Proceedings of the American Physical Society

MINUTES OF THE CHICAGO MEETING, NOVEMBER 27–28, 1936

THE 209th regular meeting of the American Physical Society was held in Chicago, Illinois, at the University of Chicago on Friday and Saturday, November 27 and 28, 1936. The presiding officers were F. K. Richtmyer, President of the Society, H. M. Randall, Vice President, Julian E. Mack and Ralph A. Sawyer. The attendance at the meeting was about three hundred.

On Friday evening in the International House the Society held a joint dinner with the Chicago Physics Club. President Richtmyer introduced Professor A. H. Compton, President of the Chicago Physics Club, who presided. Professor Compton called upon Professor John T. Tate, Chairman of the American Institute of Physics Incorporated, to extend congratulations to Professor Carl D. Anderson upon the award to him of the Nobel Prize. Professor Anderson who was present responded briefly. After this Dr. K. K. Darrow spoke on "Spinning Atoms and Spinning Electrons." There were one hundred and ninety-five guests present.

Meeting of the Council. At the meeting of the Council held on Friday, November 27, 1936, the deaths of two members were reported. (William D. Lansing and Tokutaro Sawai.) Six candidates were elected to fellowship, thirteen candidates were transferred from membership to fellowship, and twenty-eight candidates were elected to membership. *Elected to fellowship:* H. Beutler, Eli F. Burton, M. F. Crawford, Donald D. Foster, R. H. Fowler, and Sterling B. Hendricks. *Transferred from membership to fellowship:* Norris E. Bradbury, Paul H. Dike, Wendell H. Furry, Lachlan Gilchrist, H. Grayson-Smith, Frederick V. Hunt, Hubert M. James, Henry Victor Neher, John L. Rose, George H. Shortley, L. B. Slichter, Robert N. Varney and John P. Vinti. *Elected to membership:* Robert J. Adams, David L. Arenberg, Richard F. Baker, A. Clarke Beiler, Raymond M. Bell, Cornelis Bol, Dean P. Crawford, Warner Eustis, James J. Fleming, Gorton R. Fonda, Robert Hofstadter, Clifford Holley, Toyohiko Kagawa, C. D. Keen, Rolf Landshoff, Stewart W. Matson, B. S. Maximoff, Donald S. Miller, Kenneth W. Miller, John S. O'Conor, Roland Schaffert, Samuel Silver, Paul W. Thompson, George Valley, Carel W. van der Merwe, H. von Halban, Kenneth L. Warren, and Richard E. Watson.

The regular scientific program of the Society consisted of forty-one contributed papers of which numbers 17, 23, 27 and 29 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. A Million Volt Cyclotron. P. GERALD KRUGER AND G. K. GREEN, *University of Illinois.*—During the past fifteen months a cyclotron capable of producing 2.5μ amp. of deuterons at 10^6 ev energy, has been assembled and put into operation. Slides showing various features of the apparatus will be shown. The deuteron beam has been brought out of the vacuum chamber to a point about three feet from the edge of the magnet poles. This removes one of the formerly objectionable features of the cyclotron and makes it possible to study nuclear disintegrations without the intense fields of the cyclotron affecting the detecting apparatus. Examination of the shape of the beam current with an oscilloscope shows from 10 to 20 percent 360-cycle ripple, which corresponds to the rectified current supplied to the oscillators. The high frequency potential applied to the accelerating electrodes has been measured with an oscilloscope and found to be about 32 kilovolts. Various adjustments and their effect on the deuteron beam will be discussed.

2. A Radiofrequency Source and Transmission Line for the Cyclotron. G. K. GREEN AND P. GERALD KRUGER, *University of Illinois.*—Two commercial oscillator tubes have been connected in a tuned-plate tuned-grid circuit coupled to the cyclotron vacuum chamber with a matched-impedance transmission line. This system has better frequency stability than the direct coupled TNT circuit and is not thrown out of oscillation when bursts of gas occur in the vacuum chamber. In addition the radiofrequency source may be placed at any distance from the magnet.

The radiofrequency energy delivered to the electrode resonant circuit is over 60 percent of the direct current energy input. The transmission line, condensers, and other parts of the circuit have been constructed in this laboratory and will be described. Accelerating electrode insulators which will withstand the intense high frequency fields and mechanical strain have been developed. A pair of these insulators has been in operation since March 1936, with no trouble from overheating or glass puncture.

3. An Electrostatic Generator for the Production of Positrons. G. B. COLLINS, R. SCHAGER AND A. L. VITTER, *University of Notre Dame.*—An electrostatic generator of the type described by Tuve, Hafstad and Dahl has been erected in a room 40×40×40 ft. The sphere is 12 feet in diameter and was constructed at a comparatively small cost by nailing copper sheets on a spherical wooden form. The slightly irregular surface which resulted apparently does not greatly increase the corona loss since a potential of about 2 Mev is obtained with a charging current of only 10^{-4} amp. An accelerating tube 9 inches in diameter and 24 feet long has been set up for the purpose of accelerating electrons. A system of protective rings has been devised which has a small corona loss and protects the glass tube against puncture. The apparatus is to be used for the production of positrons.

4. Construction of a Voltage Multiplying Circuit to Yield 700 kv. SAMUEL K. ALLISON, GRAHAM T. HATCH AND LESTER S. SKAGGS, *University of Chicago.*—A voltage multiplying circuit of the type first used by Cockcroft and Walton in nuclear disintegration experiments has been constructed with the hope of reaching positive or negative potentials of 600–800 kv. The design of the vacuum tube rectifiers has some novel features. The filament assemblies are pushed into place or pulled out through conduit tubes which are closed at their outer ends with vacuum tight removable plates. This makes possible rapid replacement of burnt out filaments. The sign of the high voltage produced can be changed by reinsertion of the filament assemblies into the set of conduit tubes which have previously acted as electron collectors. The problem of insulating the sources of heating current for the filaments has been solved by heating each filament from the output of a small direct current generator. These generators are mounted on a vertical insulating drive shaft; their output is stabilized by small storage batteries acting as floats. Preliminary trials with 60-cycle current have produced 600 kv (tested with a gap between 75 cm spheres) and reveal no serious obstacle to operation at voltages 100 to 150 kv higher. It is intended ultimately to operate the circuit with the laboratory supply of 540-cycle current.

5. The Development and Performance of an Electrostatic Generator Operating under High Air Pressure. R. G. HERB, D. B. PARKINSON AND D. W. KERST, *University of Wisconsin.*—A belt type electrostatic generator has been developed which operates in a steel tank, 5½ feet in diameter and 20 feet long, under an air pressure of 100 lbs./in.^{2}. The generator is provided with a high potential electrode system of a new design which serves both to give a high breakdown potential and to furnish a satisfactory potential distribution along the charging belts and the accelerating tube. The maximum potential of the generator is about 2500 kv and the highest steady potential at which reliable data have been obtained is 2160 kv. An evacuated tube for acceleration of ions has been developed which withstands the highest generator potential. The apparatus has been successfully used in experiments on atomic disintegration.

6. High Potential Apparatus for Nuclear Studies. H. R. CRANE, *University of Michigan.*—A 1,000,000-volt transformer and vacuum tube apparatus for nuclear disintegration work has recently been completed at the University of Michigan. The transformer consists of five 200,000-volt sections, in a cascade circuit. The tube is made of five heavy Pyrex glass sections 24 inches long and 16 inches in diameter, with hollow steel electrodes 6 inches in diameter. Each accelerating gap in the tube is connected across one of the sections of the transformer to insure uniform potential distribution. A focused ion beam of 250 microamperes is obtained at the target. Cloud chambers are operated in synchronism with this apparatus by means of a common contact system, in such a way that both the ion source and the transformers are energized for only about ½ second, during which the chamber expansion takes place. Details of the construction and operation of this apparatus will be given at the meeting.

7. Focusing Criteria for Electrons in Superimposed Electric and Magnetic Fields. A. E. SHAW, *University of Chicago.*—The precision of most deflection measurements of e/m for electrons is limited by the uncertainties due to contact potential difference in the accelerating field. In the present paper, experiments are described which have as their purpose the investigation of supplementary criteria which eliminate these uncertainties from the method of superimposed electric and magnetic fields. The equation for e/m employed in this work is

$$e/m = 4E/(H^2\rho^2),$$

where E represents the electric field intensity; H, the magnetic field intensity; and ρ, the radius of curvature of the path. Although the velocity does not appear explicitly in this equation, provision must be made by focusing to adjust the velocity for any given ratio of intensities of electric and magnetic fields. This adjustment can be carried out by a series of observations to give the appropriate values of E and H to an accuracy of 1 : 10,000. A provisional value of e/m agrees approximately with the average of five recent results based on four different methods. A final value will be given as soon as a redetermination can be made of the geometrical constants of the apparatus.

8. An Improved Method for the Measurements of High Energy Gamma-Rays. E. R. GAERTTNER AND H. R. CRANE, *University of Michigan.*—Measurements of the quantum

energies of gamma-rays arising from artificial disintegration processes have heretofore been made by placing a cloud chamber near the source and observing Compton electrons and electron pairs ejected from the walls of the chamber or from a thin sheet of material placed within the chamber. If only those electrons which are known to come from a small depth of absorber are counted, the method becomes slow and confusion is introduced by scattered radiation. The present authors have constructed a target in a small thimble inside a cloud chamber, which is bombarded by an ion beam for an instant at the time of expansion. With almost no exception, the tracks appearing in the chamber originate in the thin wall of the thimble. In preliminary experiments with lithium bombarded with protons, using 0.7 mm brass wall, many electron pairs and single negative electrons having the entire available energy, 17 Mev were observed. Similar measurements are now being made with a thimble having a thin carbon wall.

9. The Bombardment of Gold with Deuterons. J. M. CORK AND R. L. THORNTON, *University of Michigan.*—The products of disintegration formed by bombarding gold with high energy deuterons (6 to 7 Mev) have been studied. The deuterons were produced in a new magnetic resonance accelerator. Chemical separations show the radioactivity to be associated with a gold isotope and an iridium isotope. Observations with the cloud chamber show the gold to emit negative electrons and the iridium to emit both positives and negatives. The corresponding reactions are probably as follows:

(a) $_{79}Au^{197}+{}_1H^2\rightarrow{}_{79}Au^{198}+{}_1H^1\rightarrow{}_{80}Hg^{198}+{}_1H^1+{}_{-1}e^0$,

(b) $_{79}Au^{197}+{}_1H^2\rightarrow{}_{77}Ir^{194}+{}_1H^1+{}_2He^4$,
$_{77}Ir^{194}\rightarrow{}_{78}Pt^{194}+{}_{-1}e^0$ and $_{76}OS^{194}+{}_{+1}e^0$.

Estimations of the half-life periods and of the beta-energies are made.

10. The Disintegration of Beryllium by Protons. JAMES S. ALLEN, *University of Chicago.*—In order to study the disintegration of Be by low velocity protons a three-section tube was designed. The proton source was of the low-voltage arc type and produced total ion currents of the order of 40 microamperes. The usable proton currents ranged from one to six microamperes. The energy of the protons was measured both by means of a magnetic field and by spark-gap readings of the voltage. The disintegration products were recorded by an ionization chamber 2.5 mm deep and a linear amplifier using Dunning's circuit. The yield curve for a thick target of Be was determined for voltages from 45 to 125 kv and the ratio of the number of alpha-particles and deuterons ejected from the target was found for various proton energies. The ratio was very close to unity. The ranges of both groups of particles were found to be 7.1 mm. From the energy considerations the mass of Be^8 was found to be 8.0074. The experimental value of the effective area for collision was found to be of the same magnitude as that predicted by Gamow's theory for the penetration of a potential barrier by protons.

11. Alpha-Particle Yield from Protons on Lithium. L. J. HAWORTH AND L. D. P. KING, *University of Wisconsin.*—The yield of eight centimeter alpha-particles produced when metallic lithium is bombarded with protons was obtained as a function of proton energies from 20 to 200 kilovolts. Observations were made on both massive and thin (3 kilovolts absorption at 120 kilovolts) films. To avoid effects of surface impurities new lithium was evaporated after each five minutes of bombardment. Comparison of the thick and thin film data indicates that the $V^{\frac{3}{2}}$ absorption law is probably not valid at these low energies.

12. Gamma-Ray Yield from Light Elements due to Proton Bombardment. R. G. HERB, D. W. KERST AND J. L. MCKIBBEN, *University of Wisconsin.*—With the high potential electrostatic generator recently developed at this laboratory a survey of a number of elements has been made in a search for gamma-ray emission due to proton bombardment. Six of the elements examined gave gamma-rays of sufficient intensity to permit accurate measurement. These six elements are Li, Be, B, F, Na and Al. Their gamma-ray yield was studied as a function of proton energy, or generator voltage, starting with the minimum potential at which the yield was easily measurable. In the region of fairly low potentials the yield curves from the six elements studied gave evidence for resonance excitation of the gamma-rays and certain indications of fine structure. At high potentials each of the six elements gave a gamma-ray intensity which increased nearly exponentially with voltage up to the maximum voltage obtainable from the generator (approximately 2 Mv). The other elements which were bombarded are C, O, Si, Cl, K, Ca, V, Ni, Cu, Zn, Mo, Pt, Pb. Gamma-rays from these elements were weak, and from some of them the gamma-ray intensity was not above the x-ray background of the generator.

13. An Energy Distribution Analysis of Primary Cosmic Rays. ARTHUR H. COMPTON, *University of Chicago.*—An energy distribution analysis, following the method suggested by Zanstra, is given, with the use of new latitude effect data collected on the Pacific Ocean in collaboration with R. N. Turner, of the *R.M.S. Aorangi.* The method depends upon Störmer's theory which relates the minimum energy of the vertical rays to the magnetic latitude, and the close experimental approximation that the intensity of the vertical cosmic rays is proportional to that of the total radiation coming from all directions. Below 9 Bev (Bev $= 10^9$ electron volts) the effect of the earth's atmosphere becomes evident in limiting the rays that are received to a higher energy than the minimum admitted by the magnetic barrier. The form of the curve for lower energies suggests two components, one with a limiting energy imposed by the atmosphere of about 8 Bev, and the other of about 3 Bev, though the data are inconclusive. Between 9 and 19 Bev the energy spectrum appears continuous and indicates an electrical particle origin of a large part, very possibly the whole, of the cosmic-ray ionization.

14. High Altitude Test of a Radio-Equipped Cosmic-Ray Meter. C. D. KEEN, *University of Chicago.*—A high altitude cosmic-ray meter, of the type proposed by Benade,[1] has been built and flown. The ionization current of an unshielded argon-filled chamber moves the mirror of a Dershem electrometer. When the reflected light beam falls on a photoelectric cell, the electrometer is discharged and the radio signal is modulated. A pressure device also modulates the signal when certain altitudes are reached. A small quantity of radioactive material introducing a small fixed ionization makes possible convenient measurement of cosmic-ray ionization through a large ratio. On April 14, 1936, a balloon flight was made from Shreveport, Louisiana. The instrument and batteries weighed 41 pounds, and were raised by three 8-foot balloons to an altitude of 52,000 feet. During the rapid ascent the swaying of the gondola affected the electrometer mirror, and the cosmic-ray signals were irregular. More satisfactory data were obtained on the slower descent. At 78 mm of mercury an intensity of 288 I was measured. This preliminary curve is somewhat steeper than that obtained by Millikan and Bowen[2] at about the same latitude.

[1] J. M. Benade and R. L. Doan, Phys. Rev. **47**, 198 (1935).
[2] I. S. Bowen and R. A. Millikan, Phys. Rev. **43**, 695 (1933).

15. Heights of Reflection of Radio Waves in the Ionosphere. F. H. MURRAY AND J. BARTON HOAG, *University of Chicago.*—A general method has been developed whereby, from the virtual height-frequency curves, it is possible to calculate an upper limit to the height of reflection of a radio wave of a particular frequency in the ionosphere. It is shown that a discontinuity in a virtual height-frequency curve is a necessary but not a sufficient condition for the existence of two distinct layers. The application of the method to a particular day and place, over the frequency range from 2.5 to 4.4 megacycles, has yielded several interesting results. For example, at certain times and for certain frequencies, the highest altitudes to which the waves can travel are very much lower than the virtual heights, indicating that the group velocity over extended regions in the ionosphere is much less than the velocity of light. It was also found that, during the morning hours and for the range of frequencies studied, the upper limits of the true heights in the F_2 region decreased whereas the virtual heights increased.

16. Electron Beam Oscillators. J. BARTON HOAG AND GEORGE E. FLODIN, *University of Chicago.*—In order to produce ultra-short radio waves at comparatively high power levels with the usual tubes and circuits it is necessary to employ large structures to dissipate the heat and simultaneously to use small structures to reduce the capacities and shorten the transit time of the electrons. With the object of alleviating these contradictory conditions, we have developed a type of oscillator using an electron beam. The beam passes through several electrodes whose relative potentials are varied periodically by feed-back from parts of the beam more distant from the electron gun. In one form, the electrons are deflected by periodic reversals of the potentials on condenser plates;[1] in another, they are alternately converged and diverged by an electron lens. The feed-back may be accomplished by coupling with electrodes at the end of the beam or by charges induced on electrodes through which the electrons are passing (the latter was suggested by A. and O. Heil). Under certain operating conditions, we have observed a wave with more than two hundred harmonics.

[1] C. M. Shanks, M.A. Thesis, University of Chicago, 1935.

17. The Preferred Orientation Produced in Pure Iron-Nickel Alloys by Cold-Rolling. D. MCLACHLAN, JR., AND WHEELER P. DAVEY, *Pennsylvania State College, State College, Pa.*—Ribbons whose total impurities did not exceed 40 parts per million were cold-rolled in a single direction at a speed of about 6 inches per minute. Underneath a surface skin one mil thick the degree of orientation depends only upon the percent total reduction. It is independent of the reduction per pass and of the nickel content up to 22 percent nickel. By using a quantitative concept for a unit-pole, the degree of preferment of orientation is expressed in terms of pole density on a sphere of reference. Three assumptions are made as to the mechanism of rolling. These enable orientations to be expressed by two parameters instead of three. A simple probability function has been found for the chance that a crystal fragment will have a given orientation. Pole densities from this probability function agree with those found by experiment. The theoretical equation requires a knowledge from experiment of only the ratio of two numbers which express the maximum deviation of orientation from the optimum along each of two coordinates used in plotting the results.

18. A New Method of Determining the Relative Location of Points Within a Body by X-ray Photography. A. D. HUMMELL, *Eastern Kentucky State Teachers College,* AND O. F. HUME, *Richmond, Ky.*—Two pairs of scales are mounted in parallel planes with a known distance between them in such a way that the images of these scales and the points in question will appear on the same radiograph. To determine the three-dimensional location of a point with respect to an arbitrary zero, two radiographs are necessary and differ only in a small lateral displacement of the source of x-rays. The actual relative position of the points in question and the scales must be the same for these two radiographs. The image of the point whose position is desired is found in each radiograph and perpendiculars drawn to each of the scale shadows. The intersections with the latter are noted in terms of the units into which the scale images are divided. From these readings the spatial coordinates are determined. The distance between two points may then be found. The method is useful in determining the pelvic measurements of a pregnant woman, in locating foreign particles in the human body, and its simplicity should make it applicable in industry.

19. The Atomic Vibrations of Zinc Crystals at Liquid Air Temperature. G. E. M. JAUNCEY AND W. A. BRUCE, *Washington University, St. Louis, Mo.*—The coherent part of the diffuse scattering of x-rays from a crystal is proportional to $(1-e^{-2M})$. Zener has shown from theory that for a hexagonal crystal like zinc M should be of the form

$(a\cos^2\psi+b\sin^2\psi)\cdot(\sin^2\frac{1}{2}\phi)/\lambda^2$, where ψ is the angle between the c axis of the crystal and the line bisecting the angle between the forward direction of the scattered rays and the backward direction of the primary rays. The quantities a and b are functions of the temperature and ϕ is the angle of scattering. In a previous paper[1] we have reported that, for zinc crystals at room temperature (298°K) and for $\phi=30°$, $a=2.34\text{A}^2$ and $b=0.68\text{A}^2$. These correspond to root mean square displacements of 0.172A and 0.093A, respectively. Using primary rays with the same spectral distribution as in the previous paper, we have now obtained a curve of S against ψ for the crystals at liquid air temperature (100°K) and for $\phi=30°$. From this curve we obtain $a=0.84\text{A}^2$ and $b=0.23\text{A}^2$. These correspond to root mean square displacements due to thermal vibration of 0.103A and 0.054A, respectively, parallel and perpendicular to the c axis of zinc.

[1] Jauncey and Bruce, Phys. Rev. **50**, 413 (1936).

20. Dependence of Diffuse Scattering of X-Rays from Quartz Upon the Crystal Orientation II. E. S. FOSTER, JR., G. E. M. JAUNCEY AND W. A. BRUCE, *Washington University, St. Louis, Mo.*—The coherent part of x-rays diffusely scattered from a crystal has been shown by theory to be proportional to $(1-\epsilon^{-2M})$, where M, the Debye-Waller temperature factor, is a measure of the mean square displacement of the atoms. The structure of quartz as determined by x-ray analysis has been found very complicated. A number of rules have been established concerning the symmetry of the diffuse scattering from an X-cut crystal. Whereas, in the case of zinc, M is a simple function of ψ, the orientation angle, for quartz the relation is very complicated. At a scattering angle of $\varphi=25°$ we have shown the following relations:

$$S(A,\psi)\neq S(B,\psi),$$
$$S(A,\psi)=S(B,-\psi),$$
$$S(A,\psi)\neq S(A,-\psi),$$
and
$$S(A,\psi+\pi)=S(A,\psi),$$

where $S(A,\psi)$ is defined as the diffuse scattering coefficient for a scattering angle φ when the side A of an X-cut crystal is towards the primary x-rays and ψ is the angle between the c axis and the bisector of the angle between the forward direction of the scattered rays and the backward direction of the primary rays.

21. The Structure of Molten Salts.[1] E. P. MILLER AND K. LARK-HOROVITZ, *Purdue University.*—Different methods have been worked out for the evaluation of the distribution function as determined by the x-ray scattering curve $Si(s)$ and given by the formula

$$G(r)=(1/2\pi^2r)\int_0^\infty Si(s)\sin(sr)ds.$$

As the most satisfactory method the punched card method has been found which allows a completely automatic analysis to be carried out in a few hours.[2] The results have been applied to the determination of the number of atoms around any atom in molten KCl and LiCl. In the first case both atoms can be treated as identical. In the second case Li can be neglected as compared with Cl. The results as given below indicate that for the next neighbors the coordination as found in the solid is maintained for the liquid but that the distribution of the second next neighbors is already disturbed.

	Solid		Liquid	
Substance	Number	d	Number	d
KCl	6	3.14	5.8	3.14
(K=Cl)	12	4.44	8.3	4.3
LiCl	12	3.64	9.8	3.8
(Li≪Cl)	6	5.14	(5.0?)	5.15

[1] Phys. Rev. **49**, 418 (1936).
[2] Complete sin (sr) tables and punched cards for the method worked out from these can be obtained from this laboratory

22. The Faraday Effect in the X-Ray Region. H. T. CLARK AND K. LARK-HOROVITZ, *Purdue University.*—Co $K\alpha$ x-rays produced in a tube with steel body (as magnetic shield) have been polarized by reflection from the 220 plane of Ni and were passed through iron foils of varying thicknesses and in different magnetic fields. This monochromatic radiation was then "analyzed" by scattering from crystalline tungsten and the analyzed radiation was recorded photographically on a cylindrical film coaxial with the tungsten scatterer. Records of the radiation scattered after passing the iron foil with and without magnetic field were obtained side by side on the same film. A rotation of one degree could have been detected. With completely monochromatic radiation (carefully shielding any stray radiation from the continuous background), no effect was found. This agrees with expectations from theory since for x-rays in the K region virtual transitions from the K shell to the partially filled d levels (ferro-magnetism!) are forbidden, and therefore for this region iron must be treated like a nonferromagnetic substance, and the Faraday effect calculated from the ordinary dispersion formula: $\varphi\sim10^{-50}$.

23. Crystallization of Polymorphous Substances from the Vapor Phase II. S. E. MADIGAN AND K. LARK-HOROVITZ, *Purdue University.*—A method has been developed for the quantitative determination of the constitution of polymorphous mixtures by using monochromatic x-rays and intensity comparisons of coincident lines. This was applied to the investigation of the deposition of ZnS from the vapor phase. It has been found that the amount deposited in the cubic or hexagonal form depends on pressure and temperature conditions. The results show that at high speed of evaporation and in the presence of inert gases the unstable form is always deposited regardless of what support is used: Ostwald's rule of stages. If the evaporation and deposition is conducted at slow rate in a high vacuum, most of the nuclei seem to form at the interface gas-solid as indicated by the prevalence of the hexagonal form on CdS, and ZnO as compared with the deposit of Cu and Zn cubic. Experiments with single crystals of zinc blende split in high vacuum immediately before deposition show that the crystal growth starts from different centers distributed at random over the surface.

24. Orientation of Liquid Crystals by Heat Conduction. D. O. HOLLAND AND G. W. STEWART, *University of Iowa.*—One of the authors has previously reported upon an apparently new phenomenon, i.e., a definite effect upon the orientation of liquid crystalline para-azoxyanisol presumably by heat conduction. Former results have now been checked by the density of photographs of the x-ray halo with various vertical alterations in temperature gradients. With a higher temperature at the bottom the convection currents caused a distribution favoring an orientation with "swarm" axes vertical. As the temperature gradient was varied until in the opposite sense the halo first became circumferentially uniform and then indicative of a similar orientation with "swarm" axes horizontal. These results favor the conclusion that the orientation is produced by heat conduction. Perhaps the orientation is caused by the scattering of elastic waves, but this is not certain.

25. Influence of Temperature of Uranin Solution on the Fluorescence Decay Time.* WINSTON CRAM,† *University of J. Piłsudski at Warsaw.*—The values of the fluorescence decay time for 8 different uranin solutions were measured when the temperature of the solution was varied from 0°C to 70°C, with the Szymanowski[1] version of the Gaviola fluorometer. It was found that for weak concentrations (1×10^{-4} g/cm³) in water and ethyl alcohol solutions the fluorescence decay time decreased 25 percent with increase of temperature from 0°C to 30°C. A further increase of temperature, however, caused no further observable change in the decay time. Increase in the concentration of uranin tended to weaken this observed temperature effect. At a concentration of 6×10^{-3} g/cm³ the effect was not observable, within the limits of experimental error (less than 3 percent). The use of more viscous solutions showed that the increase in viscosity also decreased the observed temperature effect. In agreement with Gaviola, no temperature effect was observed for glycerin solutions of any concentration. The temperature effect for all solutions was unchanged when the polarization system for observing the fluorescent light was rotated through 90°. The observed results are not in agreement with the equation of Franck and Wawiłów.[2]

* The more detailed report of this work will be published soon in the Zeits. f. Physik.
† Now at University of Wisconsin.
[1] Szymanowski, Zeits. f. Physik **95**, 466 (1935).
[2] Franck and Wawiłów, Zeits. f. Physik **69**, 100 (1931).

26. X-Ray Fluorescence Yields. R. J. STEPHENSON, *University of Chicago.*—The x-ray fluorescence yield for the K shell, that is, the ratio of the number of fluorescence quanta emitted from the K shell of an assemblage of atoms to the number of quanta absorbed in the K shell, has been measured for several elements whose atomic numbers lie between nickel and tin. An ionization method similar to that of Professor Compton's[1] was used. The ionization chamber contained argon under pressure. The ionization current was measured by means of an FP 54 vacuum amplifier. A rotating sector disk was used to reduce the intensity of the incident x-ray beam to a value comparable with that of the excited fluorescence beam. The results show an increase of fluorescence yield with atomic number and give a good agreement with the relativistic quantum-mechanical calculations of Massey and Burhop.[2] The fluorescence yield for the L_{III} shell has been measured for lead, thorium and uranium. In this case the incident radiation used was of such a frequency that photoelectrons from the L_{III} shell were ejected but not those from shells requiring greater energy. An increase in the fluorescence yield with atomic number was found.

[1] Compton, Phil. Mag. VIII, 961 (1929).
[2] Massey and Burhop, Proc. Roy. Soc. **A153**, 661 (1936).

27. The Zeeman Effect of Tellurium. J. B. GREEN AND R. A. LORING, *Ohio State University and University of Louisville.*—The Zeeman effect of tellurium has been studied at field strengths of about 36,000 gauss, by using an interrupted arc between powdered tellurium packed in a hollow brass electrode and a copper disk, such as was used in the study of the Zeeman effect of arsenic.[1] About 100 lines have been measured including 4 arc lines, about 20 lines of Te III and one line of Te IV (λ3585), according to the assignments given by L. and E. Bloch.[2] The spectrum of Te II was especially well excited, and the measurements lead to definitive assignment of j and g values in a large number of cases. We are at present engaged in an attempted classification of the spectrum of Te II based on this work.

[1] Green and Barrows, Phys. Rev. **47**, 131 (1935).
[2] L. and E. Bloch, Ann. de Phys. **13**, 233 (1930).

28. Two New Band Systems of Diatomic Antimony. G. M. ALMY AND H. A. SCHULTZ, *University of Illinois.*—The spectrum of diatomic antimony has been obtained by heating antimony in an atmosphere of nitrogen in a graphite tube furnace. In addition to the two ultraviolet systems photographed by Naudé, two new systems have been photographed, in absorption at temperatures of 1350–1600°C and in thermal emission at 1550–1750°C. One system extends from 4500 to 6000A and the other from 6000 to 7500A. Both of the systems involve the ground state. The three upper states which have been analyzed show a surprising similarity in vibrational constants. The analysis into two visible systems is supported by the isotope effect. The distributions of intensity are similar to those found for P_2 and for As_2, having subsidiary Franck-Condon parabolas. In each system bands are observed approximately to $v'=10$ and $v''=10$. The constants for the three states are:

State	T_e(cm^{-1})		ω_e(cm^{-1})	$x_e\omega_e$(cm^{-1})
X	0	$(A\leftrightarrow X)$	269.7±.5	0.60±.14
		$(B\leftrightarrow X)$	270.0±.2	0.60±.04
A	14,991.5		217.0±.4	0.45±.08
B	19,067.9		218.1±.4	0.52±.12

Rough extrapolation gives 3.7 volts for the heat of dissociation of the ground state; this value is almost certainly too high.

29. The Optically Active CD_4 Fundamental Bands. H. H. NIELSEN, *Ohio State University,* AND A. H. NIELSEN, *University of Tennessee.*—The two active fundamental vibration-rotation bands ν_3 and ν_4 in the spectrum of CD_4

have been located and their rotational structure studied under high resolving power. The centers of these bands have been determined respectively to be $\nu_3 = 2259.0$ cm^{-1}, in good agreement with the value 2258.0 cm^{-1} obtained by MacWood and Urey[1] from Raman spectra, and $\nu_4 = 996$ cm^{-1}. The average spacing between rotational lines in ν_3 is about 4.43 cm^{-1}. While the rotational lines of ν_4 show a multiplet structure similar to that in the corresponding short frequency bands in the spectra of other tetrahedral molecules it is nevertheless possible, especially on the positive side of the band, to determine what may be called an average spacing between lines. This spacing takes the value 3.2 cm^{-1}. It is possible to compute the value of the moment of inertia from the relation $\Sigma\Delta\nu = 3h/8\pi^2 A$ developed by Johnston and Dennison.[2] The value obtained for A is 1.091×10^{-39} gm-cm^2, or very nearly twice that for ordinary methane. The combination bands $\nu_1+\nu_4$ and $\nu_3+\nu_4$ have not been located, probably because they would lie in the region of the 3.16μ atmospheric water vapor band.

[1] G. E. MacWood and H. C. Urey, J. Chem. Phys. **4**, 402 (1936).
[2] M. Johnston and D. M. Dennison, Phys. Rev. **48**, 868 (1936).

30. Constants of $^3\Pi$ States of AlH, OH^+, BH. C. N. CHALLACOMBE AND G. M. ALMY, *University of Illinois.*—The methods of Budo[1] and Gilbert[2] for applying the theory of $^3\Pi$ states between case *a* and case *b*, developed originally by Hill and Van Vleck, and Van Vleck, have been used to determine the molecular constants B, D, λ or A/B, for the $^3\Pi$ states of AlH, OH^+ and BH. By Gilbert's method, for AlH, $\lambda = 6.02$; for OH^+, (0, 0), $\lambda = -6.35$; for BH, $\lambda = 0.47$. The determination of λ is greatly facilitated by drawing a set of graphs of W/B *versus* λ, each graph showing three levels having the same value of K(K-multiplet). If the constant B for any $^3\Pi$ state is approximately known, a value of λ is easily read off each graph by fitting the observed K-multiplet separations divided by B to the plotted separations. In practice good agreement is found among the values of λ obtained from graphs for $K = 2,3,4,5$ for each molecule, and the values of λ obtained graphically agreed well in each case with that determined by the much more laborious analytical method. The graphs also aid in analysis of certain bands, as they show clearly the confusing behavior of the K-multiplets to be expected at low K, for values of λ between $+2$ and $+7$, as is found, for example, in the AlH $^3\Sigma \rightarrow {}^3\Pi$ band.

[1] A. Budo, Zeits. f. Physik **96**, 219 (1935).
[2] Cecil Gilbert, Phys. Rev. **48**, 619 (1936).

31. Field Current Emission from Metals into Gases at High Pressures. J. B. ADAMS, J. C. HUBBARD AND R. T. K. MURRAY, *Johns Hopkins University.*—By making use of the well-known property that the breakdown gradient of a gas increases with the pressure, sufficient fields have been obtained at the surface of a metal cathode immersed in a gas at high pressures to give field currents of magnitude greater than the background currents due to residual ionization. The apparatus consisted of spherical electrodes placed in a steel chamber into which nitrogen was introduced at pressures up to 110 atmospheres. Steady potentials up to 25 kv were applied to the cathode and the resulting field calculated from the distance between the spheres as measured through a glass window. Curves of log current against reciprocal field were linear in accord with the Fowler-Nordheim equation; the curves were independent of pressure. At a pressure of 110 atmospheres a maximum gradient of 1600 kv/cm was reached without breakdown, the field current at this gradient being of the order of 10^{-5} amp. It should be pointed out that in employing high pressures for maintaining high potential gradients between electrodes the degree of insulation is limited not only by the currents due to residual ionization but also by field current emission from the cathode.

32. Contact Potential between Filaments in Vacuum by Kelvin Method. A. T. WATERMAN, *Yale University*, AND J. G. POTTER, *Armour Institute of Technology.*—Two parallel filaments constitute a condenser whose capacity is varied by vibrating one of the filaments under tension, in order to detect any unbalanced contact potential difference. An alternating current of properly adjusted frequency through this filament, in the presence of an applied magnetic field, causes it to vibrate with a satisfactory amplitude while heating it to any desired temperature above 420°K. The other filament is connected to an audio-frequency amplifier, the circuits being similar to those employed by Zisman[1] in measuring contact potentials between plates in air. Measurement consists in adjusting a measured potential applied to the electrical mid-point of the vibrating filament until the amplifier indicates that the contact potential is completely balanced out. With proper adjustment, disturbance from the applied a.c. is eliminated. The filaments are electrically shielded from external disturbance, appreciable contact P.D. between shield and filaments being compensated. To reduce the tension on the filaments while outgassing and to restore it for vibration, a system of glass levers, bearings, cams and iron armatures, encased in glass, are operated by magnets from outside the tube. Although not to be regarded as final, measurements made to date, employing two tungsten filaments, indicate an increase with temperature in the work function of tungsten of approximately 6×10^{-5} volts per degree centigrade.

[1] Zisman, R. S. I. **3**, 367 (1932).

33. Four Forms of the Copper Arc in Air. A. S. FRY, *Northwestern University.* (*Introduced by W. S. Huxford.*)—Four distinct and reproducible forms of the copper arc in air at atmospheric pressure have been identified. The following table indicates the main features of each arc form:

Electrode	Potential* (volts)	Gradient (volts/cm)	Fall near Cathode (volts)	Fall near Anode (volts)
1. Clean Cu	46	52	11	10
2. Cold CuO	41	25–31	10.5	7
3. Hot CuO	37	25	14	7
4. Hot Cu_2O	34	25	14.5	4

* Voltage across 6 ampere arc, electrode separation, 3 mm.

That the controlling gas in the first arc is nitrogen is confirmed by gradient measurements carried out in a pure nitrogen atmosphere. The gradient in arcs (3) and (4) is determined by the presence of copper vapor furnished by thermal decomposition of the oxides. Space potentials were measured by means of a Langmuir probe consisting of a tungsten wire 0.07 mm in diameter. Although the field near the center of the arc column is uniform, a continuously increasing gradient occurs within the space extending from 1 mm to $\frac{1}{2}$ mm from the electrode surfaces. The decrease in anode fall from 10 to 4 volts is accompanied by an increase in potential at the cathode. The lowering of the anode fall is due to several effects which combine to cause a decrease in electron concentration in the anode sheath. The changes in cathode fall are most easily explained on the basis of the field theory of electron emission.

34. Density of Excited Levels in Heavy Nuclei. S. GOUDSMIT, *University of Michigan.*—Bethe's calculation of the level spacing of excited nuclei does not explain why some heavy nuclei do not possess resonance levels for slow neutrons. Another method of calculating, closely related to Bethe's, seems to throw some light on this problem. The possible energies for the individual particles are calculated again statistically. Over a certain range these energies may be taken as approximately equidistant with a spacing ϵ. If the excitation of the total nucleus is $Q=n\epsilon$ the level spacing of nondegenerate levels in the neighborhood of Q is given by $\epsilon/\Sigma_\nu p_s(\nu)p_t(n-\nu)$. In this expression s and t are the numbers of neutrons and protons available for the excitation and the symbol $p_s(\nu)$ means "the partition of the integer ν into parts none of which exceeds s." If both s and t are larger than n, the result comes out to be identical with that of Bethe. The spacing will be much wider, however, if this condition is not fulfilled. This could happen if nuclei contain shells differing considerably in energy. If the stability of the normal nucleus causes the first excitation energies of the individual particles to be larger than the assumed distance ϵ, the level spacing for the total excitation will also be increased greatly.

35. On the Matrix Element in the Fermi Theory of β-Decay. L. W. NORDHEIM, *Purdue University.*—How the many body constitutions of the nuclei have to be taken into account in the theory of β-decay is discussed. It is found to be necessary to make the theory completely symmetrical in all the heavy particles (protons and neutrons). A definite prescription can then be given for computing the matrix element in terms of nuclear eigenfunctions of proper symmetry which differs slightly from what one would expect from elementary considerations. The magnitude of the matrix element will be of the order unity (as hitherto generally assumed for allowed transitions) only if there is just one surplus neutron which goes over into a proton (and *vice versa*) and if the initial and final states of the nucleus contain the same configurations, or corresponding ones if a spin dependent transformation operator is chosen. With the coupling schemes proposed at present the latter case seems to be indicated for light nuclei. If the numbers of neutrons and protons differ by more than one, the matrix element will be smaller, which explains the difference in lifetime for light and heavy β-emitters.

36. On the Non-Association of Photoconductivity with Optical Absorption in Non-Conducting Crystals. CLARENCE ZENER, *Washington University, St. Louis, Mo.*—While all the electrical and magnetic properties of a metal may be qualitatively understood by the use solely of Bloch wave functions, it is generally recognized that the strongly peaked absorption spectra of the alkali halides is due to excited atomic states. The perturbation method, which has heretofore been used exclusively, does not give definite information when the perturbations are as large as they are at the actual lattice spacing. Two new methods of approach are here used to study the electrical properties of insulators. Both methods start from the basic property of an insulator, the ability to support an electric field. The first method uses the variation principle to show that in the lowest excited state of an insulator, the negative electron in the excited band is bound to the positive hole in the lower band. The second method solves exactly an idealized model of an insulator crystal with one impurity atom. The excited Bloch energy bands, as viewed by the valence electrons of the impurity atom, have a dip in the region of the impurity ion. Both methods come to the conclusion that in insulators photoconductivity is not associated with the long wave-length edge of the first absorption band.

37. Magnetic Deflection of HD Molecules. I. ESTERMANN, O. C. SIMPSON, AND O. STERN, *Carnegie Institute of Technology.*—The magnetic deflection of molecular beams of HD (kindly furnished by Dr. Brickwedde) has been investigated by the same method previously used for H_2[1] and D_2.[2] The HD differs from H_2 and D_2 by the absence of molecules with zero moment. This makes the weakening by the magnetic field at the position of the undeflected beam very effective. This weakening is nearly independent of the magnetic moment of the deuteron and of the rotational magnetic moment, but very sensitive to the moment of the proton, much more than in the case of ordinary hydrogen. The influence of the distortion of the Maxwell-distribution has been eliminated by extrapolation to zero pressure. The accuracy of the value for the proton moment is now limited only by the accuracy of the field measurement.

[1] Frisch and Stern, Zeits. f. Physik **85**, 4 (1933); Estermann and Stern, Zeits. f. Physik **85**, 17 (1933).
[2] Estermann and Stern, Zeits. f. Physik **86**, 132 (1933); Phys. Rev. **45**, 761 (1934).

38. A Stern-Gerlach Magnetic Field as a Velocity Analyzer for Atomic Beams. ALEXANDER ELLETT AND VICTOR W. COHEN, *State University of Iowa.*—A detailed examination has been made of the deflection pattern of a beam of alkali atoms traversing an inhomogeneous magnetic field with view of determining the constancy of the gradient and the validity of the Maxwell distribution. The displacement of an atom after traversing the field will be

$$s\sim(1/mv^2)\mu(\partial H/\partial s).$$

Consequently if the gradient is constant, sv^2 will be constant. If one assumes a Maxwell distribution, one can evaluate, through graphical integration of the deflection pattern, the distance which atoms of arbitrary velocity have been deflected. The results with the beam suitably defined show that sv is constant to better than 1 percent. Conversely, if one assumes the gradient to be constant, one may use the formula of Stern[1]

$$I(s)=\frac{I_o}{2}\left[e^{-y}(y+1)\right]_{s\alpha(s-a)}^{s\alpha(s+a)}$$

to calculate the intensity distribution in the deflected beam. The results show excellent agreement in form for oven vapor pressures from 0.002 to 0.04 mm Hg and a marked deviation setting in at 0.13 mm.

[1] Stern, Zeits. f. Physik **41**, 563 (1927).

39. Velocity Analysis of K Atoms Scattered by a MgO Crystal. VICTOR W. COHEN AND ALEXANDER ELLETT, *State University of Iowa.*—A beam of neutral potassium atoms with approximately thermal velocities characteristic of the temperature of the source is directed toward a MgO crystal. The consequent scattering is adequately described by the cosine law; neither specular reflection nor any evidence of diffraction is observed. Those atoms scattered at right angles to the initial direction are passed through the magnetic analyzer described in the preceding paper. The results show that within the limits of error the velocity distribution is Maxwellian and characteristic of the temperature of the crystal. That is, the accommodation coefficient is almost unity. In the course of the experiment the source was maintained at a temperature of about 615°K, while the crystal temperature was varied from 440 to 800°K. The process is, therefore, probably one of adsorption and reevaporation, with the adsorbed atoms attaining thermal equilibrium with the crystal surface. The MgO crystals used in this work were furnished through the courtesy of the Norton Co. of Worcester, Mass.

40. An Elementary Constant of Energy. ARTHUR HAAS, *University of Notre Dame.*—The red-shift exhibited by extra-galactic nebulae can be described by the formula (1) $\Delta\nu/\nu=T/T^*$ where $\Delta\nu$ means the diminution of the frequency of a photon in a time T, whereas T^* means a period of 1700 million years. Therefore (2) $1/T^*=1.8\times10^{-17}$ sec.$^{-1}$. The product of the elementary quantum of action (h) and $1/T^*$ represents a universal constant of the dimensions of energy. We find for this constant, which might be called the primordial energy-element, (3) $w=1.2\times10^{-43}$ erg. If we denote the energy of the photon ($h\nu$) by ϵ, we may write Eq. (1) in the form (4) $\Delta\epsilon=w\nu T$. This means that every photon, independently of its wave-length, gives off a primordial energy element during each oscillation or in traveling one wave-length. There is in the universe, on the average, a quantity of radiant energy of about 3×10^{15} ergs, referred to one gram of matter.[1] The loss in radiant energy which is the consequence of the continual output of primordial energy elements would, therefore, be $3\times10^{15}\times1.8\times10^{-17}$ or about 0.1 erg per gram and sec. On the other hand, the energy produced by the stars and star-systems amounts also to about 0.1 erg per gram and sec.[1] The energy which is given off in the form of primordial energy elements might, therefore, be compensated by the energy production of the stars.

[1] Cf. A. Haas, *Die kosmologischen Probleme der Physik* (Akademische Verlagsgesellschaft, Leipzig, 1934).

41. Helium I Like Spectra. HOWARD A. ROBINSON, *Ohio State University.*—Measurements of the $1s^2\,{}^1S_0-1snp\,{}^1P_1$ series of the spectra He I, Li II, Be III, B IV, C V, N VI and O VII carried out on the new 5 meter grazing incidence spectrograph in Professor Siegbahn's Laboratory in Uppsala, Sweden, allow of accurate evaluations of the several ground states of these spectra. The Hylleraas extrapolation formula, changed slightly to include new calculations for Li II made by Mr. H. A. S. Eriksson of Uppsala, show remarkable agreement with these results when spin and relativity corrections are made. A small discrepancy appears in the case of Li II. This discrepancy undoubtedly arises from the approximate method of calculation of the final corrections.

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