Proceedings of the American Physical Society

MINUTES OF THE NEW YORK MEETING, FEBRUARY 24–25, 1933
JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

THE 183rd regular meeting of the American Physical Society was held in New York City on Friday and Saturday, February 24–25, 1933, as a joint meeting with the Optical Society of America. The presiding officers at the sessions of the Physical Society were Dr. Paul D. Foote, President of the Society, Professor Arthur H. Compton, Vice-president, Dr. Karl K. Darrow, Dr. W. E. Forsythe and Professor John Zeleny. All sessions were held at Columbia University in the Physics Laboratories.

The joint session with the Optical Society of America was held on Friday afternoon at two-thirty o'clock. This session was a symposium on "Electron Optics." The President of the Physical Society, Dr. Paul D. Foote, presided. The invited papers were as follows: *Electron Optics* by C. J. Davisson, Bell Telephone Laboratories, Inc.; *Diffraction of Low-Speed Electrons* by H. E. Farnsworth, Brown University; *A Lens for Cosmic-Ray Electrons* by W. F. G. Swann and W. E. Danforth, Jr., Bartol Research Foundation; and *On Electron Beams in High Vacuum* by Vladimir K. Zworykin, RCA Victor Company. The attendance at this symposium was about three hundred and fifty.

One hundred and sixty-five persons attended the luncheon at the Columbia University Faculty Club on Friday.

On Friday evening the Society joined with the Optical Society for dinner at the Hotel New Yorker. This dinner was attended by ninety guests. The President of the Optical Society, Dr. E. C. Crittenden, presided. The after dinner speakers were Dr. Paul D. Foote, Dr. L. B. Tuckerman and Professor Harold C. Urey.

Meeting of the Council. At its meeting on Friday, February 25, 1933, the Council elected thirty-three candidates to membership. *Elected to Membership:* Stanley S. Ballard, John F. Byrne, François Canac, Joseph F. Carroll, Lyman Chalkley, Jr., Don E. Davidson, Grant O. Gale, Max Goodrich, Cecil E. Haller, Sidon Harris, Sterling M. Heflin, N. P. Heydenburg, Roger W. Hickman, James L. Hoard, Waldo H. Kliever, John C. McDonald, D. M. Morandini, Wilson C. Morris, Harald Norinder, Austin J. O'Leary, Eugene W. Pike, Martin Rusch, Richard E. Smith, Hirsh W. Sulkowitch, Tikawo Tamura, Lauriston S. Taylor, C. Irwin Vigness, John P. Vinti, W. H. Wells, Benjamin F. Wissler, Robert C. Woods, Fumio Yamasaki and Walter H. Zinn.

The titles and abstracts of papers presented before the Optical Society of America will be found in the Proceedings of that Society, published in the Journal of the Optical Society.

The regular scientific program of the American Physical Society consisted of forty-three papers, numbers 29, 32, 33 and 37 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. Influence of the Dielectric Constant of the Medium on the Potential and Charge of a Protein Surface in a Liquid. HAROLD A. ABRAMSON, *Columbia University and* JANET DANIEL, *Harvard University.*—If the electric mobility of microscopically visible quartz particles covered with a film of adsorbed protein is studied in different concentrations of alcohol, it is possible to correlate the surface potential and surface charge calculated from these mobilities with the charge obtained by another (thermodynamic) method. The results indicate that the character-

ization by the two parameters viscosity and dielectric constant of the solvent in the Helmholtz-Debye theory is correct. This is in accord with the views of Frivold, Halpern, Gross and others who have investigated theoretically the effect of lowering the dielectric constant. The data are interpreted from the point of view of their biological importance particularly in connection with the problems of cell permeability.

2. A Vacuum Tube Instrument for Measuring Very Small Unidirectional Currents and Voltages. G. FAILLA, *Memorial Hospital, New York.*—In the "floating grid" vacuum tube device for measuring ionization currents, described by the author (Radiology, Oct. 1930), the current to be measured is "balanced" by another ionization current, whose magnitude is easily determinable. With such a device there is a lower limit for the magnitude of the current which can be detected, no matter how high the voltage producing the current may be. Similarly, there is a lower limit for detectable potential difference, irrespective of the magnitude of the current which the source might be able to produce. The current sensitivity of the device may be increased by charging a condenser for a certain time and then discharging it to the grid of the vacuum tube. The value of the current is determined by measuring directly the voltage to which the same condenser must be charged to give the same "ballistic" deflection of the plate circuit meter. The procedure for the measurements of small voltages is similar, except that the condenser capacity is decreased before discharging it to the grid.

3. A New High Tension Electrostatic Voltmeter. J. E. SHRADER, *Drexel Institute, Philadelphia.*—Several years ago the author devised an electrostatic voltmeter operating on the principle of electrostatic repulsion between stationary vanes and a set of vanes carried by a torsional suspension. The instrument was calibrated by observing with a lamp and scale the deflection of a spot of light from a mirror attached to the movable vane when known voltages were applied. This instrument proved quite reliable but had the disadvantage of not being self-contained. The present instrument is also quite reliable and is self-contained. The instrument consists of a movable plate hinged or held by a thin flat spring in a horizontal position parallel to a similar plate carried on the end of a rod carried by an insulating bushing inside a vessel containing transformer oil as an insulating medium. Upon the application of potential the movable plate will be repelled downward. Attached to the movable plate is a small glass rod extending horizontally to the extreme end of which is fastened a fairly strong silk string. This string extends upward and is wrapped about a small spindle and is held under tension by a light spiral spring at the top of the vessel. When repulsion between the vanes takes place the spindle is caused to rotate and the amount of rotation is indicated by the motion of a pointer on the end of the spindle and this motion on a circular scale is observed through a circular window on the instrument. The sensitivity is determined by the weight and stiffness of the movable vane, by the diameter of the spindle and the length of the pointer and by the stiffness of the controlling spring. For greater insulation the vessel is lined with insulating material such as fullerboard which serves as a baffle to prevent discharges to the grounded vessel.

4. High Voltage X-Ray Tube and Constant Potential Transformer Equipment. CYRUS A. POOLE AND W. S. WERNER, *Kelley Koett Mfg. Co., Covington, Kentucky.*—This is a preliminary report on the design, construction and operation of a porcelain insulated, grounded anode x-ray tube to operate at 800,000 volts constant potential. This is a hot cathode tube with water-cooled anode. A pressure of 10^{-5} or better is maintained by continuous pumping with a two-stage diffusion pump, backed by "Megavac" oil pump. Power is furnished to this tube by a Cascaded system of transformer units, with the condenser filtered La Tour circuit in each unit. The output is a constant potential direct current, having practically no ripple. Corona and secondary currents are discussed. Although high-voltage tubes have been operated at this potential before, none have been built prior to this to operate on constant potential direct current. Since all the energy is supplied at the peak voltage the output rays are comparable in frequency to gamma-rays and their intensity far exceeds the aggregate intensity of all available radium. In addition to this, the high-voltage power unit is of special interest since it can be utilized in other types of research where high voltage fields of this magnitude are required. Photographs, diagrams and characteristic measurements are presented.

5. A Balanced Receiving Circuit for Kennelly-Heaviside Layer Observations. HARRY R. MIMNO AND P. H. WANG, *Cruft Laboratory, Harvard University.*—In experiments on the effective height of the Kennelly-Heaviside layers, it is frequently desirable to place the receiving set near the transmitting apparatus. Unless precautions are taken, the direct radiation from the transmitting antenna will paralyze any receiving set which is sensitive enough to detect weak echoes. In previous experiments it has been customary to design the receiver so that it would recover as rapidly as possible from an overload. The resulting "stiffness" of the receiver has determined the resolving power of the apparatus. However, in a permanent laboratory installation it seems more logical to construct the transmitter and receiver as a duplex radiofrequency network which can respond to the reflected wave without any interference from the direct radiation. There are two convenient methods. The transmitting-set modulator may be used to vary the receiving-set gain, or the radio-frequency voltage induced in the receiving antenna may be balanced by an equal and opposite voltage obtained directly from the transmitter coils. By using the second method, successful results have been obtained with the receiving apparatus about four meters from the transmitter. Several types of receiving antennas have been employed directly under the transmitting antenna.

6. The Reflecting Layers of the Upper Atmosphere. R. C. COLWELL AND I. O. MYERS, *West Virginia University.*—During recent years it has been shown by Appleton (and others) that there are two ionized layers in

the upper atmosphere, one of which the lower (*E* layer) reflects waves above 100 meters, but is penetrated by shorter waves. The shorter waves are reflected from the upper (or *F*) layer. During the past autumn simultaneous observations were made upon the short wave from station W8XK (6140 kc) and the long wave from KDKA (980 kc). Both stations are located at Saxonburg, Pa. The fading curves obtained were plotted upon maps of the United States Department of Agriculture Weather Bureau. It is seen at once that the signal strength of the long waves varies after nightfall according to the change in barometric pressure. While the short waves have the same characteristic curve regardless of the weather. This indicates that the *E* layer is in the region connected with the varying pressures while the *F* layer is unaffected. The *F* (Appleton) layer covers the sky in a more or less uniform sheet, while the *E* (Kennelly-Heaviside) layer is concentrated in the regions of low pressure and is most active in the eastern half of the cyclone.

7. Absorption and Scattering of Neutrons. J. R. DUNNING AND G. B. PEGRAM, *Columbia University.*—The source of neutrons was beryllium powder in a glass bulb containing radon. The neutrons emitted from the beryllium under the alpha-particle bombardment were detected through the sudden ionizations produced by single recoil atoms in the ionization chamber of a vaccum tube detection apparatus that responds linearly to sudden increases of current but is little affected by the large but comparatively steady ionization caused by gamma-rays (see abstract December, 1932, meeting). With 400 millicuries of radon in the source 30 cm from the ionization chamber, about 20 neutrons per minute were recorded. Gross absorption curves were taken for lead, paraffin, water and aluminum. Paraffin and water show an absorption of the same order of magnitude as lead, per cm thickness. An absorbing cylinder of lead 20 cm long, 2.5 cm diameter cuts down to one-sixth the number of neutrons recorded, but there is evidence that some of the residual neutrons are neutrons scattered by surrounding objects. A large scattering by water is shown when, with a lead cylinder between source and ionization chamber, water is placed alongside the cylinder. The number of neutrons scattered into the chamber by the water is then nearly equal to the number in the direct unshielded beam. Scattering from lead has also been observed.

8. Detection of the Ionization by Individual Cosmic Rays. W. F. G. SWANN, *Bartol Research Foundation of the Franklin Institute.*—A copper cylinder 15 cm long and 7.5 cm in diameter was filled to 4 atmospheres with argon. It was supplied with a collecting electrode connected to a F. P. 54 General Electric Pliotron, which operated an amplifier designed to record upon moving photographic paper, through the medium of a galvanometer of period 0.1 second. A potential of 1000 volts was applied to the copper cylinder through a filter, and the sensitivity and resolving time of the instrument was sufficient to bring out the records of the individual cosmic rays or groups. Two such systems were used, and were arranged so that the axes of the copper cylinders were vertical, and in line. The simultaneous occurrence of records of a cosmic ray by the two instruments was a guarantee that in those cases the effect was produced by a ray which had passed through both cylinders and was not due to an ordinary beta-particle. Those simultaneous kicks which were equal and which also had the maximum values represented rays, or groups, which had passed the full length of both cylinders. They afforded a means of determining the ionization per centimeter of path of the ray or group, which, subject to certain corrections to be provided for in a modified form of apparatus, and arising from the time of collection of the ions came out as about 200 ions per centimeter of path per atmosphere at 4 atmospheres.

9. The Angular Distribution of the Low Energy Cosmic Rays. THOMAS H. JOHNSON AND E. C. STEVENSON, *Bartol Research Foundation, Swarthmore, Pa.*—With three Geiger-Mueller counters as a telescope the angular distribution of the cosmic radiation has been measured both with and without a lead absorbing block (3.7 cm thick) inserted just above the lowest counter. The cross-sectional area of the lead was the same as that of the sensitive volumes of the counters so that scattering effects were, as far as possible, eliminated. The intensity of soft rays from any direction is given by the difference in counting rates with and without the lead and the angular distribution of these is at least as concentrated about the vertical direction as that of the rays which are not absorbed by the lead. If the absorbed rays are regarded as secondaries produced by the penetrating rays the results show that the secondary ray has the same direction as its primary ray. The experiments are being continued with other thicknesses of lead.

10. The Response of Barrier-Layer Photo-Cells to X-Rays. PAUL R. GLEASON, *Colgate University.*—A number of Weston Photronic cells and Tungsram Type S_1 cells have been compared under exposure to the general radiation of x-ray tubes operated up to 200 kv. Special attention had to be given to the shielding of the cells and connections as electrostatic surges easily break down the contacts at the thin metallic electrode. The response of a single cell is not proportional to that of a standard ionization chamber exposed to the same radiation. In the region studied, the cells seem most sensitive at about 0.22A effective wave-length, falling off nearly 40 percent at the shortest wave-lengths. A combination of two cells with suitable filters was in agreement with the standard ionization chamber to within 10 percent until effective wave-length 0.17A was reached, failing by about 25 percent at shorter wave-lengths. The photronic cells average 1.2 microamperes when x-rays are incident of one roentgen per second. Two cells having equal sensitivities to light do not necessarily show the same response to x-rays. At a given temperature, the voltage-current characteristic curve is independent of whether light or x-rays are exciting it. The lag in response to x-rays is quite significant, particularly with the more penetrating rays. Some 15 seconds are required on the

average as compared with six seconds for the same deflection with the same galvanometer under exposure to light.

11. Variation of Photoelectric Efficiency with Work Function in the Extreme Ultraviolet. CARL KENTY, *General Electric Vapor Lamp Company, Hoboken, N. J.*—The following table shows the relative magnitudes (for each gas) of the approximate saturation currents obtained from a W surface treated in various ways when exposed to the full radiation from a 100 m.a. positive column discharge in He, Ne, or A at 0.5 mm pressure. Evidence that currents similar to these are mainly caused by the photoelectric

Surface	Work Function (volts)	He	Ne	A
W−O	>6.7	100	100	90
W	4.9	78	68	100
Mg(*A*)	3.7	39	12	60
Mg(*B*)	<3.0	22		

action of the resonance radiations concerned have already been reported (C. Kenty, Phys. Rev. **43**, 18 (1933) and **38**, 377L (1931)). In the table W−O refers to oxidized tungsten, W, to tungsten degassed by heating repeatedly in vacuum to 2000°K, Mg(*A*) to an evaporated Mg layer slightly contaminated with gas and Mg(*B*) to a relatively clean Mg surface. The work functions were located approximately in each case by the method of filters with a quartz Hg lamp as source. Regarding the actual magnitudes of the photoelectric efficiencies concerned, values of 1–5 electrons per 100 quanta, depending on the gas and cleanliness of the surface (Ni) have already been reported (C. Kenty, Phys. Rev. **38**, 2079L (1931)); these measurements are being extended to W and other surfaces.

12. Action of Mercury Metastable Atoms on Metal Surfaces. S. SONKIN AND HAROLD W. WEBB, *Columbia University.*—Mercury atoms were excited to the 2^3P_0 metastable state by electron impact, and the electron emission produced by these atoms when they struck the metal surfaces under test was measured. When the experimental tube and electrodes were thoroughly baked and outgassed different metals were found to give very nearly the same response to mercury metastable atoms. The sensitivity of any surface that was thoroughly outgassed was found to have a stable value to which it invariably returned after temporary changes which followed heating of the surface. Detailed investigation of such changes in response for a tungsten surface, with different mercury vapor pressures, showed that the presence of mercury atoms was essential for the formation of the sensitive surface and that this surface probably consisted of a layer of mercury atoms. There is evidence also that oxygen atoms play an important part in the formation of this surface and together with the mercury atoms form a complex but stable arrangement giving a very constant sensitivity to mercury metastable atoms. Under certain critical conditions very large transient values of sensitivity were observed. No correlation between the sensitivity to metastable atoms and the photoelectric response was found.

13. Dissociation Products of Carbon Monoxide Formed by Primary Electron Impact. W. WALLACE LOZIER, *National Research Fellow, Princeton University.*—The atomic ions produced by electrons passing through carbon monoxide at low pressures have been studied in an experimental tube similar to that described by Tate and Lozier (Phys. Rev. **39**, 254 (1932)). This new apparatus was constructed of tantalum, tungsten, and glass. The experimental pressure of CO used was 3×10^{-5} mm Hg and the electron current was 10^{-7} amp. O^- and C^+ ions both appear as primary products of electron impact. The O^- ions first appear at an electron energy of 9.5 ± 0.1 volts electron energy. Their ionization current when plotted against electron energy yields a sharp peak 1.2 volts wide at half-maximum. At 20.9 ± 0.1 volts electron energy O^- ions again appear, accompanied by equal numbers of C^+ ions. At 22.8 ± 0.1 volts electron energy the production of C^+ ions increases very markedly; this increase is unaccompanied by a like one in the production of negative ions. The ions mentioned above possess kinetic energies ranging from zero up to several volts. Interpretations of these results will be attempted.

14. Ionization of Argon, Neon and Helium by A, Ne and He Atoms. CHARLES J. BRASEFIELD, *Yale University.*—The ionization of argon, neon and helium under impact of A, Ne and He atoms was investigated by a method which eliminated errors due to secondary electrons. When argon, neon and helium were bombarded with their own atoms, ionization was found to set in at approximately 100 equivalent volts in each case. When either of these three rare gases was bombarded with atoms of the other two, no ionization could be detected, at least below 150 equivalent volts.

15. Magnetic Focussing Method for the Angular Distribution of Electrons after Elastic and Inelastic Collisions with Gases. A. P. GAGGE, *Yale University.* (*Introduced by John Zeleny.*)—A new method is described for studying the angular distribution of electrons after elastic and inelastic collisions in gases. The whole apparatus is placed in a uniform magnetic field. The primary electron beam is accelerated from a heated filament to a coaxial cylinder and passes through two slits into the scattering region. The filament, slits, and scattering region all lie on a circle, which may be rotated about an axis through the scattering region. The scattered electrons are focussed, as in a β-ray spectroscope, and enter the narrow opening of a movable Faraday collector. The fixed slit subtends a small angle at the scattering region and so defines the scattered direction. The various velocities of the scattered electrons are selected by moving the collector along the locus of foci. This arrangement has two advantages over the previous methods for angular distribution study. Since all electronic paths are circular, the angular distribution may be

studied completely to 180°. Secondly, since the collected beams are limited by only one slit and are magnetically focussed, the intensity of the collected beam is more efficiently preserved. For this reason the method is especially suitable for studying the elastic and inelastic collisions of slow electrons. Distribution curves for mercury vapor are shown.

16. Small-Angle Inelastic Scattering of Electrons in Helium, Mercury and Hydrogen. S. N. VAN VOORHIS, *Princeton University. (Introduced by G. P. Harnwell.)*—The variation of inelastic scattering with angle has been measured for electrons of from 100 to 300 volts energy, and for angles of from 0° to about 15° scattering. In helium the 21.1 volt loss ($1^1S_0-2^1P_1$) was used; in mercury, the 6.7 volt loss, and in hydrogen, a most probable loss of 12.6 volts was used. An electrostatic analyzer separated those electrons which had suffered energy loss, permitting readings to be taken without disturbance by the large number of unscattered electrons. A decided decrease in scattering at very small angles is found in all three cases, the maximum scattering *per unit solid angle* occurring at angles of from 2° to 6° depending on the energy of the electrons and the scattering substance. It is also found that all scattering curves for one gas are superposable if plotted against the product of the energy of the electrons and the angle of scattering, as abscissa. The data cannot be fitted nearly as well by use of the quantity $(k_0^2+k_1^2-2k_0k_1\cos\theta)^{\frac{1}{2}}$ given by the simple Born theory as abscissa.

17. The Diffraction of Electrons by Single Molecules. LOUIS R. MAXWELL, M. E. JEFFERSON AND V. M. MOSLEY, *Bureau of Chemistry and Soils, Washington, D. C.*—Diffraction photographs have been obtained for electrons (20–40 kv) scattered by the vapors of carbon tetrachloride (CCl_4), iodine (I_2), and 1,4-diiodobenzene ($C_6H_4I_2$). The following results have been interpreted by the use of the Debye scattering formula developed for coherent scattering of x-rays from polyatomic gases, together with the application of the theory of Mott and Bethe for elastic electron scattering by monatomic gases: (1) Carbon tetrachloride; the first three diffraction rings were measured and the corresponding values of $(1/\lambda)\sin\frac{1}{2}\theta$ were found to be 0.197, 0.364, and 0.548, corresponding to 2.98A as the Cl−Cl distance. These results are in good agreement with previous electron diffraction data obtained by R. Wierl (Ann. d. Physik **8**, 521 (1931)). (2) Iodine; for this molecule the I−I separation was found to be 2.64A, in agreement with 2.66A computed from band spectra data (W. G. Brown, Rev. Mod. Phys. **4**, 83 (1932) by Mulliken), and also with 2.70A the distance obtained from the structure analysis of crystalline iodine by x-ray diffraction. (P. M. Harris, E. Mack, Jr., and F. C. Blake, J.A.C.S. **50**, 1583 (1928); (3) 1,4-diiodobenzene; the computed scattering formula predicts the appearance of a maximum at about $(1/\lambda)\sin\frac{1}{2}\theta=0.22$. This diffraction ring was very prominent on the photographic plates and was used primarily for determining the I−I separation. The distance obtained was 6.85A±0.10. From an x-ray determination of the crystalline structure S. B. Hendricks has also obtained 6.85±0.10 for the I−I distance. In this case as well as for iodine it is seen that the intermolecular distances are the same in the solid and vapor phases.

18. Diffraction of Electrons by Metal Surfaces. L. H. GERMER, *Bell Telephone Laboratories, New York City.*—Fast electrons are scattered from a metal surface ruled with parallel scratches. An excellent diffraction pattern is produced (characteristic of the metal) when the scratches lie normal to the plane of incidence of the electrons. Only an extremely weak pattern is obtained with the scratches parallel to the plane of incidence. This experiment confirms directly the theory of G. P. Thomson that the diffraction of electrons from a massive polycrystalline surface results from the transmission of the electrons through little mounds of material projecting from the surface. It does not, however, confirm his view that the failure of polished surfaces to give diffraction patterns is due to the existence of a surface layer of amorphous metal. Further evidence against the amorphous layer theory has been obtained by scattering electrons from the surfaces of drawn wires. A wire drawn through a good die gives no diffraction pattern. Wires drawn through a broken die have minute fins projecting from their surfaces, caused by the forcing of metal into the cracks of the die. Such wires sometimes give complete diffraction patterns extending into the shadow of the wire. These must certainly be produced by transmission through severely worked material which is still crystalline.

19. Electron Optics. C. J. DAVISSON, *Bell Telephone Laboratories, Inc.*—The term "electron optics" is used to designate the theory and practice of focussing beams of electrons by electric and magnetic fields. Interest in this subject—by no means a new one—has increased greatly during the last few years. In 1926 Brusch showed by calculation and demonstrated by experiment that the field of a short circular coil magnet has for electrons of a given speed the properties of a positive lens of definite and calculable focal length. The possibilities of electron optical systems in which this type of lens is employed have been explored recently by Ruska and Knoll. Sharply defined images of stencils have been produced and magnifications up to 400 times have been obtained. Images of emitting surfaces also have been formed by these experimenters. The magnetic lens systems is not so well adapted to projection of this kind, however, as the purely electrical system. In this the "lenses" are the distorted fields about apertures in charged electrodes. Brüche and Johannson have demonstrated the important possibilities of this type of system in portraying the "brightness" patterns of emitting surfaces. Our interest in this subject in the Bell Telephone Laboratories has been primarily in the production of beams of electrons of prescribed characteristics—in improvement of the so-called "electron gun" as a collimator. A theory of electron optical systems of the electrical type has been developed. Its usefulness for purposes of electron optical design has been demonstrated in numerous tests. (Invited paper.)

20. Diffraction of Low-Speed Electrons. H. E. FARNSWORTH, *Brown University.*—Experiments with low-speed electrons have shown many deviations from the results to be expected on the basis of de Broglie's original relation. These deviations exist for normal incidence as well as for glancing angles of incidence used in the Bragg method, and may appear as a secondary or fine structure of the main diffraction beams. The relative intensities of the various components are extremely sensitive to small changes in the angle of incidence. This results in large variations of the relative integrated intensities of the main diffraction beams with small changes in angle of incidence. It thus appears that an understanding of the phenomenon should contain information on still obscure points in the present view of the solid state, such as the concept of an average inner potential, deviations from such an average value, and interaction between electrons in crystals. The following further experiments have been undertaken to determine possible surface effects, and in particular the "surface action" considered by v. Laue. (1) A study of the characteristics of a thin film of one metal deposited by evaporation on a single crystal of another metal. (2) Investigation of reflection from opposite sides of a given set of atomic planes when using primary electrons which enter different faces of the same crystal in the two cases. The first experiment shows that the fine structure characteristics for the film are essentially the same as those for a massive crystal of the same metal, and thus eliminates surface irregularities as a possible cause of fine structure differences. The second experiment indicates that there is an unsymmetrical reflection from opposite sides of an atomic plane, and appears to have a significant bearing on the interpretation of the fine structure. (Invited paper.)

21. A Lens for Cosmic-Ray Electrons. W. F. G. SWANN AND W. E. DANFORTH, JR., *Bartol Research Foundation of the Franklin Institute.*—The design involves the use of two vertical concentric tubes between which a potential difference is maintained. Along the axis of the tube two counters are placed, one above and the other below. It is then possible to focus the rays passing through one counter so as to pass through the other. The main features of the apparatus lie in the design of the tube. The fact that the field decreases with the distance from the axis, whereas in order to produce focussing it would have to increase, necessitates a compensation produced by causing the rays which are required to be bent through the greater angle to traverse a longer path than the others. The desired result is secured by flaring the ends of the tubes in such a manner that the different rays enter the field and also leave it at different points. The portions of the tube between the end flares have to be properly formed in order that the rays shall not be lost by passing through the walls. The characteristics may be described as follows. The tube system is one meter long. The distance between the two tubes is of the order of one centimeter, but varies along the length. The mean radius is five centimeters, at the entrance end. 10^8 volt-electrons passing through a point one meter above the upper end of the tubes would be focussed to a point one meter below the lower end, by a potential difference of 100,000 volts between the two cylinders. A ring counter is placed at the entrance end of the tubes, so that the rays which are recorded are those which pass through the ring counter and the conjugate foci. With the conditions cited, about five counts per day would be expected if all of the corpuscular rays had 10^8 volts velocity. A test of the two counters together with the circular counter in the absence of the cylinders should of course reveal a number of accidental counts sufficiently small to avoid masking the main effect. A preliminary test has indicated only one count in thirty-six hours with this arrangement. If the linear dimensions of the apparatus be increased certain advantages are gained. The field necessary to produce focussing of rays of assigned energy diminishes inversely in proportion to the linear dimensions, so that with an apparatus extending over a length of thirty meters, a field strength of 15,000 volts per centimeter may be utilized and the apparatus can be used in air. The principal advantage, however, is gained in an increase in the number of rays which can be obtained. Increase of the linear dimension in a constant ratio does not increase the solid angle but it does increase the area permissible for the initial counter. With a system thirty meters long, the counts can be increased to such an extent as will permit 500 counts per day and provide a source of radiation of convenient strength for use in experiments. By increasing the maximum field between the tubes to 20,000 volts per centimeter, which is permissible, the distance between the counters may be shortened to about 20 meters, which is a distance attainable without very much difficulty. This would increase the number of counts. (Invited paper.)

22. On Electron Beams in High Vacuum. VLADIMIR K. ZWORYKIN, *Research Division, RCA Victor Company, Camden, N. J.*—In order to concentrate a beam of electrons into a high intensity, sharply defined bundle, various methods have been used. The concentration of electron beams in high vacuum depends entirely upon fields of force, either electric or magnetic, while in low vacuum or in rarefied rare gas it depends also upon the action of gas molecules. In high vacuum the fields of force act upon the electron beam similar to the action of lenses upon a beam of light. An improperly shaped field produces effects similar to spherical aberration in poorly corrected lenses; non-uniform velocity of electrons in the beam results in effects similar to chromatic aberration of light. This optical analogy is not perfect. In the case of the electron beam the velocity varies continuously throughout most of the path and indices of refraction employed usually are greater than in the optical case. Moreover, space charge in beams of high intensity limits the concentration attainable: consequently, even theoretically, an electron beam can never be brought to a mathematical point as in the case of light optics. Other secondary effects are described. In focussing electron beams, both electrostatic and electromagnetic methods have been used extensively. The electrostatic method, however, seems to be preferable, especially when the beam is to be deflected. Precautions should be taken not to destroy the focussing of the beam during deflection. A

list of references on the subject is given at the end of the paper. (Invited paper.)

23. The Decomposition of Ozone. ARTHUR W. EWELL, *Worcester Polytechnic Institute.*—Warburg and later Clement studied the decomposition of ozone in the absence of oxidizable material, water vapor and catalytic agents. They found the reaction to be $2O_3=3O_2$ or bimolecular and that the velocity constant at 16°C was of the order of 10^{-10}, the concentration being expressed in parts per million by volume and the time in minutes—thus making ozone relatively stable under these conditions. The writer has studied the decomposition of ozone under the various conditions of its extensive use in purifying air in cold storage plants, air conditioning, etc. Under these practical conditions the reaction is monomolecular, $O_3=O_2+O$, and very closely follows the equation $dc/dt=-kc$. The value of k varies from 0.01 to 0.1, corresponding to half disappearance in from 69 to 6.9 minutes. Experimental observations of the concentration, c, at different times, t, confirm the two equations $c=C(1-e^{-kt})$ and $c=Ce^{-kt'}$ where C is the final equilibrium concentration, t the time after the supply $m=kC$ per minute starts, and t' the time after the supply of ozone is cut off.

24. A Logarithmic Protractor. H. J. YEARIAN, *Purdue University.*—An instrument has been designed to rapidly transpose microphotometer records to blackening, according to the relation: $S=\log(i_0/i)=\log(d_0/d)$ where i_0 is the incident and i the transmitted intensity, d_0 and d the corresponding photometer deflections. To a vertical axle mounted on a parallel ruler, is fixed a drum and a brass template cut according to the curve $\log\rho=a\theta$. A cable passing around the drum moves a plotting pencil along the ruler as the template and drum are turned. A zero line is placed parallel to the ruler and passing through the axis of drum and template. In use, as the axis of the instrument is run along the zero line of the record to be transposed, the template is turned to keep its edge in coincidence with the record and the zero line of the instrument. The pencil then plots the logarithm of the microphotometer deflection, and the distance between the plotted curve and the plotted position of d_0 is a measure of the blackening. The instrument has been found exceedingly useful and could be adapted to transposition according to almost any single valued function of the type $f(\rho)=a\theta$, within reasonable limits of ρ and θ.

25. A Note on Photographic Intensity Measurement in the Schumann Region. EDWIN G. SCHNEIDER, *Harvard University.*—The object of the experiment was to measure the transmission of a piece of optical fluorite for a series of wave-lengths between 1250 and 1600A by a photographic method. The light from a direct-current hydrogen discharge entered a vacuum spectrograph and was recorded on a Cramer Contrast plate sensitized with a ten percent solution of Cenco Pump Oil 11021-C in petroleum ether. It was necessary to assume the reciprocity relation to deduce the transmission from the relative times of exposure. This assumption is held to be valid in view of the work of G. R. Harrison (J. Opt. Soc. Am. **11**, 341 and **20**, 313) for the plate and oil chosen. The greatest source of random error was probably the irregularity of the plate grain. Ten determinations of each point on the wave-length transmission curve were made; the error of location of each point is of the order of magnitude of three percent. The results agree with those obtained by W. M. Powell photoelectrically within the limit of error. The same piece of fluorite was used in comparing the two methods of measurement.

26. Intensity Measurements Between 1650A and 1240A with a Photoelectric Cell. W. M. POWELL, *Harvard University.*—The source is a hydrogen discharge tube with a 3 mm water-cooled quartz capillary fed by 800 volts and 1 ampere d.c. A vacuum grating spectrograph is used as a monochromator to shine light into a photographic cell with a fluorite window. The grating, of 1 meter radius and 15,000 lines to the inch, can be turned and the slit in front of the cell can be focussed from outside. The photoelectric surface is platinum. The cell contains argon at 7 mm pressure. Voltages from 250 to 450 are used for varying the sensitivity. Currents from 10^{-9} to 10^{-10} amperes with slit widths of 0.05 mm are measured by a Compton electrometer, and a 3×10^{-10} ohms resistance to ground. The absorption of pieces of fluorite of different thicknesses have been measured. It appears that the surfaces are very sensitive to polishing. Chemically precipitated fluorite powder and water on silk on a piece of glass produces the best results so far. The accuracy of measurement is of the order of 1.5%. The resolving power is about 1.5 Angstroms.

27. Improvements in the Mechanical Interval Sorter for Complex Spectra. GEORGE R. HARRISON, *Massachusetts Institute of Technology.* The spectrum interval sorter recently described (R.S.I. **3**, 753 (1932)) has been improved so that greater wave-number separations can be recorded without increased error due to irregular tape stretch. 35 mm paper tape with perforated edges is used with a sprocket wheel device which prevents transmission of forces along the tape beyond the one meter lengths which are being recorded. By the use of formulas for the probability of any number of accidental coincidences, and by analysis of a number of different types of complex spectra which have already been worked out, one can arrive at a set of optimum conditions for making apparent the atomic energy levels by application of the combination principle. In most cases it is best to divide the spectrum up into groups of lines according to intensity or some other characteristic and to compare the records obtained with the various groups, rather than to use all the lines at once. The machine is now being used in the analysis of certain rare earths and complex hot spark spectra.

28. Transmission Band of Alkali Metals in Ultraviolet. R. W. WOOD, *Johns Hopkins University.*—The high transparency of sodium and potassium films deposited on the inner surface of quartz bulbs at liquid air temperatures was described by the author in 1919 (Phil. Mag.). The matter has now been more fully investigated. Lithium is highly

transparent in the region below 1800A, sodium at 1900A, potassium at 2800A, rubidium at 3100A and caesium at 4300A. A film of the latter metal transmits a blue color as pure as that exhibited by dense cobalt glass or a strong solution of cuprammonium. A technique has been developed of making durable films for use as ray filters, and quantitative measurements of the transmission in various spectral regions have been made.

29. Internal Resonance in the CO Molecule. G. H. DIEKE, *The Johns Hopkins University.*—The initial state ($^3\Sigma$) of the third positive CO bands shows some perturbations of very remarkable characteristics. The deviations from the simple quadratic formula show for the ten observed perturbations the characteristic form of resonance curves. The energies show, however, a constant displacement of roughly 25 cm^{-1} after each perturbation. Such behavior must be expected if the nondiagonal elements in the perturbation matrix of two levels is proportional to J. As all three triplet components are affected in the same way the perturbing term must be also a $^3\Sigma$-level. The only known term of the CO molecule which satisfies all the requirements is the initial $^3\Sigma$-state of the far red bands. The successive perturbations are then caused by successive high vibrational states of this level, which must have a much larger moment of inertia. The perturbations are larger than those usually found. The deviations in a single perturbation exceed 50 cm^{-1} and the cumulative effect of all ten perturbations is about 200 cm^{-1}. The intensities of the strongly perturbed lines are abnormally weak in all branches.

30. The Effect of Hyperfine Structure on Magnetic Depolarization of Resonance Radiation. ALLAN C. G. MITCHELL, *New York University.*—Breit [Rev. Modern Physics, (in press)] has derived formulae giving the polarization $P(H)$ and the angle of maximum polarization φ of a resonance line showing hyperfine structure, as a function of a weak magnetic field applied in the direction of observation of the resonance radiation. The formulae give a means of estimating the effect of hyperfine structure on the calculation of the mean life τ of an excited atom from experiments on the magnetic depolarization and rotation of the plane of polarization of resonance radiation. The calculation has been carried through for the case of the resonance line of Cd (λ 3261) and that of Hg (λ 2537), and it is found that the differences between the value of τ calculated using hyperfine structure data and that calculated from $\tan 2\varphi$ by the usual non-hyperfine structure method lie well within the experimental error. $P(H)/P_0$ is found to be practically the same taking into account or neglecting hyperfine structure. This is due to the fact that the greatest contribution to the polarization in these cases comes from the isotopes having no nuclear spin and the g-value for the upper state of these isotopes is larger than any other upper hyperfine structure state involved. The mean lives of the visible triplet in mercury are also discussed.

31. Zeeman Effect for Perturbed N_2^+ Terms. ALLAN E. PARKER, *Yale University.*—A study of the Zeeman effect for the N_2^+ bands has been made with plates taken at six different field strengths from 6000 to 27,000 gauss. The unperturbed bands show no Zeeman effect as is to be expected for a $^2\Sigma \rightarrow {}^2\Sigma$ transition having no appreciable spin-doubling. Zeeman patterns for the perturbed 1, 3 and 3, 5 bands are observed. The perturbation in the T_1' terms of the 1, 3 band reaches a maximum at $K'=13$ but does not vanish at higher K' values. Zeeman patterns were calculated from Hill's formula for $^2\Sigma$ states assuming as ν_0, the separations between the T_1 (perturbed) and T_2 (unperturbed) terms. Excellent agreement was found between the observed and computed patterns for $K'>14$. This is notable as the T_2' terms in the absence of the field show no perturbation and would be expected to show no change as a result of the magnetic field. Furthermore the T_2' terms for the K' values corresponding to the largest perturbation of the T_1' terms, give rise to doublets in the field as do the T_1' terms. Similar results are obtained for the 3, 5 band. A consideration of the interactions with the perturbing $^2\Pi$ state gives an explanation of these patterns.

32. Conservation Theorems in Quantum Mechanics. E. L. HILL, *University of Minnesota.*—The perturbation theory is generally developed from the energy equation alone. It is well known that this is but one of a set of quantization equations equal in number to the number of degrees of freedom of the system. If the perturbation function commutes with one or more of the corresponding auxiliary operators, the perturbation equations are separable into two or more unrelated groups implying conservation theorems for the associated dynamical variables. The general theory is easily written out. Application has been made to the theory of electron scattering by a given field of force in order to exhibit explicitly the conservation of angular momentum. This leads to a scattering formula expressed as a Fourier sum with the associated Legendre polynomials as basic functions.

33. Symmetry Properties and the Indistinguishability of Similar Particles. E. E. WITMER AND J. P. VINTI, *University of Pennsylvania.*—It has been shown by Heisenberg and Wigner that in a system of n similar particles, the wave functions fall into a number of non-combining sets with different symmetry properties. Of these it has been found empirically that for a given type of particle only those states occur whose wave functions are symmetrical in all the like particles or else antisymmetrical in all the like particles. The authors show that this result follows from the principle of the indistinguishability of similar particles as applied to the probability density $\psi\bar{\psi}$, which requires that $\psi\bar{\psi}$, being in concept a measurable quantity, shall be invariant with respect to any interchange of like particles.

34. A Modification of Brillouin's Unified Statistics. R. B. LINDSAY, *Brown University.*—Brillouin has proposed the statistical assumption that the capacity of a cell in phase space depends on the number of particles in it. The capacity of a cell with p occupants is $1-pa$ where a is a parameter. According as $a=0$, -1 or $+1$, one gets the

classical, Bose or Fermi distribution law. The present paper investigates the case where a is not restricted but allowed to vary between 0 and +1, corresponding physically to a loosening of the Fermi restriction while still allowing less freedom of occupancy than the classical theory. The resulting distribution law is $N_i = n_i/(a+e^{-\alpha+E_i/kT})$, where N_i is the number of particles in the i-th energy shell containing n_i cells. In applying this law to a degenerate electron gas it is found that: (1) the zero-point energy now becomes $3/10 \cdot Nh^2/m \cdot (3aN/8\pi V)^{2/3}$ in place of the Fermi value $3/10 \cdot Nh^2/m \cdot (3N/8\pi V)^{2/3}$; (2) the contribution of the free electrons to the specific heat of a metal is still negligible even if a is as small as 1/10; (3) there is now a zero-point entropy proportional to $\log a$; (4) the thermal and electrical conductivity expressions are modified, but the Wiedemann-Franz law is still satisfied; (5) the Thomson thermoelectric coefficient for $0<a<1$ is larger than on the Fermi statistics, corresponding to better experimental agreement in several cases.

35. Field Electron Currents from Liquid Mercury Surfaces. J. W. BEAMS, *University of Virginia.*—Surge potentials of about 10^{-6} sec. duration (circuit time constant 4×10^{-6} sec.) were applied between a 2 cm steel spherical anode and a liquid mercury cathode in vacuo and the breakdown fields observed. The liquid mercury cathode was cooled to a few degrees above its freezing point and part of the tube was surrounded with dry ice to lower the vapor pressure of the mercury. The mercury surface of the cathode could be changed or cleaned by "overflowing" in vacuo. Since the free path of an electron was very great in comparison to the distance between the electrodes and the potential was applied for only about 10^{-6} sec. the discharge was initiated by electrons pulled out of the liquid mercury cathode (See Hull and Burger, Phys. Rev. **31**, 1121 (1928) and Snoddy, Phys. Rev. **37**, 1678 (1931) for analogous cases with solid metal electrodes). The short time of application of the electric field also prevented appreciable distortion of the mercury surface by the forces arising from the field. The electric field at the cathode necessary to produce sufficient field electron current to start the discharge, varied with the purity of the mercury and the condition of the surface. In the case of some of the mercury surfaces, fields of 9×10^5 volts per cm were required to start the discharge.

36. Electron Flow in Large Direct Currents. ERNST WEBER, *Polytechnic Institute of Brooklyn, Brooklyn, New York.*—It is shown experimentally that the distribution of large direct currents, subjected to a steady magnetic field perpendicular to the axis of flow, is not uniform over the cross section of the conductor. The macroscopic field theory of Maxwell must be altered to account for the non-uniform flow of electrons in direct currents, and it is shown that, for an adequate theory, Maxwell's picture of a non-compressible liquid must be changed into that of a compressible gas. The theory given presents, therefore, a combination of electron theory and macro-field theory for the conduction of electricity through metals. A comparison of the data obtained from experiments, still in progress, with theoretical results will then yield a first approximate determination of the number of free electrons in the metal. The effect investigated, although related to, is distinctly different from, the Hall effect.

37. Actinouranium and the Geologic Time Scale. FORREST WESTERN AND ARTHUR RUARK, *University of Pittsburgh.*—The actinium series arises from a uranium isotope U^{235}, or from two such isotopes, U^{235} and U^{239}, genetically connected. From work of Hahn-Meitner the first possibility is almost certainly right. Its consequences are studied. Equations are derived for finding the decay constant λ^4 of U^{235} (actinouranium) from data on radioactive minerals. They also yield the decay constant, λ_1, of U I, and the mineral age. Four minerals are studied, using two values of the "branching ratio." Means from Karlshus bröggerite and Wilberforce uraninite are:

Branching ratio B:	0.03	0.04
λ^4	2.28 10^{-9} yr.$^{-1}$	1.79 10^{-9} yr.$^{-1}$
λ_1	0.1514	0.1509

Ages (insensitive to B): Karlshus, 0.81 10^9 yr.; Wilberforce, 1.04 10^9 yr. The effect of leaching is analyzed. Very early leaching does not affect age determinations. Very recent leaching does not affect isotopic constitution of radiogenic lead. Equations for *uniform* leaching are developed and applied to Katanga pitchblende: Results $\lambda^4 = 2.83\ 10^9$ yr.$^{-1}$; age, 0.55 10^9 yr. Using our mean λ^4, "age" of the Vesuvian lava of Piutti-Migliacci is 1.5 10^9 yr., assuming that its lead is a mixture of RaG, AcD, ThD, and common Pb in the proportions occurring in average igneous rock.

38. Measurement of the Range of Alpha-Particles from Thorium with the Wilson Chamber. F. N. D. KURIE AND G. D. KNOPF, *Yale University.*—The range of the α-particles from thorium has been measured by the methods used by one of the authors previously (Rev. Sci. Inst. 3, 655 (1932)). At 0°C and 760 mm the extrapolated number-distance range is 2.72 ± 0.03 cm. This range is derived from 300 tracks. It is pointed out that the great deviation of this range from that of Henderson and Nickerson (2.46 cm) is partially due to these authors' treatment of their data. The Geiger-Nuttall law is given according to the latest data for the uranium and thorium series in the form indicated by Gamow's theory.

39. The Unit Cell of Uranium Calculated from X-Ray Powder Method Data. THOMAS A. WILSON, *Union College, Schenectady.*—Photographs were supplied by Dr. W. P. Jesse, of the General Electric Research Laboratory which had been obtained by allowing unfiltered iron x-radiation to graze the surface of a block of uranium which had been rendered plane by filing in hydrogen. The uranium was of the highest purity obtainable. The block was rotated by hand in the x-ray camera. Exposure lasted $2\frac{3}{4}$ hours. The photographs showed 13 different plane reflections. By a mathematical analysis based on vectors, the equation for

the interplaner spacings of the parallelogram containing one uranium atom was found to be:

$$2.535^2/d^2 = h^2+k^2+l^2-0.878\ hk-0.758\ (h+k)l.$$

The unit cell of uranium accordingly has equal face perpendiculars of 2.535 Angstrom units in length, arranged in space at angles of 64°, 67° 45′, and 67° 45′ respectively. The volume of the cell is 20.26 cubic Angstrom units, which gives uranium an x-ray density of 19.32, as against 18.68 reported previously, a difference of 3.3 percent.

40. (a) **Raman Spectra Made with a Quartz High Potential Mercury Vacuum Tube (Hannovia Tube).** (b) **Exhibition of Phase-Reversal Zone-Plates Ruled on a Specially Constructed Machine.** R. W. Wood, *Johns Hopkins University.*

41. Related Figures on Circular Plates. R. C. Colwell, *West Virginia University.*—In 1850, Kirchhoff gave a complete mathematical solution for a vibrating circular plate with free edges. This solution in Bessel functions allows only for circles and diameters or combinations of these. When a plate is vibrated, however, many other figures are formed beside these mentioned above. A mathematical calculation shows that Kirchhoff's solution is complete but is for the simplest case only, corresponding to squares and rectangles on square plates. The proper combination of two Kirchhoff solutions will give the other figures. Photographic reproductions of certain families of curves will be shown.

42. Kowalewski's Top in Quantum Mechanics. Otto Laporte, *University of Michigan.*—It is well known that in classical mechanics algebraic integrals of the top equations only exist in the cases of Euler (asymmetric top, no electric moment), of Lagrange (symmetric top, electric moment parallel to the axis of figure) and of Kowalewski. The latter case is that of a symmetric top whose two equal moments of inertia are twice as large as the third ($A=B=2C$) with an electric moment perpendicular to the axis of figure. The quantum mechanical analogue to Euler's and Lagrange's cases being well known, Kowalewski's case was tried. If ϑ, φ, ψ are the Euler angles, $Q_{\mathrm{I}}=Q_1+iQ_2$, $Q_{\mathrm{II}}=Q_1-iQ_2$, linear combinations of the moment around the principal axes and

$$U=Q_{\mathrm{I}}^2+4CFe\cdot\sin\vartheta\exp(i\psi),$$

then Kowalewski's integral becomes:

$$UU^*+U^*U+4h^2(Q_{\mathrm{I}}Q_{\mathrm{II}}+Q_{\mathrm{II}}Q_{\mathrm{I}})=\text{const.},$$

which differs from the classical result by the symmetrization and by the last term proportional to h^2.

43. Non-unidirectional Emission of Hoffman's Stösse. W. F. G. Swann and C. G. Montgomery, *Bartol Research Foundation of the Franklin Institute.*—A piece of lead about 3″ thick and 30″ in diameter formed a central partition between the two halves of a large iron vessel 4′ high, containing nitrogen at 100 lbs. pressure. Two independent collecting electrode systems were provided for the top and bottom halves, so that the ionization in each could be independently measured. Each system was connected to an independent FP 54 pliotron system operating a short period galvanometer. The two galvanometers recorded simultaneously on a moving photographic record. Suitable means for compensation for average ionization current and for fluctuations of applied potential were employed. It was found that Stösse recorded themselves simultaneously in the two halves of the vessel, showing that the emission was not unidirectional. If the particles emitted were of electronic ionizing capacity, it would be necessary to suppose that at least 100 were emitted during each observation of Stösse. In order to provide further evidence, experiments were performed in which a counter system consisting of 3 sets of counters placed at different positions around the vessel were used, and arranged so as to discharge only if a ray went through each simultaneously. The probability that a ray would go through each of the counter sets with a total emission of 100 particles was less than unity, but in one out of two Stösse observed in this experiment a result was obtained indicating Stösse emission in each half accompanied by the record that the counters had simultaneously discharged.

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