Proceedings of the American Physical Society

MINUTES OF THE STANFORD, CALIFORNIA MEETING, JUNE 28–JULY 1, 1939

THE 229th regular meeting of the American Physical Society was held at Stanford University, California, on Wednesday, Thursday, Friday, and Saturday, June 28, 29, 30, and July 1, 1939.

Morning sessions were held on Thursday, Friday, and Saturday for the presentation of the 57 contributed papers abstracted below. The symposium on Wednesday afternoon, held jointly with the Astronomical Society of the Pacific, was concerned principally with the problem of limb darkening, and was addressed by C. D. Shane, Edison Pettit, A. B. Wyse, and E. M. McMillan. On Thursday afternoon a demonstration symposium on "Some New Ultra-High Frequency Radio Apparatus" was addressed by D. L. Webster, W. W. Hansen, and S. F. Varian. On Friday afternoon a symposium on "Methods and Results of X-Ray Structure Determination" was held, the speakers being M. L. Huggins, J. D. Bernal, and O. L. Sponsler.

Attendances ranged from about 50 to 230 persons.

PAUL KIRKPATRICK,
Local Secretary for the Pacific Coast

ABSTRACTS

1. Initial Recombination. N. E. BRADBURY, *Stanford University.*—In an attempt to determine the fraction of ions lost by recombination in an x-ray ionization chamber, a theory has been developed for the processes involved in preferential and initial ionic and electronic recombination. The theory considers the change of the energy distribution of the electrons as they diffuse away from the parent atom. From this together with a knowledge of the electron capture process, the space distribution of negative ions formed may be obtained. The probability of the initial electron recombining preferentially with the parent positive ion is considered as well as the preferential process for the negative ion. Knowing the initial spacing of the ions, it is possible to calculate the recombination occurring during the diffusion process until random distribution is reached. The final volume recombination may then be calculated in the usual manner. The theory may be employed in both electronegative and free electron gases and to ions formed in the presence or absence of an electric field.

2. Experiments on the Multiple Scattering of Electrons and Positrons. C. W. SHEPPARD AND W. A. FOWLER, *California Institute of Technology.*—Measurements on multiple scattering[1] have been continued in lead, aluminum and carbon foils of various thicknesses. The distribution in energy times scattering angle has been found to be Gaussian as predicted by the theory of E. J. Williams but with a smaller arithmetic mean angle than given by the theory. No difference in the scattering of positrons from that of electrons could be found within the experimental error. The results are contained in the following table:

SCATTERER	THICKNESS	NO. OF TRACKS	OBS. $\overline{W\alpha}$	THEO. $\overline{W\alpha}$
Lead	0.015 cm	362	45	106.0
Lead	.033	415	89	173.5
Aluminum	.102	423	46	64.0
Carbon	.114	401	38	42.7
Carbon	.330	252	57	75.7

W. A. Fowler, Phys. Rev. **54**, 773 (1938).

3. Energy Fluctuations in the Electromagnetic Field. P. MORRISON, *University of California.*—There is a well-known analogy between the quantized electromagnetic field and a system of Bose particles. This analogy is strict in the case of the total energy and momentum; the infinite zero-point energy of the field can be removed by introducing a term independent of the occupation numbers. But the energy localized in a small volume fluctuates even for a field containing no quanta in a way to which there is no particle analogue. These zero-point fluctuations arise from terms corresponding to the emission and absorption of two quanta. The zero-point energy fluctuations actually diverge for instantaneous measurements of energy. The effects of time averaging and of smearing the space-time boundaries of the defining region are examined. Various methods of measuring energy density are compared.

4. Conduction and Mobility of Thin Lead Films. M. G. FOSTER AND A. GOETZ, *California Institute of Technology.*—From measurements of electric conductivity made on thin films of Pb obtained by condensing the metal on cooled glass surfaces at rates from 5×10^{12} to 100×10^{12} atoms

sec.$^{-1}$ cm^{-2} under high vacuum conditions designed to eliminate contamination, the following results are obtained: The critical film thickness at which the (specific) conductivity of the metal begins changing rapidly from its low value (10^{-6} mho-cm^{-1}) in the thinnest films to that of the bulk metal (10^{+6} mho-cm^{-1}) is in the neighborhood of 60A for room temperature films and of 30A for films cooled with liquid air. The mutual configuration of the condensed Pb atoms changes with time as is shown by a decrease observed in the conductivity when the film was isolated from external influences, and by the eventual appearance of a granular structure visible under the ultramicroscope. In some cases a reproducible dependence of the conductivity on the applied potential was observed. These effects prove to be in harmony with the thermodynamic expectancy for the stability of such films (tendency toward aggregation) resulting in the removal of mobile atoms into crystallization centers, and thus in gaps which obstruct the conduction electrons. Certain deficiencies in quantitative reproducibility are ascribed to variations in the physical surface conditions on the glass plate.

5. Concentration of C^{13} and Measurement of its Nuclear Spin. CHARLES H. TOWNES, *California Institute of Technology.*—Heavy carbon was concentrated with a Hertz diffusion apparatus of 34 members to a maximum of 50 percent, and enough carbon at 30 to 40 percent concentration was obtained to make possible spectroscopic and nuclear disintegration work. The concentration was in two processes. Ordinary methane was let continuously through the light reservoir of a Hertz apparatus for the collection of a large quantity of gas containing 6 or 7 percent heavy methane, then this gas reintroduced into the system for a final concentration. From measurements on the $C^{13}-C^{13}$ band spectrum, the C^{13} nucleus obeys Fermi-Dirac statistics and apparently has a spin of 1/2. A 21-ft. grating and Lummer-Gehrke plate combined were used to resolve some of the close Λ-type doublets of the (O—O) band of the $C^{13}-C^{13}$ Swan system. Resolution was not complete, but was enough to determine the nuclear statistics and allow a good estimate of the spin from preliminary measurements. It is hoped that a microphotometric analysis will allow a conclusive measurement of the spin.

6. The Generation of Square-Wave Voltages at High Frequencies. W. H. FENN, *University of California (Introduced by L. C. Marshall).*—Two methods are described for the generation of high frequency alternating voltages having a square wave shape. The first method is based on a previously developed system utilizing an overloaded direct-coupled amplifier. The second method makes use of a special pulse generator followed by a vacuum-tube trigger circuit. Square waves are obtained with both methods at frequencies above 200 kilocycles per second. The applications of such square waves are considered, as well as the importance of the circuits for other purposes. Of special interest are the suggested improvements in conventional "scale-of-two" counting circuits and the description of the high-frequency pulsing circuit.

7. A Question in General Relativity. L. I. SCHIFF, *University of California.*—Professor J. R. Oppenheimer has suggested the following question: Consider two concentric spheres with equal and opposite total charges uniformly distributed over their surfaces. When the spheres are at rest, the electric and magnetic fields outside the spheres vanish. When the spheres are in uniform rotation about an axis through their center, the electric field outside vanishes, while the magnetic field does not. Suppose that the spheres are stationary; then an observer traveling in a circular orbit around the spheres should find no field, for since all of the components of the electromagnetic field tensor vanish in one coordinate system, they must vanish in all coordinate systems. On the other hand, the spheres are rotating with respect to this observer, and so he should experience a magnetic field. The resolution of this apparent paradox shows in an interesting manner how the warping of the metric caused by the rotation in the observer's coordinate system of the distant masses that determine our inertial frame introduces current-like terms into Maxwell's equations at the surfaces of the spheres. These just cancel the currents caused by the rotation of the spheres in this system.

8. The Contact Difference of Potential Between Silver Films on Glass and on Rocksalt. PAUL A. ANDERSON, *State College of Washington.*—Study of the structural dependence of the work function has been hampered by the experimental difficulties involved in preparing monocrystalline metal surfaces of known orientation which are free from mechanical deformation and atmospheric contamination. A new method of attack, suggested by Brück's observation[1] that certain metals when condensed on rocksalt cleavages form mosaics of crystals all oriented with their (100) planes parallel to NaCl (100), has been tested for silver films formed on rocksalt at 200°C in the measuring tube. Using methods of measurement previously described[2] and a tube which was intensively outgassed and gettered with barium, the contact P.D. between these films and polycrystalline silver surfaces of known work function,[2] formed on glass at room temperature, is found to be $0.12\pm.01$ v. Referred to a work function of 4.46 ev for Ag (glass), the work function of Ag (rocksalt) is then 4.58 ev. Since deviation of the Ag (rocksalt) films from the ideal structure would lower the contact P.D., 4.58 ev is to be regarded as a minimum value for the work function of Ag (100).

[1] Brück, Ann. d. Physik **26**, 233 (1936).
[2] P. A. Anderson, Phys. Rev. **49**, 320 (1936); **54**, 753 (1938).

9. About the Physical Nature of the Graininess of Photographic Emulsions. W. O. GOULD AND A. GOETZ (in collaboration with F. W. Brown, III), *California Institute of Technology.*—Measurements concerning the cause and nature of the graininess of photographic emulsions are described. They are obtained with the use of the graininess meter previously reported,[1] with particular reference to the definition of the graininess coefficient (G) as parameter of the Gaussian integral.

$$\left(\frac{.2}{\sqrt{\pi}\cdot G}\int_0^x e^{-(x/G)^2}dx;\ x=\Delta T/T_m.\right)$$

The G values vary for commercial emulsions between 30 and 150. The G density function $G(D)$ has a maximum for $D \leq 1.0$, which is in qualitative agreement with subjective graininess measurements (Lowry).[2] For a given emulsion the position of the maximum as well as dG/dD depends upon the aperture with which the emulsion is observed as the optical scattering power of the emulsion (Caillier coefficient) causes a dependence of the objective graininess upon the optics of the illuminating and observing system. The scattering power of different emulsions depends only upon the grain size (granularity). It increases nearly linear with $D(\leq 1)$ and is almost independent of the graininess. Effects of the superposition of the graininess of two different emulsions upon another are studied as they appear in the printing process. The printing factor $P=G_P/G_N$ has been determined for a number of emulsions and has been found to be smaller than 1 for small densities of the print and for closely identical gamma.

[1] A. Goetz and W. O. Gould, J. Soc. Mot. Pic. Eng. **24**, 510 (1937); W. O. Gould, A. Goetz and A. Dember, Phys. Rev. **54**, 240 (1938).
[2] E. M. Lowry, J. Opt. Soc. Am. **26**, 65 (1936).

10. A Note on the Wave Functions of the Relativistic Hydrogenic Atom. LEVERETT DAVIS, JR., *California Institute of Technology*.—It does not appear to have been noticed that the radial functions of Dirac's relativistic hydrogenic atom can be expressed in terms of generalized Laguerre polynomials. By using the known properties of these polynomials, it is easy to evaluate the normalization constants and to calculate the average value of r^q. The expressions for r^q involve the sum of three generalized hypergeometric functions of the type ${}_3F_2$ with unit argument. All results are obtained in closed form since the series terminate. It should be noted that while the properties of the generalized Laguerre polynomials[1] are well known to mathematicians, these functions are slightly different from the associated Laguerre polynomials ordinarily used in quantum mechanics.

[1] E. T. Copson, *Functions of a Complex Variable* (Oxford University Press, 1935), pp. 269–270.

11. A Low-Background Electron Counter. ROBERT R. WILSON AND DALE R. CORSON, *University of California*.—We have successfully applied Winkler's[1] arrangement to count weak beta-radioactive samples. The counter consists of a wire surrounded by a cylindrical electrode in which is a small hole that permits electrons to pass to a collecting plate. The radioactive wire is maintained at a negative potential with respect to the cylinder which is negative with respect to the plate, the voltages being just below corona onset. The whole arrangement is maintained at a pressure of one or two cm. The secondary electrons ejected from the surface of the wire by the beta-particles are multiplied by collision in the intense field near the wire. The electrons passing through the hole are further multiplied by collision in the field between the cylinder and plate. The total multiplication is of the order of 10^5 and the impulses are easily amplified to register on an oscillograph or mechanical counter. The background counting rate is low because of the small volume of the high field region around the wire. By using many holes in the cylinder the effective solid angle can be made to approach 4π. The method is applicable to substances which can be deposited on a wire, or which can be bombarded in wire form.

[1] Winkler, Zeits. f. Physik **107**, 235 (1937).

12. Growth of Droplets in an Expansion Chamber. R. M. LANGER, *California Institute of Technology*.—The temperature of the drop in a Wilson chamber at all times is essentially the temperature at which the drop has a vapor pressure equal to the partial pressure of the vapor in the chamber. This physical condition permits an approximate solution for the radius r of a drop in a fog of moderate density as a function of time t after expansion. The gas in the chamber is supposed to warm up to room temperature T after expansion x as $(1-e^{-\alpha t})$ and the fractional volume increase on expansion is supposed small compared with unity. Then if r_0 is the drop radius before expansion

$$r^2-r_0^2=(6K/\lambda\rho\alpha\mu^2)\{1-e^{-\mu\alpha t}\},$$

where

$$\mu=1/[(1+\sigma)\kappa-1]xT$$

and λ = latent heat of evaporation of the drop liquid, ρ = density of the liquid, $\sigma=RT/\lambda$, K = thermal conductivity of the gas and κ = the ratio of specific heats of the expanding gas. For alcohol vapor in air at about room temperature and pressure and with $\alpha=2$ which is about right the formula leads to

t (in seconds)	0.01	0.1	0.2	0.3	0.4	0.5	1
r (in microns)	4	18	28	32	37	41	60

Slight corrections from more detailed theory have been made for the early stages. These values are in approximate agreement with qualitative observations of Anderson, Neddermeyer and Bøggild who, in studying distortions, took motion pictures at 40 frames per second during the first $\frac{1}{2}$-second after expansion in various chambers.

13. Effect of Cloud Chamber Expansion Ratio on Drop Count Determination of Specific Ionization of Cosmic Rays. DALE BAGLEY, *University of California (Introduced by Robert B. Brode)*.—The variation with expansion ratio of the number of positive and negative ions on which condensation takes place in cosmic-ray cloud-chamber tracks has been studied. The tracks were separated into columns of positive and negative ions by an electric field applied in the plane of focus of the camera. In order to count the number of drops in each track, it was necessary to allow the tracks to broaden by diffusion. This was accomplished by means of a cam mechanism which delayed the expansion of the chamber 0.2 second. The delay circuit was set in operation by the passage of an ionizing particle through Geiger counters placed above and below the chamber. Nitrogen, oxygen, or argon at 1.5 atmospheres pressure containing alcohol, water, or a mixture of two parts ethyl alcohol and one part water was used in the chamber.

14. Transport Phenomena in a Mixture of Gases. E. J. HELLUND AND E. A. UEHLING, *University of Washington*.—The theory of transport in gases obeying the quantum statistics is extended to include mixtures as well as one component gases. Expressions for the coefficients, into

which assumptions with regard to the interaction laws may be introduced, have been obtained. From the point of view of separating the two effects of quantum mechanics, the problem of thermal diffusion seemed to be of particular interest since the ratio of the thermal to pressure diffusion coefficients depends only on the ratio of integrals involving the molecular cross sections. As contrasted with all other transport coefficients the phenomenon of thermal diffusion might be expected, therefore, to depend less sensitively on the diffraction effect in collision in comparison with the interference effect than the other coefficients do. A preliminary caclulation based on the elastic sphere model for helium and neon bears out this presumption only slightly, however, the temperature effect between 10°K and 273°K amounting to 20 percent as compared with temperature effects of the order of 30 percent for the pressure diffusion coefficient itself in this range of temperatures. However, it is just for the case of thermal diffusion that the elastic sphere model is particularly inadequate. Calculations based on a five-parameter potential are now in progress.

15. A Quantitative Study of the Clean-Up of Hydrogen by Barium. G. W. JOHNSON, W. A. HANE AND P. A. ANDERSON, *State College of Washington.*—A known mass of barium, thermally vaporized to form a film of uniform thickness on a spherical surface of known area, was exposed to a succession of measured, approximately equal "doses" of pure hydrogen. After each admission of hydrogen, pressure-time curves were taken with an ionization gauge operating automatically at constant grid current. The clean-up time (time required to reduce the hydrogen pressure from 10^{-2} to 10^{-6} mm) decreased progressively (from 8 min. to <2 min.) during the admission of a quantity of hydrogen equal to *ca.* 25 percent of that required for saturation, then remained constant until the absorption of hydrogen ceased abruptly with saturation. The initial increase in the rate of clean-up with the amount of hydrogen absorbed is probably due to break-up of the original mirror smooth barium surface under the corrosive attack of the first doses of hydrogen, with consequent increase in the effective surface area. Analysis of the pressure-time curves, taken after the initial break-up, shows the diffusion of hydrogen into the barium-hydrogen mass to be the limiting factor determining the rate of removal of gaseous hydrogen. At saturation, and within an experimental error estimated as <10 percent, one molecule of hydrogen was absorbed per atom of barium, pointing to BaH_2 as the end product in the gettering of hydrogen by barium.

16. Adsorbed Films on Interferometer Mirrors. W. V. HOUSTON AND S. RUBIN, *California Institute of Technology.*—One of the methods of measuring the index of refraction of air involves the measurement of the order of interference in a Fabry-Perot interferometer, in air, and with the air removed. The calculations are usually based on the assumption that the phase change upon reflection is independent of the presence of the air. A series of observations has shown that the order of interference changes steadily after the air has been removed or admitted, and the equilibrium is not reached for some eight days. This is presumably due to the breaking down and building up of an adsorbed layer on the reflecting surfaces. The total observed change has amounted to about 0.06 fringe, and probably considerably more before the first observation could be made. This effect must be taken into account in measurements of the index of refraction, and its neglect may be a cause of some of the existing discrepancies.

17. Virtual Level of He^5 and Meson Forces. S. M. DANCOFF, *University of California.*—Resonance neutron scattering in helium observed by Staub indicates a virtual level of He^5 near ground. If this is the lowest level of He^5 the added neutron is probably in a P state, forming either a $P_{1/2}$ or a $P_{3/2}$ doublet. Splitting of these two states by the spin-orbit forces of the type $(\boldsymbol{\sigma}_i\cdot\mathbf{r})(\boldsymbol{\sigma}_j\cdot\mathbf{r})V(r)$ resulting from meson theory might be expected to be considerable, since the above type of force seems to be present in nuclei in large amounts. However, a first-order perturbation calculation yields no splitting for the above two states. Higher order splitting should be reduced by the fact that the only states combining with these involve excitation of the alpha-particle core.

18. Normal Modes of Vibration of a Body-Centered Cubic Lattice. PAUL FINE,* *California Institute of Technology.*—An atomic model has been set up for the purpose of finding the frequencies of vibration of a crystal lattice. The potential energy was assumed to be a quadratic function of the displacements of the atoms from their equilibrium positions, and actual solutions of the secular equation were found by selecting suitable atomic force constants for tungsten, a body-centered cubic crystal whose elastic constants satisfy the isotropy condition. Numerical methods yield a frequency distribution which is characterized by two rather steep maxima. The result has been used in evaluating the specific heat of tungsten as a function of temperature, and a better fit with observed values is obtained by this method than by the particular Debye distribution with which it agrees at low frequencies. Discrepancies at low temperatures are partly due to the necessity of using experimental elastic constants determined at room temperature. Calculations have also been carried out for the thermal variation of the intensity of reflection of x-rays. Deviations from the Debye theory are apparent at absolute zero and become more pronounced at higher temperatures. However, there are no experimental data available for tungsten to compare with the theoretical values in this case.

* Now at the University of Oregon.

19. Streamline Flow of Water from an Artesian Basin into Horizontal Drains: Theory Compared with Experiment. DON KIRKHAM, *Utah State Agricultural College.*—Farr and Gardner[1] and Muskat[2] have obtained theoretical expressions for the pressure distribution in artificially drained homogeneous soil overlying an artesian basin. The tile drains are circular and are laid horizontally with equal spacing and at equal depths. In order to simulate an actual field case and to test the theory a small model[3] with a plate glass front is constructed. Theoretical equations for the streamlines corresponding to various boundary conditions

are obtained and are plotted on photographs of the experimentally obtained streamlines. Theory agrees well with experiment.

[1] Doris Farr and Willard Gardner, Agricultural Eng. **14**, 349 (1933).
[2] M. Muskat, *The Flow of Homogeneous Fluids Through Porous Media* (McGraw-Hill, 1937), p. 356.
[3] D. Kirkham, Trans. Am. Geophys. Union. (Now in press.)

20. The Validity of the Field Current Equations. FRANK R. ABBOTT AND JOSEPH E. HENDERSON, *University of Washington.*—Under good experimental conditions, field currents become practically as steady as thermionic currents. It is thus possible to test the form of the equation relating the current to the generating potential. A series of six precise point to plane field current curves was taken. Both the applied voltage and the emission current were measured, using type K potentiometers. A consistent deviation from linearity was apparent when the log of the total emission current was plotted against the reciprocal voltage. The field currents within the accuracy of the experimental work are described by the equation

$$I=\alpha V^4 e^{-\beta/V},$$

in which I is the *total* emission current, V is the applied voltage, while α and β are numerical constants. This differs from the Millikan-Lauritzen experimental equation only in the dependence of the coefficient of the exponential on V^4. Although this is in disagreement with the equation for the *specific* emission as given by the Fowler-Nordheim theory of field emission it is shown that it is not necessarily in disagreement with the basis of that theory. The effect of Nordheim's modification of the theoretical equation through consideration of an image force is indistinguishable from that given by a simple barrier.

21. The Quenched Primary Spark of an Induction Coil. W. P. BOYNTON, *Whittier, Calif.*—The author extends his previous study of circuits containing a spark gap to the case of the circuit breaker of an induction coil. The behavior of the primary current is described through three stages: the period of "make," the duration of the primary spark, and the oscillatory discharge of the condenser. The condenser potential is also described through the two later periods. A plausible approximate formula for the secondary e.m.f. is also deduced.

22. Spinor Equations for the Meson and Their Solution When No Field is Present. A. H. TAUB, *University of Washington.*—The spinor equations equivalent to the Proca equations for the meson are found. They differ from those proposed by Dirac in three ways: (1) They contain two symmetric spinors A_{1AB}, A_{2AB} and a spinor $B^A{}_B$, whereas the Dirac ones contain only one symmetric spinor and the spinor $B^A{}_B$. (2) They are invariant under spin transformations corresponding to both proper and improper Lorentz transformations whereas the Dirac ones are invariant under the former alone. (3) When a field is present they contain terms which cannot be obtained from the equations for free particles by replacing the operator p_ν by $p_\nu - e\varphi_\nu/c$ as was proposed by Dirac. In case there is no field present the equations can be solved by introducing two pairs of simple spinors (ψ^A, φ^A) and (χ^A, η^A) each of which satisfies a Dirac equation for a free particle of spin one-half. It is proposed to interpret each pair of spinors as representing a free particle of mass m_1 and m_2, respectively. With this interpretation it follows that a free particle of mass m and spin one satisfying the Proca equations is equivalent to a pair of particles of masses m_1 and m_2 satisfying the Dirac equations. If the three particles of masses m, m_1 and m_2 are in states determined by the energy momentum vectors p_ν, $p_{1\nu}$, and $p_{2\nu}$, respectively, and if $m\neq 0$, then $p_{1\nu}=m_1 p_\nu/m$ and $p_{2\nu}=m_2 p_\nu/m$, and $m=m_1+m_2$.

23. Contact Electric Phenomena in the Flow of Oil. S. KYROPOULOS, *California Institute of Technology (Introduced by A. Goetz).*—Phenomena of contact electricity associated with the flow of gasoline through pipes are well known for their disastrous effects. It is also known that they can be suppressed by imparting electrical conductivity to the gasoline. A simple model bearing permitted to detect the same effect with lubricating oils. It can be demonstrated by means of the oscillograph and its cleaning effect on the oil. The potentials appear high enough to result in "field currents." The phenomenon is particularly easy to understand in the case of lubricating oils with their highly dissymmetrical molecules as a consequence of the interaction of molecular surface- and flow-orientation. This means contact of molecules approximately with their maximum and minimum polarizabilities respectively and separation of charges according to Coehn's law. In the technical process of lubrication this electrical effect results in increased wear due to its clean-up effect with respect to dispersed solid particles. Addition of polar molecules tends to suppress the effect, resulting in lower friction and improved apparent "film strength" of the oil.

24. A Thermoelectric Method for the Determination of Work Functions. G. M. FLEMING AND JOSEPH E. HENDERSON, *University of Washington.*—During the process of investigating the temperature effects accompanying field current emission it was found feasible to measure the corresponding effect for thermionic emission. This was done calorimetrically using essentially the same method as for field currents, in which a tantalum-tungsten thermocouple junction was incorporated in the cathode to measure changes of temperature. This method gives experimental values for the average net energy loss per electron emitted. The value given by theory for this energy loss is $\phi+3kT$, where ϕ is the work function of the emitting metal. With the use of this relation the work function of tungsten has been computed to be 4.46 ± 0.09 ev. This method was originally applied to thermionic emission, where a cooling effect was known to exist, in order to test the sensitivity of the apparatus. It is believed that the measurements are capable of considerable refinement.

25. Absorption Spectrum of CN. JOHN U. WHITE, *University of California.*—Free CN radicals in the gaseous state are formed in the electric discharge through cyanogen. By using a very intense low pressure spark as a background the 0,0 and 1,1 bands of the $^2\Sigma \leftarrow {}^2\Sigma$ transition of CN have been observed in absorption at short intervals of time

after the end of this discharge. The intensities of the lines were measured by calibration of the plates and corrected for the imperfect resolving power of the spectrograph. Relative concentrations of CN were calculated. By diluting the cyanogen in the discharge tube with argon until the CN bands were no longer visible an upper limit to the partial pressure of CN was calculated on the assumption that near this point all the cyanogen present was dissociated. From this a lower limit to the f value of the 0,0 band was calculated to be $f=0.04$. The rate of disappearance of CN after the end of the discharge was studied and found to be exponential. It is unaffected by pressure or by dilution with argon. Possible mechanisms of the disappearance are discussed. Using data from the thermal dissociation of cyanogen a lower limit to the heat of reaction is calculated.

26. Transition Probabilities of Forbidden Lines. SIMON PASTERNACK, *California Institute of Technology.*—Recent work on forbidden lines has made it desirable to reexamine and extend the calculations made by E. U. Condon[1] on the theoretical transition probabilities of these lines. The method used is essentially that developed by Condon, with a few modifications. Formulae are derived for the magnetic dipole and electric quadrupole contributions to the transition probabilities for the p^2, p^3, p^4 and d^2 configurations. A few errors are found in Condon's calculations for the p^k configurations; in particular, a non-zero value is found for the probability of the $^3P_0-{}^1D_2$ transition in the p^2 configuration. This line was recently observed in O III by Bowen and Wyse.[2] Numerical computations are made of the transition probabilities for about fifty atoms in the p^k configurations. The formulae for the d^2 configuration are applied to the case of Fe VII, and give satisfactory agreement with the observed relative intensities. An application of the calculations is made to a question concerning the permitted lines of O III present in nebular spectra.

[1] E. U. Condon, Astrophys. J. **79**, 217 (1934).
[2] I. S. Bowen and A. B. Wyse, Pub. A. S. P. **50**, 348 (1938).

27. Twinning in Bismuth Crystals. ALFRED B. FOCKE, *Brown University.*—The segregation of impurities in very pure bismuth crystals offers a tool for a large scale study of the twinning process if polonium is used as one impurity. The range of the α-particles leaving the crystal gives a measure of the location of the polonium. This is found to be segregated into relatively small regions separated by specific distances dependent upon crystallographic direction. If the twinning process is atomic in nature, the effective distance between polonium groups should be unaffected by it. The results of this investigation show that this is not the case. In fact the spacing of the polonium groups when measured perpendicular to the imperfect cleavage plane is found to be $(0.86\pm0.03)\mu$ whether the face is one cut from an undeformed crystal, or formed by twinning from a perfect cleavage face. The normal spacing perpendicular to the perfect cleavage face is $(0.55\pm0.01)\mu$ in the undistorted crystal. It is found that the change of spacing due to twinning is reversible.

28. The Function of Anode Spots in the Glow Discharge. S. M. RUBENS AND J. E. HENDERSON, *University of Washington.*—Anode spots have been further investigated in nitrogen glows maintained in a large, spherical copper, discharge chamber with a disk anode at its center. Spots were grown on a flat probe mounted flush with the surface of the circular disk anode but insulated from it. When the probe potential is raised slightly above that of the anode a spot forms upon it. Plots of the probe current against the probe potential exhibit sharp peaks. These peaks account for the formation of many spots rather than a single large one. A study of the external circuit characteristics reveals that anode spots occur chiefly in a regime in which the voltage remains constant or increases but slightly with increasing current. The function of the spots is evidently that of furnishing sufficient positive ions to maintain a stable discharge. A theory is proposed which accounts for the formation and stability of the spots. As a consequence of this theory anode spots must appear whenever a critical current density at the anode is exceeded.

29. The Half-Life of B^{12}. R. A. BECKER AND E. R. GAERTTNER,[1] *California Institute of Technology.*—The half-life of the beta-ray active B^{12} produced according to the reaction $B^{11}+H^2\rightarrow B^{12}+H^1$ was measured by Crane *et al.*[2] with a cloud chamber, and estimated to be about 1/50 sec. The result however was open to the objection that the method of taking delayed expansions with a cloud chamber set only an upper limit on such a short half-life. To check this result we have re-measured the half-life by activating a rotating target of boric acid in the form of an annular ring of mean diameter 20 cm fused on an aluminum disk which was rotated 1800 r.p.m. with a synchronous motor. By observing the activity as a function of the angular displacement from the point of bombardment it was possible to follow the decay of the radiation. The ratio of the activities at different points on the target was measured with two Lauritsen electroscopes. The average of many measurements gave the value of 0.022 ± 0.002 sec. for the half-life of the radiation.

[1] H. H. Rackham Fellow, University of Michigan.
[2] Crane, Delsasso, Fowler and Lauritsen, Phys. Rev. **47**, 887 (1935).

30. Further Resolution of the 10μ and 16μ Ammonia Bands. E. F. BARKER AND H. Y. SHENG, *University of Michigan.*—Because of the existence of two minima in the potential function of NH_3, the energy levels for oscillations along the symmetry axis occur in pairs, and the parallel type bands are double. The separations of these pairs of levels for the vibration ν_3 are very sensitive to the height of the potential barrier, which in turn is considerably affected by centrifugal deformations. In consequence a new type of vibration-rotation interaction appears. An examination of the 10μ double band (ν_3) under the highest available resolution reveals many new details of structure. Lines corresponding to a given transition in J, originally observed as single, now appear as groups, the different members being associated with different values of K. The component band of lower frequency shows much more structure than does the other. In it, as theory predicts, the $K=0$ lines are missing whenever the initial value of J is odd. The band at 16μ arises from a transition for which the initial state is the upper level of the higher frequency 10μ band. Only a part of the negative branch

has been resolved, but it is found to fit consistently into the scheme. The following values (in cm^{-1}) for the vibrational terms W, and for $2B=h/4\pi^2A$, are computed for the molecule with $J=0$, from the pure rotation spectrum for the level 0_β and from the present observations for the other three states.

Level	W	$2B$
0_β	0.67	19.890
1_α	932.8	20.116
1_β	968.4	19.766
2_α	1597.9	

31. Phase Control Circuit and Mercury Arc Illumination of Cloud Chamber. Carl E. Nielsen, *University of California.*—An atmospheric pressure quartz capillary mercury arc has been used as a light source for a cloud chamber. It has been possible to get a 90° illumination intense enough and of short enough duration to take satisfactory drop count photographs. A spherical lens condensing system has been used. Comparison is made with an incandescent filament lamp and a low pressure mercury arc. In order to flash the arc on high voltage for one-half cycle of the 60-cycle power supply, a phase controlled tripping circuit has been designed. A gas discharge tube, thyratron, and ignitron are employed. Two alternate circuits for giving a phase controlled pulse of several cycles duration have been constructed.

32. The Gamma-Radiation from Nitrogen Bombarded by Deuterons. Louis A. Pardue[1] and E. R. Gaerttner,[2] *California Institute of Technology.*—The energies and the relative intensities of the gamma-rays emitted from nitrogen bombarded by deuterons of 700 kv have been measured by the positron-electron pairs and recoil electrons ejected from thin laminae placed inside a cloud chamber.[3] The distribution of pairs ejected from a lead lamina 0.026 cm thick reveals two strong components of quantum energy 7.2 ± 0.4 Mev and 5.3 ± 0.4 Mev, and a number of weaker components which may be attributed to radiation of about 4, 3, and 2 Mev. There are also a number of pairs which extend up to 11 Mev. The distribution of recoil electrons from a carbon lamina 0.12 cm thick indicates two strong groups of quantum energy 4.4 and 2.2 Mev. No attempt was made to extend the recoil measurements to higher energies. The 7.2-Mev radiation is attributed to the reaction

$$N^{14}+H^2\rightarrow C^{12}+He^4 \qquad (1)$$

because radiation of this energy has been observed in other reactions producing C^{12}.[3, 4] The 5.3-Mev radiation is attributed to an excited state of N^{15} of this energy according to the reaction

$$N^{14}+H^2\rightarrow N^{15}+H^1 \qquad (2)$$

in good agreement with the value of 5.4 Mev predicted by the range measurements of Cockcroft and Lewis.[5] An attempt will be made to correlate the energies and intensities of the gamma-rays produced by excited states in C^{12} according to several reactions.[3-5]

[1] On Sabbatical leave of absence from the Physics Department of the University of Kentucky.
[2] H. H. Rackham Fellow, University of Michigan.
[3] Fowler, Gaerttner and Lauritsen, Phys. Rev. **53**, 628 (1938); Phys. Rev. **55**, 27 (1939).
[4] Bothe, Zeits. f. Physik **100**, 273 (1936).
[5] Crockcroft and Lewis, Proc. Roy. Soc. **154**, 261 (1936).

33. The Mobility Spectrum of Atmospheric Ions. E. A. Yunker, *Stanford University* (*Introduced by N. E. Bradbury*).—The mobility spectrum of atmospheric ions is being studied by using the classical air blast method with the collecting electrode divided into segments for resolution. The apparatus is designed for continuous operation with photographic recording. The sensitivity is such that the range of mobilities from 2.0 to 5×10^{-4} cm/sec./volt/cm, when divided into eighteen groups, is covered in one hour. Simultaneous and continuous measurements of the density of atmospheric condensation nuclei using the cloud chamber expansion method[1] enable a study to be made of the change of small ions into large ions and of the mass and character of the condensation nuclei involved. Preliminary investigations have shown that the number of small ions changes markedly with the concentration of nuclei with appropriate changes in the magnitude of the local component of the earth's electric field. The ion spectrum appears to consist of rather prominent groups superimposed upon a general background.

[1] Bradbury and Meuron, Terr. Mag. **43**, 231 (1938).

34. Quantitative Analysis of Rubidium in Plant Sap by Spectrographic Means. Louis A. Strait, *University of California.*—The source of light is a condensed spark between an upper point electrode and a lower cylindrical electrode on which a small amount (0.04 cc) of the prepared plant sap is deposited. The cylindrical electrode of copper is mounted on a screw arrangement which allows uniform sparking of the complete area of the surface of the cylinder. The light from the spark is photographed with a quartz spectrograph of large dispersion. Photometric measurements are made of the relative intensities of the spectral lines λ4215.6 and λ4201.8 of rubidium and λ4101.8 of indium, which serves as internal standard. A working curve is determined from known concentrations of rubidium bromide introduced into prepared plant sap. Correction for the influence of varying amounts of potassium on the rubidium determinations is made by a method of excess. In preliminary testing of the method the accuracy of analysis is of the order of 10 percent. Aliquots of 0.04 cc of solution of prepared sap are used for a single analysis. A minimum concentration of $N/400$ rubidium is measurable. This corresponds with measurement in absolute amount of 0.085 mg of rubidium. The method can be adapted to simultaneous determination of potassium.

35. The Far Infra-Red Water Bands and Heat Transfer in the Atmosphere. Walter M. Elsasser, *California Institute of Technology.*—Thermal radiation at the temperatures prevailing in the atmosphere has its maximum near 10μ; consequently the rotational and the lowest vibrational water bands are the main carriers of heat radiation in the atmosphere. During the last two years extensive computations have been undertaken in order to apply spectroscopic results to the physical conditions under which water vapor radiates in the atmosphere. The absorption of the rotational band is obtained from the analysis of Randall, Dennison and collaborators. The envelope of the vibrational band at 6μ can be obtained from this by a

simple transformation since the two bands have parallel electric moments. The absolute intensity of this vibrational band has recently been measured by T. Strong of the California Institute. With these data as a basis the equations of radiative transfer have been integrated numerically for a large range of temperatures and optical thicknesses. The results are given in form of a graph-paper in which temperature and moisture appear as independent variables. If the vertical temperature-moisture relationship in any actual atmosphere is plotted on this paper, the radiative heating and cooling at any height can rapidly be obtained by a graphical quadrature.

36. The Dielectric Constant of Water Vapor at a Frequency of 42 Megacycles. ANGUS C. TREGIDGA, *California Institute of Technology.*—A heterodyne beat apparatus was constructed for the measurement of the dielectric constant of water vapor at 42 megacycles. One of the oscillators was crystal-controlled, the other having a tuned circuit containing a condenser which could be evacuated and filled with water vapor. A cathode-ray oscilloscope was used to indicate zero beat. Drift of the oscillators was eliminated from the results by plotting readings on a time base and alternating between vacuum and water vapor as rapidly as physical limitations would permit. Air was used as the calibration gas, because it is composed of nonpolar molecules. It should therefore have the same dielectric constant at this frequency as at the lower frequencies at which it has been measured by other investigarors. The Clausius-Mosotti relation was verified for water vapor at constant temperature, and the dielectric constant of water vapor at 100 degrees centigrade and 760 mm of mercury determined. It has the value 1.0060. This research was undertaken because of its connection with the transmission of radio signals of this frequency. The optical path for such waves in a medium of varying index of refraction is curved, and it was desired to know the magnitude of the curvature which a gradient of water vapor content in the atmosphere can produce.

37. Fine Structure in the Absorption and Emission Spectra of X-Rays. S. T. STEPHENSON, *State College of Washington.*—The K x-ray emission spectrum of pure copper has been studied. K absorption spectra of pure copper, of copper and selenium in cupric selenate, and of elements in other compounds have been obtained. The spectrograms were all taken with a focusing curved crystal (mica) spectrograph and analyzed with a recording microphotometer. Faint copper emission lines were found extending more than 300 volts to the short wave-length side of Cu $K\beta_2$. It is suggested that these lines are due to the transition of conduction electrons into the K shell. The positions of these lines have been compared with the Kronig type fine structure found in the absorption spectrum of copper. The results of this comparison point to the conduction electron origin of the emission fine structure. The absorption fine structures of two elements in the same crystalline compound have been studied for cupric selenate, cupric arsenate, rubidium bromide and other compounds. The structures in many cases are different for the two elements making up the compound. Similar discrepancies have been obtained by other investigators for a few compounds.

38. Experiments on the Scattering of Fast Neutrons. E. R. GAERTTNER,[1] LOUIS A. PARDUE,[2] AND J. F. STREIB, *California Institute of Technology.*—A description of a series of experiments on the scattering of fast neutrons in gases of low atomic number with a linear amplifier and a mechanical oscillograph will be given. Since the angular distribution of the scattered neutrons is reflected in the distribution in energy of the recoil nuclei, this experimental method also affords a means for studying the angular distribution of the scattered neutrons. An investigation of the scattering in helium of the low energy group of neutrons ($Q=0.9$ Mev) produced in the reaction $Be^9+H^2 \rightarrow B^{10}+n^1$ [3] has confirmed the existence of an anomalous scattering for neutrons of 1 Mev.[4] The position of the anomaly was found to be independent of the deuteron energy (500 kv–800 kv). The distribution of helium recoils indicates also a maximum at about 0.8 Mev. An attempt is now being made to extend the measurements to lower energies to investigate further the character of this anomalous scattering.

[1] H. H. Rackham Fellow, University of Michigan.
[2] On sabbatical leave from the Physics Department of the University of Kentucky.
[3] Bonner and Brubaker, Phys. Rev. **50**, 308 (1936).
[4] Staub and Stephens, Phys. Rev. **55**, 131 (1938).

39. Luminescence of Synthetic Halite Crystals. BRYON E. COHN, *University of Denver.*—Synthetic halite crystals were grown from sodium chloride melts to which had been added small amounts of manganese chloride. Crystal specimens were prepared which analyzed from 0 to 0.25 percent manganese. The specimens were analyzed by the periodate method. For the determination of luminescence crystals were cleaved to a uniform face area and thickness and were excited with ultraviolet light. The thermoluminescence emission was determined by photographic methods. Curves of luminescence are presented. Optima were observed at 0.0042 percent and at 0.05 percent manganese.

40. X-Ray Spin Doublet Splittings. R. F. CHRISTY AND J. M. KELLER, *University of California.*—Professor R. T. Birge[1] has suggested the possibility of a precision determination of the fine structure constant α from his recently compiled data on $L_{II}L_{III}$ x-ray spin doublet splittings. This method involves some theoretical information on the variation of the "screening constant" s with Z. We propose to write

$$\Delta = S(Z)[1-(b/Z)\varphi(\alpha^2Z^2)-(c/Z^2)\psi(\alpha^2Z^2)-\cdots],$$

where Δ is the observed $L_{II}L_{III}$ splitting, $S(Z)$ is that given by the Sommerfeld formula with $s=0$, and where the functional forms of φ, ψ, $\cdots$ are to be given theoretically. The determination of α would then involve a least squares solution for α, b, c, $\cdots$. In this form of expansion, the term φ is given by the first order interaction energies of the L electrons with all other atomic electrons. We are determining its functional form using Dirac hydrogen-like

wave functions for charge Z and Breit's approximate Hamiltonian. The dependence of ψ and higher terms on α^2Z^2 is relatively unimportant and can be taken as that given by Sommerfeld's formula $S(Z-s)$ with constant s. We have calculated the first order electrostatic interaction due to the K and L shells, which provides the major portion of φ, and are now calculating smaller terms in φ due to the electrostatic interactions of higher shells and to the magnetic interactions.

[1] R. T. Birge, Bull. Am. Phys. Soc. Vol. 14, No. 2, abstract 47.

41. Recording Bragg Spectrometer for Use Between Room Temperature and Helium Temperature. A. GOETZ AND A. DEMBER, *California Institute of Technology.*—A Bragg spectrometer with stationary ionization chamber is described where the crystal is rigidly attached to a He-liquifier, so that neither the incident nor the reflected radiation has to pass through liquid gases. The helium liquifier is of the "single adiabatic expansion" type with a capacity of 80 cm^3 and is arranged in such a manner that by means of liquid H_2, solid H_2, and ultimately liquid He, any temperature between 300 and <4.2°K can be attained. The adiabacy is sufficient to maintain temperatures between such fixed points constant for the time necessary for recording. The temperature is measured at the crystal with resistance thermometers and within the expansion chamber with a gas thermometer.

42. The Measurement of Intensity Profiles of Bragg Reflections from Calcite Between 300° and 4.2°K. A. DEMBER AND A. GOETZ, *California Institute of Technology.* —The intensity profiles of Mo $K\alpha_1\alpha_2$ radiation reflected from calcite are determined for different orders between room temperature and the boiling point of helium. To eliminate distortion due to the gradation of the emulsion and the indeterminacy by its graininess, inseparable from the use of photographic methods, an ionization chamber connected to a linear d.c. amplifier and galvanometer is used for recording the intensity distribution of the reflected radiation either as function of the position of the crystal within the rocking angle or across the angle of reflection for a stationary crystal. Consequently the recording speed can be set in fixed relation to the rotation of the crystal or the motion of a scanning slit in front of the ionization chamber. For recording the full profile of the Mo $K\alpha$ doublet the time necessary is approximately $3\frac{1}{2}$ min. which is sufficiently short for measurements under stable temperature conditions at and between the thermal fixed points of the gases used for the cooling of the crystal. From the integrated intensities of reflection the values of the characteristic temperature with and without zero point energy are calculated. The shape of the profiles is discussed.

43. Theory of X-Ray Lines Resulting from Double Ionization of the L-Shell. ROBERT D. RICHTMYER, *Stanford University.*—We describe theoretical calculations of the wave-lengths and intensities of some very faint lines in L-series x-ray spectra. The lines are produced by atomic transitions from initial states in which two electrons are missing from the L-shell; these initial states are in turn produced by Auger transitions which take place in atoms originally ionized in the K-shell. Very careful experimental work by Cecil Burbank and later by Werner Veith has brought out several of these lines photographically. The experimental and theoretical results agree within the estimated error of the calculations; furthermore this error is small enough to allow us to deduce a correlation of observed lines to theoretically predicted ones, the correlation being unique for most of the observed lines.

44. A New Method for the Measurement of Work Functions. WILBUR H. GOSS AND JOSEPH E. HENDERSON, *University of Washington.*—A new method for the measurement of work functions has been devised. It depends for its success upon the high energy cut-off in the normal energy distribution of field current electrons; this cut-off is quite sharp.* These high energy electrons are unable to enter a collector unless the potential of the collector is higher than that of the emitter by an amount at least equal to the work function of the collector. This should be true if the electrons "tunnel" the surface barrier of the emitter and go over the surface barrier of the collector. Thus the collector potential at which field electrons begin to be measured gives directly the collector work function. A tube has been built containing copper, platinum, and nickel, any of which can be used independently as a collector. Preliminary data show a progressive increase in the potential thresholds at which current is collected in line with accepted values of the work functions of these three elements and of approximately the accepted value.

* Jos. E. Henderson and R. K. Dahlstrom, Phys. Rev. **55**, 473 (1939).

45. Limiting Solutions for Collapsing Masses. H. SNYDER, *University of California (Introduced by J. R. Oppenheimer).*—Volkoff and Oppenheimer have shown that the general relativistic field equations do not possess any static solution for a spherical distribution of neutrons if the total mass is greater than $\sim 0.7\odot$. We have made a qualitative investigation of the behavior of non-static solutions under the assumption that the total loss of mass by radiation is small. The characteristics of the solutions are: (1) The radius of the star approaches its gravitational radius asymptotically with time, as measured by an observer at a great distance from the star. (2) An observer co-moving with the matter in the star would not be able to communicate with an observer outside the star after a finite time, as measured by a co-moving clock. Neglecting the pressure we have obtained analytic solutions which confirm the general behavior indicated above. If R is the radius of the star and R_0 the gravitational radius, then asymptotically

$$R/R_0 - 1 \sim \exp(-cT/R_0).$$

This characteristic time R_0/c is of the order 10^{-5} sec. for stars of the mass of the sun.

46. The Fields Involved in Field Emission. JOSEPH E. HENDERSON, *University of Washington,* AND K. V. MACKENZIE, *Oregon State Highway Department, Salem, Oregon.* —One of the noteworthy characteristics of the energy

distribution curves for field emission is the occurrence of a sharp maximum near the maximum energy observed. This maximum has been observed at various positions usually within a few volts of each other. By using a Fermi distribution and the transmission coefficient as given on the Fowler-Nordheim theory of field emission, it has been possible to solve for the position of the maximum as a function of the field present during emission. This yields values for the field of about 10^8 volts per cm. Assumption of an image force lowers the value of the field only slightly in the region where the maxima are observed. Comparison with the values obtained from the slopes of the corresponding $\log i$ versus $1/V$ curves is quite satisfactory. These values seem quite high unless the areas involved in emission are smaller than usually supposed.

47. On the Proper Energy of the Electron. G. M. VOLKOFF, *University of California.*—The method used by Serber[1] to evaluate the proper energy of the electron by introducing an off-diagonal distance into the commutation rules for the wave functions of the positron-electron field has been extended to include time-like off-diagonal distances. Following a suggestion of Dirac[2] for eliminating the singularities in the classical treatment of the radiation field of the electron by antisymmetrizing the solution in the retarded and advanced potentials, the present results are symmetrized in positive and negative values of the off-diagonal time. Calculations of the electrostatic energy of an electron at rest were made both with the negative energy states filled (positron theory), and empty (single electron), and are summarized in the table below.

	Electron Proper Energy Single Electron	Positron Theory
Serber's results for space-like off-diagonal distance R	$e^2/2R$	$-\frac{e^2}{\pi}\left[\log\frac{1}{2}CR-1+O(R)\right]$
Present results for time-like off-diagonal distance τ	$-\frac{e^2}{2}\left[\frac{3}{2}\tau+O(\tau^3)\right]$	$-\frac{e^2}{\pi}\left[\log\frac{1}{2}C\tau+1+O(\tau)\right]$

Although the introduction of an off-diagonal time removes infinite terms in the single electron case, positron theory still leads to a logarithmic singularity.

[1] R. Serber, Phys. Rev. **49**, 545 (1936).
[2] P. A. M. Dirac, Proc. Roy. Soc. **167A**, 148 (1938).

48. Forbidden Transitions in Nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles.*—A number of new afterglow spectra in pure nitrogen and in nitrogen containing a small concentration of oxygen are presented. These include the weak high-pressure afterglow in nitrogen in very small bulbs in which the nebular transition $^2D\rightarrow{}^4S$ has been observed for the first time in the laboratory. The high relative intensity of the $^2P\rightarrow{}^4S$ line and the absence of first-positive bands are other important characteristics of this afterglow. The first observation of the transauroral line $^1S_0\rightarrow{}^3P_1$ of oxygen in a weak afterglow at medium pressures, accompanied by a strong emission of the Vegard-Kaplan bands and the green auroral line, is also included. The absence of the normally strong β bands of NO is an important and curious feature of this spectrum. The bearing of these spectra on the Cario-Kaplan theory of the Lewis-Rayleigh glow and on excitation processes in the earth's upper atmosphere is briefly discussed. There are indications that the strong relative intensities of forbidden lines in these and upper atmosphere spectra arise from the dissociation of molecules into metastable atoms rather than in direct excitation of atoms.

49. The Positron Spectra of N^{13} and Na^{22}. F. OPPENHEIMER AND E. P. TOMLINSON, *California Institute of Technology.*—A semi-circular focusing spectrograph of high resolution was used to examine the positron spectra and the gamma-rays of N^{13} and Na^{22}. The gamma-rays were examined by placing the source in contact with a one-half mil Pb foil. The positron distribution of Na^{22} has an upper limit of 0.55 Mev. The peak of the distribution is rather broad, suggesting a complex spectrum. However no low energy gamma-rays, corresponding to different components of the spectrum, were found. Only one gamma-ray at 1.3 Mev was found for Na^{22}. By comparing the intensity of this gamma-ray with that of the annihilation radiation it is found that there are $1.1\pm.1$, 1.3 Mev quanta per positron. The N^{13} positron spectrum is distinctly resolved into two components, the two peaks being at about 0.370 and 0.540 Mev. This complexity has already been reported by E. Lyman.[1] The peak of the lower energy component is very broad, suggesting that there may be other unresolved components of the spectrum. The gamma-ray, reported by Richardson,[2] at about 280 kev has been examined. It appears as a broad group of photoelectrons rather than as a sharp line such as is produced by the N^{13} annihilation radiation. The 250-kev radiation must be produced by two or more gamma-rays.

[1] E. M. Lyman, Bull. Am. Phys. Soc. **14**, 2, 19 (1939).
[2] J. R. Richardson, Phys. Rev. **55**, 609 (1939).

50. The Second Townsend Ionization Coefficient for Nickel Cathodes in Pure Hydrogen. DONALD H. HALE, *University of California.*—Measurements of the Townsend ionization coefficients in pure hydrogen for platinum and NaH cathodes have been reported.[1] An improved ionization chamber has been designed and the Townsend γ coefficient determined for a nickel cathode in pure hydrogen. It is found that the curve of values of α/p plotted as a function of X/p shows a negative slope in the range of values of X/p from 1000 to 1400 after which it again rises. The curve of values of γ plotted as a function of X/p shows the same general characteristics as the curve for the platinum cathode. However, the increase in the value of γ at the higher values of X/p is less rapid for the nickel cathode. A sparking potential curve has been calculated using the values of γ found in this work and is in agreement with the curves found experimentally except at values of $p\delta$ near the minimum sparking potential.

[1] Donald H. Hale, Phys. Rev. **55**, 815 (1939).

51. Gamma-Radiation from Fluorine plus Protons. C. C. LAURITSEN, W. A. FOWLER AND T. LAURITSEN, *California Institute of Technology.*—An investigation has been made of the gamma-radiation from fluorine bombarded with

protons at 330 kv and 950 kv, with a pressure Van de Graaff generator. Analysis of 38 pairs in cloud-chamber photographs at 330 kv gives a mean energy of 6.2 ± 0.2 Mev for the radiation, in agreement with earlier measurements, while the mean of 122 pairs obtained at the higher voltage, covering all resonances up to 1 Mev, is 6.3 ± 0.1 Mev. This result, which is in essential agreement with the work of Dee, Curran and Strothers,[1] indicates that the radiation is due to an excited state in O^{16} which is reached by the ejection of a short range alpha-particle from Ne^{20},[2] and that the various resonances represent similar states of the Ne^{20} nucleus.

Five pairs, corresponding to a gamma-ray of energy 10.5 Mev, were found at the higher bombarding voltage, but it is not certain whether they can be due to contamination or whether they arise from one of the intermediate resonances at 479 or 660 kv.

[1] Dee, Curran and Strothers, Nature **143**, 759 (1939).
[2] McLean, Becker, Fowler and Lauritsen, Phys. Rev. **55**, 796 (1939).

52. Infra-Red Pleochroism and Fermi Resonance Associated with CH_2 Groups in Crystals. JOSEPH W. ELLIS AND JEAN BATH, *University of California at Los Angeles.*—The near infra-red absorption spectra of two dissimilar organic crystals, pentaerythritol, $C(CH_2OH)_4$, and diketopiperazine, $(CH_2NHCO)_2$, have been obtained with plane polarized waves. Both crystals display marked pleochroism. Of particular interest is the region 1.7μ associated with the vibrations of the methylene groups, CH_2. Both spectra show a strong band at 1.703μ when the electric vector E parallels the bisector of the HCH angle. This practically disappears when E is perpendicular to this symmetry axis. We identify it as $2\nu_\pi$, the first overtone of the symmetrical valence vibration. Pentaerythritol gives a double band at 1.735, 1.763μ with components of equal intensities. These are excited by E in either its parallel or perpendicular positions but more efficiently in the latter instance. We interpret these as $[2\nu_\sigma, 4\delta_\pi]$, the first and third overtones, respectively, of asymmetrical valence and deformation vibrations. Fermi resonance must occur and equality in intensities indicates perfect superposition of the two frequencies. Diketopiperazine shows bands at 1.745, 1.754μ, the former strong when E is perpendicular to the symmetry axis and the latter strong when these are parallel. Our interpretation is similar to that for the 1.735, 1.763μ pentaerythritol bands, with the exception that Fermi resonance must be greatly reduced owing to a less exact superposition of $2\nu_\sigma$ and $4\delta_\pi$.

53. Resonance in the Production of Short Range Alpha-Particles from $F^{19}+H^1$. W. B. MCLEAN AND R. A. BECKER, *California Institute of Technology.*—Resonance in the production of the short range alpha-particles from $F^{19}+H^1$ recently reported from this laboratory[1] has been shown to coincide with the gamma-ray resonance at 330 kv[2] within ±5 kv. Cloud chamber determinations of yield curves requiring extended periods of observation are found to be feasible if the alpha-particle yields are measured as a function of the range of the scattered protons appearing on individual photographs. Relative voltage measurements were made with an inexpensive resistance voltmeter consisting of a circulating solution of xylol and alcohol. Variations in the specific resistance of the solution were compensated for by applying a known potential of the order of 3000 volts across a short section of the resistance column and balancing out the current in the column due to the high potential.

[1] McLean, Becker, Fowler and Lauritsen, Phys. Rev. **55**, 796 (1939).
[2] Hafstad, Heydenberg and Tuve, Phys. Rev. **50**, 504 (1936).

54. Photoconductivity of Tartaric Acid Crystals. JAMES J. BRADY AND JOHN D. TODD, *Oregon State College.*—Recent work[1] has shown that tartaric acid crystals, when illuminated, produce an electrical current without the aid of an external source of e.m.f. In the present work, we have investigated the effect of applying an external e.m.f. on the crystal. The dark current depends on the time the potential difference has been applied across the crystal. With 100 volts across the crystal for 24 hours, the dark current drops to less than one hundredth of its original value. The final value of the dark current depends on the magnitude of the potential difference. The application of voltages up to 300 has *no measurable* effect on the actinoelectric current for illumination with light in the visible part of the spectrum. The investigation was carried out at room temperature.

[1] J. J. Brady and W. H. Moore, Phys. Rev. **55**, 308 (1939).

55. Proton Activation of $_{48}$Cd and $_{49}$In. S. W. BARNES, *University of Rochester.*—Indium activated by 7.2 Mev proton exhibits two activities, one due to In^{115*} and one due to Sn^{113}. The other two activities previously reported[1] have been shown to be due to impurities. Sn^{113} has a half-life of about 100 days and decays by K electron capture, emitting In K x-rays. An active In of 105 minutes' half-life with a γ-ray of 0.39 Mev has been chemically separated from an aged Sn^{113} sample. An exactly similar In has been formed by proton bombardment of Cd, which suggests the assignment of this activity to In^{113*}. The absence of Cd K x-rays indicates that In^{113*} decays to In^{113} with the emission of the 0.39 γ-ray. In addition Cd shows the expected In isotopes In^{111} $20m$ e^+, In^{114} $48d$ e^- and In^{116} $54m$ e^-. A positron emitter of 65 minutes' half-life with a maximum positron energy of 1.6 ± 0.3 Mev is found and tentatively assigned to In^{110}. Activities of $72s$ e^- and $2.7d$ e^- with γ's of 170 and 245 kev are ascribed to isomeric states of In^{112}.

[1] S. W. Barnes, Phys. Rev. **55**, 241 (1939).

56. Production of Secondary Electrons by High Energy Electrons. W. A. FOWLER AND C. W. SHEPPARD, *California Institute of Technology.*—In nearly two thousand traversals of a 0.033-cm lead foil by high energy electrons and positrons ($W\sim10$ Mev), we have observed the production of six secondary electrons with energy greater than 1 Mev. The cross section is thus $\sim5\times10^{-24}$ cm^2 and is of the order of the theoretical cross section $\sigma\sim2\pi r_0^2 Z/W_s\sim10^{-23}$ cm^2 where W_s ($\ll W$) is the minimum observed secondary energy. Energy was approximately conserved in all cases but conservation of momentum apparently did not hold in several cases due probably to scattering in the lead foil. No authentic cases of pair production were observed, in

agreement with the small cross section (10^{-25}) for this process.

57. Experimental Studies of Energy Releases in Reactions of Light Nuclei. SAMUEL K. ALLISON, LESTER S. SKAGGS, AND NICHOLAS M. SMITH, JR., *University of Chicago.*—The study of the energy spectra of particles emitted from beryllium under proton bombardment has been continued, with the electrostatic analyzer previously described. Energy spectra have been obtained at proton energies or 262, 315, and 351 kv, and show quantitatively the conservation of energy and momentum in the two modes of disintegration. Approximately equal numbers of alpha-particles and deuterons are produced. The determination of the energy releases in the reactions $Li^7(p,\alpha)\alpha$ and $Li^6(d,\alpha)\alpha$ has been repeated by the range method in an absorption cell in which the only absorbing medium other than air is cellophane of 5 mm stopping power. Thin targets were used, heated to prevent carbon deposition, and the ranges were compared with those of the 8.5-cm particles from ThC′. Preliminary results are 17.31 Mev for the Li^7 reaction and 22.24 Mev for the Li^6 reaction.

AUTHOR INDEX TO ABSTRACTS OF THE STANFORD MEETING