydrate of KB_5O_8. The structure contains complexes B_5O_{10}. A BO_4-tetrahedron forms the nucleus of the complex. Each of the four corners of this tetrahedron are shared with a BO_3-triangle, and the four triangles are grouped together in two pairs by a shared corner. These complexes are held together by potassium atoms, hydrogen bridges and hydronium radicals. Each potassium atom has eight oxygen neighbors at an average distance of 2.92A. The hydronium groups are not rotating, but are linked to potassium and to oxygen atoms, to the latter by weak hydroxyl bonds.

6. Variation of Characteristic Temperature with the Temperature of Zinc Crystals. G. E. M. JAUNCEY, *Washington University, St. Louis.*—Two characteristic temperatures are necessary for the explanation of the variation of the diffuse scattering of x-rays from a single crystal of zinc with the angle of orientation. Indications are that the characteristic temperature for vibrations parallel to the *c*-axis has the constant value 170°K for the range 100° to 200°K but that for higher temperatures it falls to the value 122°K at 550°K. The characteristic temperature for vibrations perpendicular to the *c*-axis remains practically constant at the value 280°K over the same range of temperatures. It seems that the characteristic temperature remains constant as long as the root mean square displacement in the corresponding direction is less than about 0.1A. It is found that the characteristic temperatures of KCl and NaCl crystals also depart from constancy when the root mean square displacement exceeds 0.1A. The relation between the characteristic temperature for x-ray scattering and that for specific heat will be discussed.

7. The Effect of Temperature on the Atomic Distribution in Liquid Sodium. FRANK H. TRIMBLE, *Northeast Missouri State Teachers College*, AND NEWELL S. GINGRICH, *University of Missouri.*—The work of Debye,[1] and Zernike and Prins[2] enables one to interpret x-ray diffraction patterns of liquids quantitatively, giving, as a result, the distribution of atoms about any one atom. This distribution function has been determined in the case of a few liquids, notably sodium[3] a few degrees above its melting point. In this work, x-ray diffraction curves of liquid sodium at several temperatures ranging from 100°C to 400°C have been obtained. Mo *K* radiation monochromatized by reflection from rock salt was diffracted from liquid sodium contained in a thin capillary and the diffracted x-rays were recorded photographically. An electric heater maintained the sodium at a constant temperature which was measured by a thermocouple. Exposures of 36 hours gave convenient photographic densities on the films. The films were microphotometered and the resulting intensity curves were analyzed. The two intensity curves which were analyzed were those obtained at 100°C and 400°C. The angle at which maximum intensity occurred was 6° 36′ at 100° and 6° 24′ at 400°. A comparison of the atomic distribution curves at the two temperatures shows that at 400°C the concentration of atoms about any one atom is much less than at 100°C. The first peak in the distribution curve for the 100°C case shows that there are approximately 8 atoms at a distance of 3.83A, and that for the 400°C case shows that there are approximately 8 atoms at a distance of 3.90A.

[1] Debye and Menke, Erg. d. tech. Rontgenkunde, II.
[2] Zernike and Prins, Zeits. f. Physik **41**, 184 (1927).
[3] Tarasov and Warren, J. Chem. Phys. **4**, 236 (1936).

8. X-Ray Investigation of the Asymmetry of the Atoms and of the Atomic Vibrations in a Silver-Cadmium Alloy. E. O. WOLLAN, *Washington University, St. Louis.*—Previous investigations[1] on the reflection of x-rays from crystals of zinc and cadmium have shown that for these crystals the atoms are more or less ellipsoidal in shape, with the long axis parallel to the *c*-axis of the crystal, and also that the mean amplitude of the atomic vibrations is considerably greater along the principal axis than perpendicular to it. This asymmetry is associated with the fact that the axial ratio for these crystals is 1.86 and 1.89, respectively, as against a value of 1.633 for close packed spheres. This report deals with measurements of the intensity of reflection of x-rays from an alloy of silver and cadmium in the ϵ-phase. This alloy consists of a solid solution of about 20 atomic percent silver in cadmium. The hexagonal cadmium lattice is retained but the presence of the silver atoms has the effect of reducing the axial ratio to 1.56, which is now below the value for close packed spheres. In contrast to the results for pure cadmium, the x-ray measurements on this alloy show that the cadmium atoms are now extended in a direction at right angles to the principal axis of the crystal and also that the amplitude of thermal vibration is greater in this direction than at right angles to it.

[1] G. W. Brindley, Phil. Mag. **21**, 790 (1936); Proc. Leeds Phil. Soc. **3**, 200 (1936). G. E. M. Jauncey and W. A. Bruce, Phys. Rev. **50**, 408 (1936). E. O. Wollan and G. G. Harvey, Phys. Rev. **51**, 1054 (1937).

9. The Rate of Production of Large Cosmic-Ray Bursts as a Function of Lead Shield Thickness. RICHARD L. DOAN, *Phillips Petroleum Company*, AND WILLIAM P. JESSE, *University of Chicago.*—During the last two years a series of experiments has been carried out at Chicago on two of the model C type cosmic-ray meters of the Carnegie Institution of Washington. The rate of occurrence of bursts of magnitude 2.3×10^7 ion pairs and upward was measured in relation to the thickness of shielding over the ionization chamber. Such bursts probably represent a passage through the chamber of more than a hundred ionizing particles. The lower half of the spherical chamber was surrounded with lead shot. The upper half was shielded with a series of hemispherical lead caps, each of 0.3 cm thickness. For both meters the rate of burst production rose with the addition of successive caps, reached a maximum for a thickness of about 3 cm of lead, and then slowly fell off with increasing thickness. Because of different experimental conditions it is difficult to compare these results exactly with the results of other experiments. However, the maximum rate of production of these

extremely large bursts occurs at a considerably greater shielding thickness than that obtained by most experimenters for showers and small bursts. This is at least qualitatively in accord with the theory of Carlson and Oppenheimer.

10. Cosmic-Ray Intensities at Great Depths. V. C. WILSON, *University of Chicago. (Introduced by Arthur H. Compton.)*—A fourfold Geiger-Müller tube telescope was employed to count the relative number of cosmic rays under different thicknesses of rock. Each Geiger-Müller tube consisted of a 5 mil tungsten wire anode and a copper cathode 9 cm in diameter and 71 cm in length sealed in a glass envelope filled with hydrogen to a pressure of 9.6 cm of mercury. The experiment was performed at Mohawk, Michigan, in a mine of the Seneca Copper Corporation. The shaft of the mine is inclined at an angle of 34 degrees from the horizontal; thus the telescope could be set up in the shaft under any desired thickness of rock. The surrounding rock is very uniform in density, and comparatively free from radioactive material. Up to the time of this preliminary report, counts were made at thirty different stations at depths from zero to 1033 meters water equivalent. When the intensity is plotted against the depth, the resulting curve shows no points of inflection, and resembles, but is not, an exponential decay curve. The intensity at 1033 meters is approximately one ten-thousandth of the surface intensity.

11. The Profile of the Compton Modified Band as Determined by Electron Scattering Measurements. A. L. HUGHES AND MARVIN M. MANN, JR., *Washington University, St. Louis.*—When electrons of energy exceeding about 1000 electron volts are scattered by helium atoms, it is possible to regard an elastically scattered electron as one scattered by a nucleus, and an inelastically scattered electron as one scattered by an atomic electron. The energy distribution of inelastically scattered electrons can be related to the distribution of component velocities of the atomic electrons by means of a formula, due to Jauncey, which is derived from the same principles as those used by him in his theory accounting for the finite width of the Compton modified band. The formula states that the shape of the distribution of *energies* of the inelastically scattered electrons is identical with that of the distribution of *component velocities* among the atomic electrons, which, in turn, is identical with that of the *profile* of the Compton modified band. Quantum mechanical calculations, giving the profile of the Compton modified band, have been made by Hicks and by Kirkpatrick, Ross and Ritland. Our results on the inelastic scattering of electrons by helium atoms are in excellent agreement with the theoretical calculations. Where the two theoretical calculations differ slightly, our results agree better with those of Hicks.

12. Characteristics of the Glow-Arc Transition in Mercury Vapor. FREDERICK A. MAXFIELD, *University of Wisconsin.*—The probability of the transition from glow discharge to arc discharge at graphite electrodes has been investigated under carefully controlled cathode conditions. The increase in transition probability with current density at the cathode of the glow has been found to be much more pronounced, and the increase with cathode fall of potential has been found to be much less pronounced than previous work would lead one to believe.[1] The curve of transition probability as the cathode temperature was increased was found to exhibit a distinct maximum at a temperature of about 400° or 450°C. The probability of the transition occurring at lower or higher temperatures was not more than one half or one third the maximum. It was also found that the frequency of transitions was a steadily decreasing function of time even during the last tests. A possible explanation of these results has been based on the hypothesis that it is never possible to degas completely the cathode electrode even after prolonged operation in a high voltage discharge. The continual non-uniform emission of this gas from the cathode in the form of bursts from minute patches can lead to a greatly increased probability for transition from glow to arc.

[1] Slepian and Ludwig, Trans. A. I. E. E. **51**, 92 (1932).

13. A Vacuum Tube Scale of Eight Circuit. HAROLD LIFSCHUTZ AND J. L. LAWSON, *University of Michigan. (Introduced by O. S. Duffendack.)*—A vacuum tube scale of two has been devised which is much faster than previous scale circuits.[1, 2] The principle of the present circuit is similar to a multivibrator except that direct coupling is used, accomplished very simply by means of a resistor between plate and grid. Two triodes are used in each scale of two, their inputs being in parallel. Jamming is impossible as the circuit is stable only when the tubes are at opposite ends of their $I_p - E_g$ characteristics. Due to the direct-coupled regeneration, an incoming pulse causes an extremely rapid phase reversal of the tubes. Thus the plate voltage of the tubes increases or decreases on alternate pulses, making possible an electrical division by two. This circuit is independent of the polarity of input pulse so that coupling to a succeeding scale of two must be made through a triode biased past cut-off. A scale of eight was built as above and counted 55,000 random counts per minute when the Cenco counter choked, the circuit itself still counting. Oscillograph tests showed proper halving when tried at 180,000 sweep circuit pulses per minute. Counting losses began at about 3000 random pulses per minute, the losses being due to the Cenco counter. Higher scale ratios are, therefore, justified.

[1] Stevenson and Getting, Phys. Rev. **51**, 1027 (1937).
[2] Wynn-Williams, *Reports on Progress in Physics* (1936), p. 239.

14. Operating Characteristics of a Voltage Multiplying Circuit for Nuclear Disintegration Experiments. S. K. ALLISON, G. T. HATCH, L. S. SKAGGS AND N. M. SMITH, JR., *University of Chicago.*—A voltage multiplying circuit, similar to that first used for nuclear investigations by Cockcroft and Walton, has been constructed and operated at 60 and 540 cycles. The amplification ratio (output volts)/(peak input volts) at the higher frequency is found to be very close to the ideal 4, while at 60 cycles it lies between 3 and 3.5. The expected large reduction in ripple

at 540 cycles has been experimentally observed. A horizontal tube for the acceleration of positive ions has been constructed and is in satisfactory operation. The type of construction permits the assembly and lining up of the accelerating segments to be accomplished before insertion into the tube. The ion beam has been analyzed magnetically and the intensity of beams corresponding to the formation of ions in the various gaps relative to the full energy beam estimated. For measuring the voltage a resistance of 750 ten megohm resistors in series has been constructed and installed in a vacuum tight case filled with nitrogen at atmospheric pressure.

15. Photographic Measurements of the Brownian Motion. CHAS. HIRE, *Murray State Teachers College. (Introduced by W. L. Severinghaus.)*—Gamboge particles of uniform size were suspended in water. Positions of the particles in a suitable sealed microscope slide were recorded instantaneously at intervals of 1/128 second by a photographic method using an electric spark as the light source. Particle diameters were determined from the rate of settling by applying Stokes' formula. In addition to the Brownian agitation, the photographs revealed field vibrations in which all particles moved in the same directions simultaneously. Simple corrections for the field vibrations gave the true Brownian displacements. Calculations from the corrected data gave for Avogadro's constant a value of 7×10^{23} molecules per mole, and calculations from the uncorrected data gave results comparable with those of Henri. The paper contains a brief discussion of corrections needed for the law of Stokes. Apparatus and data table are illustrated with lantern slides.

16. On the Deviations from Ohm's Law at High Current Densities. EUGENE GUTH, *University of Notre Dame,* AND JOSEF MAYERHÖFER, *University of Vienna. (Introduced by George B. Collins.)*—The deviations from Ohm's law have been studied experimentally by Bridgman[1] and Barlow[2] with conflicting results. According to Bridgman this deviation amounts to 1 percent at a current density of 10^6 amp./cm^2, whereas Barlow finds no deviation for this current density. A theoretical investigation by the authors yields the results that a stationary state (i.e. stationary currents) is possible only when the ratio of the mass of the metal ion to the mass of the conduction electron has a finite value, and hence in the Lorentz-Sommerfeld theory of metallic conduction, which assumes fixed metal ions, a stationary state is not possible. Using the work of Peterson and Nordheim,[3] the authors found that a one percent deviation from Ohm's law is only possible in the region of 10^8 amp./cm^2. The investigation is based upon Bloch's wave mechanical theory of metallic conduction in the form given by Bethe.[4] This study also leads to new results in the role played by the "Umklapp-Prozesse" of Peierls in the theory of electrical conductivity.

[1] Bridgman, Proc. Am. Acad. **57**, 131 (1922); Phys. Rev. **19**, 87 (1922).
[2] Barlow, Phil. Mag. **9**, 1041 (1931).
[3] E. L. Peterson and L. W. Nordheim, Phys. Rev. **54**, 355 (1934).
[4] A. Sommerfeld and H. A. Bethe, *Handbuch der Physik* Vol. 24, (Berlin 1933) p. 11.

17. Asymmetric Radiation Produced by High Velocity Electrons. GEORGE B. COLLINS AND VICTOR G. REILING, *Department of Physics, University of Notre Dame.*—Čerenkov[1] has reported the existence of an asymmetric visible radiation produced when electrons pass through liquids or solids such that $\beta n>1$. This effect has been verified using a well collimated beam of 1.5 million volt electrons from an electrostatic generator. By using thin films of liquids and solids to avoid scattering of the electrons, it is established that the direction of emission of the radiation is quite definite. For alcohol and water the direction of emission of the radiation with respect to the electron beam seems to be accurately given by the expression, $\cos\theta=1/\beta n$. It is also found that the fluorescence produced by high velocity electrons in such substances as glass, mica, and water is small and that essentially all the visible radiation which is observed is of the type discussed above.

[1] Čerenkov, Comptes rendus, Acad. Sci. USSR. **14**, 3 (1937).

18. The Interaction of Neutrons with Normal and Parahydrogen. J. R. DUNNING, H. J. HOGE, J. H. MANLEY, AND F. G. BRICKWEDDE, *Columbia University and National Bureau of Standards.*—Teller,[1] and Schwinger and Teller[2] have shown that (1) the spin dependence of proton-neutron forces and (2) the real or virtual character of the singlet state of the deuteron can be investigated by scattering slow neutrons in *o*- and *p*-H_2. We have investigated the transmission of a beam of slow neutrons through two thin glass cells, 6 and 2.5 mm thick, into which liquid *p*- and *n*-H_2 could be condensed independently. The neutrons were produced in a "howitzer"[3] which could be cooled to 90°K and were detected by a BF_3 pressure ion chamber connected to a linear amplifier. The more important preliminary results uncorrected for neutron energy distribution are summarized in the table:

Composition	Temperature of Incident Neutrons	Cross Section per Molecule cm$^2\times10^{24}$
97% *p*-H_2	~300°K	29
72% *o*-H_2	~300°K	48
96% *p*-H_2	~100°K	21
72% *o*-H_2	~100°K	63
99% *p*-H_2	~100°K neutrons filtered through liquid *p*-H_2 in 6 mm cell, transmission of 2.5 mm cell measured.	<14
74% *o*-H_2		~75

The trend of the cross sections with lowering neutron temperature proves conclusively the existence of spin dependent forces. The magnitude of the change shows that the singlet state of the deuteron is definitely virtual. These conclusions are further substantiated by the scattering of neutrons after filtration through parahydrogen.

[1] Teller, Phys. Rev. **49**, 420 (1936).
[2] Schwinger and Teller, Phys. Rev. **52**, 142 (1937).
[3] Powers, Carroll and Dunning, Phys. Rev. **51**, 1112 (1937).

19. The Oppenheimer-Phillips Mechanism of d-p Reactions. H. A. BETHE, *Cornell University.*—In the light of Bohr's picture of nuclear reactions the Oppenheimer-Phillips (O-P) process[1] is unique in that compound and final nuclei are identical. The number of emitted protons per unit energy (within certain energy limits) is propor-

tional to the "sticking probability" between neutron and initial nucleus, in contrast to ordinary nuclear reactions in which it is given by the density of levels of the final nucleus. An experimental determination of the proton energy distribution would give the width of very low levels of the final nucleus which is important for the theory of the α-decay and would permit a better determination of the nuclear radius R. An intermediate value, *viz.* $R\sim10^{-12}$ for naturally radioactive nuclei, is now considered most probable. The O-P mechanism is favored compared to the ordinary one mainly because the proton emission does not need to compete with neutron emission. The mechanism is probably valid for nuclear charges greater than about 25, and for even lighter nuclei if the product nucleus is radioactive. However, an appreciable difference between the excitation functions of O-P and ordinary reactions should only be found for heavy nuclei ($Z>40$). The O-P process is usually not followed by secondary (cascade) disintegrations.

[1] Oppenheimer and Phillips, Phys. Rev. **48**, 500 (1935).

20. On the Theory of Focusing in the Cyclotron. M. E. ROSE AND H. A. BETHE, *Cornell University.*—The effect on the motion of the ions of the inhomogeneities in the electric and magnetic fields has been investigated. The electric focusing is predominant over approximately the first half of the path, the magnetic over the second. The most important factor in the electric focusing is the change of the field during the acceleration of the ion. If the *electric* field decreases during the acceleration, the ion will oscillate about the median (central horizontal) plane, the amplitude *increasing* as $\nu^{\frac{1}{2}}$ where ν is the number of accelerations; otherwise, the ions are defocused. The *magnetic* field always gives strong focusing resulting in a *decreasing* amplitude. Therefore the amplitude reaches a maximum about halfway out to the exit slit. Upon emergence, the beam will therefore occupy only a fraction ($\sim\frac{1}{3}$) of the dee spacing, in accord with observations. Similarly, only the middle portion ($\sim\frac{1}{4}-\frac{1}{3}$) of the source will be effective. The magnetic focusing would be improved if the magnetic field is made to decrease more rapidly towards the edge of the poles; a balance must be struck between this effect and the resonance condition. This explains the large effect of "shimming." The theoretical results are independent of the special geometry.

21. Induced Radioactivity in Silver by Fast Neutrons. M. L. POOL, *Ohio State University.*—The work, previously reported,[1] on the radioactive isomeric nucleus in silver, Ag^{106}, has been continued and extended during the summer at the University of Michigan with the aid of the cyclotron. The 8-day period then reported has been repeatedly measured to be $8.2\pm.3$ days. The β-ray (electron) spectrum has an upper limit of 1.3 Mev. The γ-rays are very strong compared to the β-rays; about 35 γ-rays are emitted per β-ray. Nuclear κ-electron capture is offered to explain this anomalously high γ to β ratio. The γ-ray spectrum is complex, having 1 Mev as its maximum. The positron emitting member of the isomer has a period of $24.5\pm.5$ min. and a β-ray spectrum upper limit of 1.9 Mev. No γ-rays are emitted other than the annihilation γ-rays. A $3.2\pm.2$ hr. period in silver has been found and is attributed to Ag^{112}. About 4 γ-rays per β-ray are emitted. The β-ray (electron) spectrum upper limit is 2.2 Mev. For the purpose of identification of radioactive products, α-particles, deuterons, protons, γ-rays, slow and fast neutrons have been used as bombarding particles on Rh, Pd, Ag, Cd, and In. A total of 20 nuclear reactions all leading to radiosilver has been observed.

[1] Phys. Rev. **52**, 380 (1937).

22. Nuclear *K*-Electron Capture and Negative Beta Emission. EDWARD C. CAMPBELL, *Ohio State University.*—In order to explain the abnormally high γ to β^- ratio found experimentally by Pool in the 8.2-day period of Ag^{106}, calculations have been made extending those of Møller to the case in which the emitting nucleus is positron-stable but is unstable with respect to the absorption of a K-electron and also to the emission of an electron. The calculations show that this can be explained only if it is assumed that the β-transition is of the forbidden type. It is pointed out that no meaning can be ascribed to the point in the Sargent diagram corresponding to the observed decay constant for such nuclei, because that constant is the sum of the intrinsic decay constants for the two processes.

23. The Energy Loss of Positrons Passing Through Matter. B. R. CURTIS AND J. M. CORK, *University of Michigan.*—In a hydrogen-filled expansion chamber placed in a uniform magnetic field, the energy loss of positive electrons obtained from the radioactive isotopes of Co^{55} (upper limit 1.6 Mev) and of Ag^{106} (2.24 Mev) has been investigated by measuring the curvature of the tracks before and after traversing aluminum absorbers of 0.0275, 0.053, and 0.114 cm thickness. A comparison of the amount of energy lost by the positron has been made with the energy lost by negative electrons emitted by P^{32}. The results show that no difference in the amount of energy lost can be detected by this experimental method. The initial energies of the particles range from 0.3 to 1.6 Mev. The data have been grouped into definite intervals, and the average incident energy determined for each interval. The theoretical values for the average loss have been calculated from Bloch's formula, in which calculations the energy of the particles is taken as equal to the incident energy minus one-half of the energy lost in traversing the

THICKNESS (cm)	AVERAGE INCIDENT ENERGY (Mev)	AVERAGE ENERGY LOSS (Mev)	
		Exp.	Theor.
0.0275	0.55	0.123	0.100
0.053	.55	.230	.214
	.60	.251	.202
	.63	.237	.203
	.87	.259	.204
	.99	.270	.206
0.114	.92	.480	.425

foil. The discrepancy between the theoretical and the experimental values may be due in part to the particles having traversed a greater path in the aluminum than the actual thickness of the material.

24. The Numerical Solution of Laplace's Equation. G. H. SHORTLEY AND R. WELLER, *Ohio State University.*—In the Liebmann procedure for the solution of Laplace's equation in an arbitrary two-dimensional region with given boundary conditions, the continuum is replaced by a net, a trial function is assumed, and successively improved by replacing the value at each point by the mean of the values at the four neighboring points. We have investigated the rate of convergence of this iterative process to the exact solution of the Laplace difference equation. This leads us to the formulation of an iterative procedure which converges many times more rapidly than the Liebmann; essentially it involves the improvement of nine points at once in place of a single point. By using this method one can arrive at a solution of Laplace's equation of the required accuracy in a fraction of the time necessary in the case of the Liebmann procedure, which is the only practical method which has previously been given for handling the problem in question. While we are particularly interested in applications to photoelasticity, the method should be of interest in numerical solutions of potential problems in other fields, such as electrostatics, heat conduction, shapes of films and membranes, and perhaps hydrodynamics.

25. The Relation Between the Gravitational Constant and Hubble's Factor. ARTHUR HAAS, *University of Notre Dame.*—An idea recently developed by Dirac and Jordan may be expressed in a more specialized form by postulating that the ratio R/a (R, the radius of the universe, and $a=e^2/(mc^2)$, the classical radius of the electron) be equal to the well known dimensionless physical constant: $A=e^2/(fm_pm)=2.30\times10^{39}$, where f is Newton's gravitational constant, and m_p is the mass of the proton. We may combine this postulate with two additional assumptions: R is at the same time the gravitational radius of the universe and is therefore equal to fM/c^2, where M is the mass of the universe; for the largest distance possible in a closed universe, that is for the distance πR, Hubble's recessional velocity becomes equal to the velocity of light. The combination of the first two principles leads to the equation: $M/m_p=(R/a)^2=A^2$. From our principles we can also derive a relation between f and Hubble's factor u; we find: $f=(\pi ua^2c)/m_p$. Inserting the well-known values for the quantities on the right-hand side of this equation (u is about 500 km per sec. per mega-parsec. or 1.6×10^{-17} sec.$^{-1}$) we obtain for f the value 7×10^{-1}, in agreement with the accepted observational value.

26. The Red Shift of the Nebular Spectrum Lines. IRA M. FREEMAN, *Central College, Chicago.* (*Introduced by Vergil C. Lohr.*)—Rejection of actual expansion as the explanation of the red displacement of nebular lines implies, as suggested by Hubble, that some yet undiscovered principle may be responsible for the effect. MacMillan, and more recently Haas,[1] have proposed an energy decrease of the photons as a possible reason for the red shift, and Sambursky[2] has attempted to attribute the effect to a change in the value of Planck's constant. The present paper seeks to show that the observed displacements may be accounted for by assuming a secular decrease in value of the gravitational constant in an otherwise static universe. A decrease with time of the gravitational constant means a decrease of the gravitational potential of all the matter in the universe. Consequently, during the time elapsing between the origin of a nebular photon and its reception on earth the potential will have decreased, so that the gravitational red-shift formula of relativity is capable of accounting for the effect. The calculations give results in harmony with known cosmic data and with other theoretical investigations.

[1] W. D. MacMillan, Nature **129**, 93 (1932); A. Haas, Science **84**, 578 (1936).
[2] S. Sambursky, Phys. Rev. **52**, 335 (1937).

27. On the Superstructure and Magnetism of Pyrrhotite. S. S. SIDHU AND VICTOR HICKS, *University of Pittsburgh.*—Pyrrhotite (FeS+S) solid solutions appear in one or the other of two low-temperature forms depending on whether they contain more or less than about 7 molecular percent sulfur: the boundary[1] is close to the composition $FeS_{1.07}$. The low-temperature low-sulfur form is not appreciably magnetic, but the low-temperature high-sulfur form is strongly magnetic. In solid solutions from 50.0 to 51.2 molecular percent sulfur (corresponding to $Fe_{19}S_{20}$), a "superlattice," in addition to the basic hexagonal lattice, has been reported.[2] At about 51.6 mole percent sulfur the "superlattice" is said to disappear and magnetism to appear. The relation of the "superlattice" to magnetism has been further investigated by us through x-ray studies of powder specimens as well as single crystals of both magnetic and nonmagnetic pyrrhotite. The evidence for the presence of a "superlattice" in nonmagnetic pyrrhotite has been confirmed by means of powder diffraction spectra of samples of natural and synthetic pyrrhotite. Further, identically the same evidence has been obtained from both natural and synthetic magnetic pyrrhotite. The diffraction lines for the "superlattice" are found in varying numbers in the diffraction patterns of all the specimens studied and give the same structure as reported;[2] hence, the presence of a "superlattice" is not considered essential to the magnetic properties of the material.

[1] H. S. Roberts, *Carnegie Institution of Washington Year Book* **30**, p. 84 (1931).
[2] G. Hagg and I. Sucksdorff, Zeits. f. physik. Chemie **B22**, 444 (1933).

28. Space Group of Pyrrhotite. VICTOR HICKS AND S. S. SIDHU, *University of Pittsburgh.*—X-ray diffraction studies have been made on single crystals of pyrrhotite. In addition to Laue photograms, rotation photograms about the a, c, and (110) axes have been prepared with filtered molybdenum radiation. These photograms lead to a hexagonal lattice with the following dimensions: a_0, 3.453 ± 0.009A; c_0, 5.670 ± 0.020A; d_{110}, 5.976 ± 0.029A; c/a, 1.644. The density of certain powder specimens has been determined by us as 4.55 g/cc. Using this value, the number of molecules of pyrrhotite per elementary cell is

approximately 2. The Laue photograms appear to have the symmetry D_{6h}. Rotation photograms, giving 51 independent reflections in the (100) zone, 70 in the (110) zone, 29 in the (001) zone showed that diffractions from general planes (*hkl*) appear in all orders. Characteristic halvings are (001) and (*hhl*). Accordingly, the most probable space groups are D_{6h}^4, D_{3h}^4, and C_{6v}^4, and of these, D_{6h}^4 may be chosen as adequately representing the symmetry.

29. Diamagnetism of Small Regions and the Superconducting State. J. C. SLATER, *Massachusetts Institute of Technology.*—In a recent paper[1] it was suggested that a free electron gas confined in small cells of the order of 137 atom diameters would show magnetic properties similar to superconductivity. For small magnetic fields, such a model shows very large diamagnetism, disappearing above a critical magnetic field, which is of the order of the observed threshold fields. Reasons were given for thinking that the electrons in an actual superconductor, at low temperatures, might approximate this simple model. The suggestion is now carried further by detailed calculation of the motion of free electrons in a cylindrical box with an axial magnetic field, verifying the results of the earlier qualitative discussion. Energy levels of individual electrons are split in the magnetic field, as in the normal Zeeman effect in atoms. This is the region of anomalously high diamagnetism. The critical field arises when levels begin to cross each other. Below this field, though electrons are accelerated by the induced e.m.f. associated with the magnetic field, there are no lower electronic levels which they can reach by collision with the lattice and no resistance. Above the critical field the magnetic behavior oscillates erratically, and finally the Landau theory of diamagnetism applies, showing an analogy to the Paschen-Back effect.

[1] Phys. Rev. 52, 214 (1937).

30. A New Method for the Precision Determination of *e/m* for Electrons. A. E. SHAW, *University of Chicago.*—The focusing properties of crossed electric and magnetic fields for electrons have been investigated[1] for the case of circular orbits. The measurement of *e/m* based on these properties possesses simplicity, high objectivity and freedom from uncertain corrections. This method differs from all other deflection methods in that the uncertainty attached to the electron velocities does not affect the final result. Final computations of *e/m* by this method reveal the curious fact that these uncertainties in velocity may range from 9 volts for an accelerating field of 120 volts, to 24 volts for an accelerating field of 395 volts. The order of magnitude of this effect and its apparent dependence upon the accelerating field remove it from the category of a contact potential. However, the focusing criteria developed for this new crossed field method make the final result independent of the accelerating potential. The methods employed by Kirchner and others to correct for these spurious effects in their methods for the measurement of *e/m* will be discussed; and the ultimate attainable precision of the crossed field method will be considered from the standpoint of modifications of the present mechanical design by the further application of kinematic principles.

[1] A. E. Shaw, Phys. Rev. 44, 1006 (1933); 51, 58 (1936).

31. Production of Uniform Magnetic Fields. R. J. STEPHENSON, M. FERENCE AND A. E. SHAW, *University of Chicago.*—In the magnetic focusing of electron beams and ion beams, it is important to secure magnetic fields which possess homogeneity over the region in space traversed by the beam. A pair of Helmholtz coils is usually used for this purpose. This combination of coils provides the desired uniformity of field only for a limited region coaxial with the coils, but for regions off the axis in the median plane the magnetic field is not uniform. It has been shown theoretically that in order to obtain the necessary uniformity off the axis in the median plane, the axial separation of the coils must be diminished; this separation depends upon the region at which uniformity is desired. The theory was applied to a pair of coils having a finite cross section of windings of 6 cm$\times$6 cm and a mean radius of 30 cm. The necessary separation of the coils was determined and the uniformity of the field calculated for a cross-sectional area of 1 cm^2, 10 cm from the axis and found to be superior to that of the Helmholtz arrangement.

32. Quadrupole Rotation-Vibration Spectrum of H_2. HUBERT M. JAMES, *Purdue University,* AND ALBERT SPRAGUE COOLIDGE, *Harvard University.*—Herzberg has suggested that it may be possible to prove the existence of H_2 in planetary atmospheres by observation in absorption of its quadrupole rotation-vibration spectrum. To make possible a quantitative discussion of this problem the theory of quadrupole transitions between $^1\Sigma$ states of homonuclear diatomic molecules has been worked out and applied to this system. The quadrupole moment has been computed as a function of nuclear separation by the use of electronic wave functions obtained by a variational process. Matrix elements of this quantity have been computed using Morse and Pöschl-Teller vibrational functions. It is found that the intensity of the first line of the *S* branch of the fundamental band of H_2 is 8.1×10^{-9} of that of the first line of the *R* branch in the fundamental band of HCl. The first and second overtone bands have respectively 0.91 and 0.19 of the intensity of the fundamental band. It appears that this relative intensity, very much greater than that observed with dipole bands, is of the order to be expected in quadrupole overtone bands in general.

33. A Simplified Method of Obtaining the Integrated Intensity from X-Ray Powder Photographs. E. O. WOLLAN, *Washington University, St. Louis.*—One of the disadvantages associated with the measurement of intensity of reflection of x-rays by the photographic method is the amount of work involved in the analysis of the films. In this report a method will be described which has been found to reduce very materially the time needed for the

analysis without cutting down on the accuracy of the result. If an x-ray photograph is microphotometered with the usual type of instrument one obtains a record of photographic blackening which must be converted to a corresponding scale of intensity. To accomplish this, some investigators have made use of a functional relation between x-ray intensity and blackening. Another method consists in putting on each film calibration marks which relate the blackening to the intensity. In the method to be reported, such calibration marks are made use of. The usual method of replotting the microphotometer traces on an intensity scale and then integrating with a planimeter is not used. The area under the traces is obtained in terms of a linear measure by means of an especially constructed rule, which gives the integrated intensity directly from the traces themselves.

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