Proceedings of the American Physical Society

MINUTES OF THE PASADENA, CALIFORNIA, MEETING

June 18–20, 1941

THE 242nd regular meeting of the American Physical Society was held at the California Institute of Technology, Pasadena, California. On the afternoon of June 18 a joint session with the Astronomical Society of the Pacific was addressed by J. Holmboe, J. Strong, E. C. Slipher, and S. B. Nicholson, who spoke on various aspects of the dynamics of atmospheres. The afternoon session of June 19 consisted of a symposium on electron microscopes in which Otto Beeck, Alfred Marshak, and William V. Houston participated. A dinner for physicists, astronomers and guests on the evening of June 18 was attended by 100 persons. A physics luncheon on June 19 was addressed by President George B. Pegram. The thirty-five contributed papers abstracted and indexed below were presented in three morning sessions on June 18, 19, and 20. Numbers 5, 28, and 31 were read by title.

PAUL KIRKPATRICK
Local Secretary for the Pacific Coast
Stanford University, California

ABSTRACTS

1. A Radiant Energy Theory of the Absorption of Primary X-Rays, Ionization and Photoelectron Emission. SAMUEL R. COOK, *Sacramento, California.*—An explanation of the absorption of primary x-rays by matter has been made, in accordance with the tenets of the radiant energy theory of primary x-rays. It has been shown that the products of the absorption of an x-ray or radiant energy quantum by an electron are a high speed beta-electron and an ionized molecule. It has also been shown that the high speed beta-electron, if it does not escape from the absorbing material, may make collision with a nucleus of the adsorbing material and generate secondary or fluorescent x-rays and that if it does escape it is what is known as a photoelectron, which explains photoelectron emission. Both ionization and photoelectron emission are, therefore, according to the tenets of the radiant energy theory, products of the absorption of x-rays. Equations for the absorption of x-rays were developed and it is shown that the equation for the absorption of a primary x-ray and the liberation of a beta-electron was identical with Einstein's equation for photoelectron emission which has been verified by Millikan and associates.

2. Internal Conversion in Photosynthesis. J. R. OPPENHEIMER, *California Institute of Technology.*—In some chlorophyll (cpl) containing algae, light absorbed by a fluorescent dye apparently produces photosynthesis. It has been suggested that this is because the cpl absorbs the fluorescent radiation of the dye, but the calculated absorption, using the known fluorescent yield, cpl concentration n and absorption coefficient σ, is far too small. We wish to point out that energy transfer from dye to cpl can be enormously enhanced by the fact that there are cpl oscillators far closer than a wave-length to the fluorescent source. This transfer gives a large scale model of the internal conversion of nuclear gamma-rays. A simple calculation gives, for the ratio of quanta transferred to cpl to those emitted in fluorescence, $n\sigma\lambda\!\!\!^{-4}/d^3$, where $2\pi\lambda\!\!\!^{-}$ is the fluorescent wave-length in water, and d the closest distance of approach of cpl and dye oscillators. With reasonable values for d this can explain a very high photosynthetic yield.

3. The Theory of Light Nuclei. EDWARD GERJUOY AND JULIAN SCHWINGER, *University of California.*—The existence of the deuteron quadrupole moment indicates the presence of tensor nuclear forces which destroy the constancy of orbital angular momentum, and thus necessitates a revision of the theory of light nuclei. In H^3, the tensor forces directly couple to the fundamental $^2S_{\frac{1}{2}}$ state a $^4D_{\frac{1}{2}}$ state, which in turn interacts with $^3P_{\frac{1}{2}}$ and $^4P_{\frac{1}{2}}$. To the fundamental $^1S_0$ state of He^4 is admixed a $^5D_0$ state which interacts with $^3P_0$. Thus all states consistent with the total angular momentum occur. These nuclei therefore constitute the simplest examples of the break-down of spin conservation laws. We have performed a variation calculation employing trial wave functions of the character $^2S_{\frac{1}{2}}+^4D_{\frac{1}{2}}$ for H^3, and $^1S_0+^5D_0$ for He^4, with simple Gaussian radial functions. Using the known force constants for rectangular well potentials, the calculations yield 40 and 50 percent of the binding energy for H^3 and He^4, respectively. A similar test calculation for H^2 gave 20 percent of the binding energy. The probability that these nuclei are in the D state was found to be 4 percent for all three nuclei; this value is in agreement with the exact deuteron computations. Calculations with improved trial functions are in progress.

4. Nuclear Electron Pairs from O^{16}. E. P. TOMLINSON, *California Institute of Technology.*—A magnetic electron pair spectrograph[1] has been used to investigate the energy of the excited pair-producing state of O^{16}.[2] A discussion of the data both for singles and coincidence measurements is presented. Comparison of the singles positron spectra of the nuclear pairs and of photoelectric pairs from the 6.2-Mev γ-rays of another excited state of O^{16} supports qualitatively the theoretical prediction for energy distribution discussed by J. R. Oppenheimer in paper No. 11 of this meeting. The energy of the pair producing state is found to be 6.0 ± 0.2 Mev above the ground state of O^{16}.

[1] E. P. Tomlinson, Phys. Rev. **59**, 216A (1941).
[2] Fowler and Lauritsen, Phys. Rev. **59**, 253 (1941).

5. Statistical Analysis of the Earth's Internal Magnetic Field. WALTER M. ELSASSER, *California Institute of Technology.*—In order to represent the irregular (non-dipole) part of the internal magnetic field of the earth the following model is considered. A finite number of dipoles are distributed with random positions inside a spherical shell concentric with the earth. Probabilities are calculated for the amplitudes with which the higher spherical harmonics appear in the field thus produced. The results are statistically compared with the harmonic components of the observed field of which 42 are numerically known, making a sufficiently large population to permit significant statistical inferences. The theory may be used to determine the outer radius of the spherical shell from the magnitude of the observed coefficients. This radius is found to be approximately $0.50R$ (where R is the earth's radius) and it is definitely not in excess of $0.55R$, the radius of the earth's core. The result is independent of the number of dipoles used to represent the irregular field, provided the latter is not excessively large.

6. The Latitude Effect of Primary Cosmic-Ray Intensity. SHUICHI KUSAKA, *University of California.*—Relative values of the total incident energy and the energy incident vertically of the primary cosmic rays have been calculated for the geomagnetic latitudes at which high altitude experiments were carried out by Pickering and Neher[1] in India. These calculations were based on the Lemaitre-Vallarta theory of the geomagnetic effect, and it was assumed that the distribution in number of the primaries was given by the inverse cube of the energy. The results of the calculation are:

Geomagnetic latitude	3°	17°	25°
Total incident energy	100	110	130
Vertically incident energy	100	108	125

The values given are relative values normalized to 100 at 3°. It may be noted that the approximate $\cos^4\lambda$ law for the variation of the minimum energy for vertical incidence gives much greater variation of the vertical intensities at 3° and 17°.

[1] W. H. Pickering and H. V. Neher, Bull. Am. Phys. Soc., Washington Meeting, May 1, 1941, No. 84.

7. The High Energy Soft Component of Cosmic Rays. R. F. CHRISTY AND J. R. OPPENHEIMER, *University of California.*—The recent proof[1] that the majority of the primary cosmic rays are not electrons necessitates an entirely different explanation of the atmospheric transition curve, and demands a separate source for the energetic soft radiation responsible for large showers and bursts at higher elevations and for Auger showers. Schein's suggestion that the primary protons are, in the stratosphere, almost entirely converted into preferentially low energy mesotrons which mostly decay in the atmosphere, is capable of accounting for the transition curve in air, but fails to explain the source of the energetic soft component. Apart from the possibility that a small but sufficient fraction of the primaries are electrons, two possibilities suggest themselves. There will be a weak radiation associated with the creation of mesotrons, analogous to the internal bremsstrahlung of electrons, although complicated by the probably multiple production of mesotrons. Or we may have to do with production, in numbers roughly equal to that of penetrating mesotrons, of fast-decaying mesotrons. Mesotrons decaying in $\sim 10^{-8}$ sec. would account for the increase in large bursts and showers with elevation, as well as for β-decay lifetimes.

[1] M. Schein, W. P. Jesse and E. O. Wollan, Phys. Rev. **59**, 615 (1941).

8. On the Charged Scalar Mesotron Field. JULIAN SCHWINGER, *University of California.*—The charged nature of the mesotron field and the large magnitude of nuclear coupling prohibit both the conventional perturbation discussion and the classical approach to mesotron dynamics. This situation is particularly evident in the current treatment of the anomalously large theoretical scattering of charged mesotrons by nuclear particles. To circumvent these difficulties, Bhabha and Heitler have proposed the existence of slightly more massive states of the nucleon with charges of 2 and -1 units. However, such isobaric states may be expected to be a consequence of the large nuclear coupling binding mesotrons in stationary states around the nucleon. This has been investigated for the scalar mesotron field interacting with an infinitely massive nucleon through a finite-distance coupling, in the limit of large coupling strength. Stationary states of the system exist for all values of the total charge number Q, the energy exhibiting a quadratic charge dependence, $E = E_0 + \frac{1}{2}\epsilon(Q - \frac{1}{2})^2$. The quantity ϵ varies inversely with the square of the coupling strength. The mesotron scattering cross section is of the order of nuclear dimensions for large coupling. The scattering is non-multiple, the scattered field consisting of equal numbers of positive and negative mesotrons.

9. Multiple Production of Mesotrons by Protons. E. C. NELSON AND J. R. OPPENHEIMER, *University of California.*—A puzzling feature of mesotrons is that their production in the upper atmosphere by primary cosmic rays (presumably protons[1]) in collisions with nuclei is copious, and probably highly multiple, while their subsequent absorption through nuclear scattering is apparently not multiplicative, and rare. This feature appears in a model in which

the mesotron field is strongly coupled to the proton,[2] instead of weakly coupled as is assumed in usual perturbation treatment of nuclear problems. A proton scattered by a nucleus radiates a mesotron field which is given, for short collision times, by the difference between the field of the proton before and after the collision. Calculation of the number of mesotrons emitted, using a charged, scalar mesotron field and determining the cut-off in momentum space by conservation of energy, gives for large energy loss of the proton a multiplicity

$$\frac{1}{3\pi}\frac{g^2}{\hbar c}\ln\left(\frac{10\Delta E}{\mu c^2}\right),$$

in close analogy to the corresponding radiation problem, and for

$$\frac{\Delta E}{\mu c^2}\frac{\hbar c}{g^2}\ll 1$$

a multiplicity $\Delta E/\mu c^2$.

[1] M. Schein, W. P. Jesse and E. O. Wollan, Phys. Rev. **59**, 615 (1941).
[2] See abstract No. 8 of this meeting.

10. Cloud Chamber for Cosmic-Ray Studies. CARL D. ANDERSON AND SETH H. NEDDERMEYER, *California Institute of Technology.*—A large cylindrical cloud chamber of 60-cm diameter and 7.5-cm depth has been constructed for observations on cosmic rays. It is mounted in an electromagnet capable of producing a field of 7000 gauss throughout the whole volume of the chamber at a power consumption of 60 kw. Higher field strengths (up to 12,000 gauss) are obtainable at the same power under conditions where the full vertical length of the chamber can be photographed, but where the horizontal width available for photography is limited. All the necessary operations are carried out automatically and Geiger counters are used for tripping the chamber. By means of two cameras, two views are taken and by reprojection through the same optical system the tracks are reproduced in space for stereoscopic measurements.

11. Long-lived Radioactive Cd from Deuteron Bombardment of Ag. A. C. HELMHOLZ, *University of California.*—In connection with work on the 40-sec. Ag isomer growing from the 6.7-hr. Cd activity,[1] a long period Cd also resulting from the Ag(d,2n)Cd reaction has been observed. Its half-life is 158±7 days. The radiations consist of soft electrons, x-rays and γ-rays, in agreement with the findings of Krishnan.[2] In addition it has been found that a 40±3 sec. Ag activity grows from this long-lived Cd. Attempts to find isomerism of the 158-day activity decaying to the 6.7-hr. activity have failed. Photographs taken with a β-ray spectrograph show for the short period a converted γ-ray of energy 92 kv, for the long period a converted γ-ray of 86 kv. It is believed that this difference is real. If so, both Ag^{107} and Ag^{109}, formed by K capture, have excited states which decay to the ground states with half-lives of about 40 sec. Both long and short periods have weak γ-rays of energy about 600 kv. A discussion of possible level schemes will be given.

[1] L. W. Alvarez, A. C. Helmholz and E. Nelson, Phys. Rev. **57**, 660 (1940).
[2] R. S. Krishnan, Proc. Camb. Phil. Soc. **36**, 500 (1940).

12. Circuit Independence of Charge in Fast Counter Pulses. H. G. STEVER, *California Institute of Technology.*—The mechanism of discharge of fast, or self-quenching, counters, which was postulated to explain the dead-time and associated phenomena,[1] demands efficient ionization in the neighborhood of the wire. This ionization must take place in a short time and be largely independent of the external circuit constants such as series resistance and capacity to ground of the wire system. The independence of amount of charge with respect to the external resistance is easily shown. The charge in a single pulse was measured for various values of resistance and voltage. At a particular voltage, the charge did not vary with series resistance. The charge did increase approximately linearly with overvoltage, or voltage above threshold. The independence of charge with respect to the wire-to-ground capacity was shown by varying both R and C to keep RC constant. The voltage pulse varied linearly with $1/C$ indicating independence of amount of charge with respect to capacity.

[1] H. G. Stever, Phys. Rev. **59**, 219 (1941).

13. The Energy Spectrum of H^3 β-Rays. CARL E. NIELSEN, *University of California* (*Introduced by R. B. Brode*).—H^3 is β-radioactive with long half-life; the maximum β-ray energy is of the order of 10 kev. The total ionization, hence the energy, of a low energy β-particle can be measured with the Wilson cloud chamber, if individual droplets can be counted, and if the correlation between droplets formed and ions present is known. The drop-ion correlation and the average energy loss per ion pair were determined from a study of the droplet clusters produced in the chamber by 8.86-kev x-ray photoelectrons. H^3 β-rays result in similar clusters. Count of the droplets gives the β-ray energy. 108 H^3 clusters photographed have a mean energy of 6.5 kev. For a Fermi distribution, the maximum energy is 9/5 of the mean; 9/5 of 6.5 kev is 11.7 kev. In disagreement with this value, linear extrapolation from the observed distribution indicates a maximum of 14.5 kev; and several clusters of 13.5 kev were observed. It is believed that the maximum energy is 14.5±1 kev.

14. Recoil from K Capture. L. W. ALVAREZ, A. C. HELMHOLZ AND B. T. WRIGHT, *University of California.*—Using a method similar to that used in the classical β recoil experiments,[1] we have exposed in vacuum a clean surface to a vacuum distilled layer of 6.7-hour Cd, formed by the Ag(d,2n)Cd reaction. We collected on this clean surface an activity of 40 seconds half-life, which must be the Ag activity known to be the daughter of the 6.7-hour Cd.[2] This passage of the Ag from one surface to the other may be due to (1) recoil from the neutrino emitted in the K capture of the Cd, (2) recoil from the x-ray following K capture, or (3) a change in the surface binding of the atom when it undergoes K capture.

[1] Philipp Donat, Zeits. f. Physik **45**, 512 (1927).
[2] L. W. Alvarez, A. C. Helmholz and E. Nelson, Phys. Rev. **57**, 660 (1940).

15. The Crystal Photo-Effect in d-Tartaric Acid. CHUNG KWAI LUI, *Oregon State College* (*Introduced by J. J. Brady*).—Brady and Moore[1] observed a crystal photo-effect in

tartaric acid. They reported that certain crystals which appeared to have flaws and were not very transparent gave a current response which started out in one direction just after the light was turned on, decreased rapidly with time of illumination, and then flowed in the opposite direction. This phenomenon has been investigated in detail. All clear well-formed single crystals exhibit this current-reversal phenomenon when light falls on certain points of the crystal surface. These points always lie between two regions which respond with normal current flows in opposite directions. The superposition of the two normal current-response curves gives a resultant which agrees with the observed current-reversal curve within the experimental error. The various current response curves for different illuminated faces of the crystal, including the current-reversal effect, are correlated by assuming a particular direction in the unit cell of the crystal for which the electrical conductivity is a maximum. The crystal photo-effect decreases rapidly as the temperature is raised above 23°C. At 50°C the photo-current approaches zero.

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

16. Diffusion in Alloys and Mechanical Strength. S. KYROPOULOS, *California Institute of Technology.*—In general, the structure of cast alloys does not represent equilibrium conditions. Thus, solid solutions tend to approach equilibrium by diffusion. If its rate differs for the components, diffusion must result in local volume expansion and formation of gaps. An extreme case has been previously studied by Masing and Overlach. It suggested itself in a typical case of bearing failure by cracking. Preceding cracking, mostly individual crystallites rise from the surface and carry the load in nonfluid lubrication, reducing the available surface by about 50 percent. The crystal boundaries are richer in the faster diffusing Sn. Consequently, gaps must form at the boundaries causing there stress concentrations which explains the predominance of boundary cracks, previously communicated by the author. Volume expansion was demonstrated by an optical method and confirmed by density measurements on annealed specimens. The cracked alloys show typical annealing structure. The phenomenon is general with current bearing alloys and sets a basic limit to strength obtainable with multi-component alloys. Due to its fundamental nature it may play a part in other fatigue phenomena.

17. Atmospheric Potential Gradient at Exposed Coastal Stations. E. J. FARRELL AND N. E. BRADBURY, *Stanford University.*—The diurnal variation in the fair-weather potential gradient of the earth involves two components. One of these, the unitary variation, changes simultaneously over the earth, and the other, the local variation, varies with local station time. Since the latter is primarily due to the normal daily convective cycle in the atmosphere over land stations, it should disappear over the open sea, and should be greatly reduced at exposed coastal stations subjected to a prevailing on-shore wind. Accordingly a portable recording potential gradient apparatus was constructed and set in operation on an exposed bluff near Golden Gate. The potential gradient values were compared with those recorded simultaneously at Stanford University. From the differences in the type of variation observed, an estimate of the magnitude of the effect of the unitary variation may be obtained.

18. Rapid Precision Gas Analysis by Infra-Red Absorption. R. ROBERT BRATTAIN AND O. BEECK, *Shell Development Company, Emeryville, California.*—Binary or, in some cases, multi-component mixtures of hydrocarbon gases are analyzed for a specific component by determination of the percent transmission at a single spectral position. Choice of this wave-length, which need not necessarily coincide with an absorption maximum of the component in question, and the method of finding the most favorable spectral slit width and specific adsorption path will be described. Application of this method in the analysis of two isomeric mixtures proved accurate to ± 0.5 percent for rapid routine analyses, but is more accurate under special precautions. One analysis (including sampling) takes about one-quarter man-hour as contrasted with 5 to 10 man-hours for the usual low temperature distillation. The method is easily adapted to continuous recording and to plant control for both gaseous and liquid streams. By selecting several suitable spectral positions more complicated mixtures could be completely analyzed. Although these analyses were performed on the research instrument described in abstract number 35, an inexpensive, simplified control instrument has already been constructed.

19. Direct Pen Recording of Galvanometer Deflections. D. J. POMPEO AND C. J. PENTHER, *Shell Development Company, Emeryville, California (Introduced by O. Beeck).*—A recorder is described which records directly the deflections of any instrument, using a light pointer, without recourse to photographic development processes. The recording is easily accomplished at pen speeds of 12.7 cm. per second across 25 cm. of chart without "hunting" taking place. The instrument has been satisfactorily used, with considerable saving in time, for recording current-voltage curves in polarographic analysis; for obtaining infra-red absorption curves; and for recording ion currents in mass-spectrographic work. Essentially the basic idea of this recorder is that the pen follows the light beam from an external galvanometer by mounting a double cathode photo-tube on the pen carriage so that both move as a unit. By means of vacuum tube amplifiers operating a reversible motor, the pen carriage moves to the left when the light beam deflects to the left on to the left photo-tube cathode and to the right when the right photo-tube cathode is exposed.

20. Infra-Red Reflectivities of Nickel at High Temperatures. CURTIS REID, *Oregon State College.*—The changes in the spectral reflectivity of nickel with temperature have been measured directly between 20° and 920°C in the region between 0.8 and 11μ. The reflectivities and their changes with temperature for wave-lengths longer than 5μ were found to be entirely in accord with Drude's formula $R=100-3650(\rho/\lambda)^{\frac{1}{2}}$; ($\lambda$ in microns, ρ in ohm-cm). In passing to shorter wave-lengths the reflectivity decreases more rapidly than the formula indicates and passes through

a sharp minimum of 58 percent at 1.0μ. The ratio of the reflectivity at 920°C to that at 20°C changes from 0.96 at 5μ through 1.00 at 2.15μ to 1.06 at 0.8μ. This corresponds to a change in the temperature coefficient of reflectivity from -4.4×10^{-5} per degree at 5μ through zero at 2.15μ to $+6.6\times10^{-5}$ per degree at 0.8μ.

21. Electrical Conduction and Crystallization Phenomena in Thin Films Deposited at Low Temperatures. EDGAR L. ARMI, *California Institute of Technology.*—An apparatus for depositing metal films by evaporation in high vacuum and measuring their electrical resistances up to 10^{15} ohms, previously described,[1,2] was redesigned for work at temperatures down to 14°K. After 4 minutes of deposition at low temperatures, at a rate of 2A/min., Pb films showed beginning of electrical conduction. When the molecular beam had been shut off, films 10A thick displayed the following behavior: Below 100°K, conductivities increased by a factor of several hundred towards stationary values, a phenomenon which was accelerated by raising the temperature. At ca. 100°K, decrease of conductivity set in and was greatly speeded up by higher temperatures, leading finally to complete destruction of conduction. To explain this behavior, it may be assumed that two different processes are occurring in the films: (1) formation of conductive metal from the deposited molecules, (2) agglomeration into crystallites, the latter process taking place at appreciable rates at temperatures only above 100°K.

[1] A. B. Anderson and A. Goetz, Phys. Rev. **45**, 293 (1934).
[2] M. G. Foster, Phys. Rev. **57**, 42 (1940).

22. A Carbon Carrier of Oligodynamically Active Silver for Water Disinfection. F. S. HARRIS, JR., A. GOETZ AND R. L. TRACY, *California Institute of Technology.*—A carbon carrier of active silver has been developed to utilize the disinfecting properties of oligodynamic silver ion concentrations (0.05–0.5 parts per million). A certain type of hard carbon, consisting mainly of lamp-black, was found to fulfill the prerequisite conditions of electrical conductivity and capacity for electrolytic adsorption. This material in the form of small cylinders is impregnated with silver by soaking it first in a silver nitrate solution. After air-drying the carbon is heated in a muffle furnace to reduce the silver to metallic form, finely dispersed throughout the body of the carrier. The silver is then "activated" by making the carrier anode in an electrolyte and charging with 50–60 coulombs/g carbon at a current density of about 7 ma/cm^2 for 30 minutes. Subsequently, the carbon-silver-carrier is rinsed, dried and ready for use. It is stable over very long periods of time, unaffected by temperatures (<300°C) and humidity. Upon immersion in water the carrier emits germicidally active silver; the emission, declining exponentially with time, is complete in a few hours. Water thus treated oligodynamically is nontoxic, tasteless and odorless.

23. Dependence of Band Absorption on Pressure. MARTIN SUMMERFIELD AND JOHN STRONG, *California Institute of Technology.*—Experiments on carbon dioxide,[1] water vapor,[2] and ozone[3] have yielded the result that, over a wide range of pressure, the infra-red absorption is proportional to the fourth-root of the total pressure. This fact suggested that the widths of infra-red lines are proportional to the square-root of the pressure, not to the first power, as the Lorentz theory requires. Formulas for the integrated absorption of a band[4] were applied to our measurements on ozone[5] and an "effective value" of the rotational spacing of the 9.6μ band was calculated. Using this value, it is shown that the empirical $p^{\frac{1}{2}}$ relation can be derived on the basis of Lorentz line broadening, and is consistent with the proportionality of width to pressure. This slower increase of absorption with pressure is due to the overlapping of the wings of lines, the fourth-root dependence appearing even though the width is less than 1/10 of the spacing.

[1] G. Hertz, Verh. deut. phys. Ges. **13**, 617 (1911).
[2] J. Kühne, Zeits. f. Physik **84**, 722 (1933).
[3] Strong and Watanabe, Phys. Rev. **57**, 1049 (1940).
[4] Elsasser, Phys. Rev. **54**, 126 (1938).
[5] Summerfield and Strong, Phys. Rev. **59**, 217A (1941).

24. X-Ray Studies of Magnesium Single Crystals at Low Temperatures. A. DEMBER AND A. GOETZ, *California Institute of Technology.*—The effect of temperature on the reflection of x-rays from Mg single crystals was investigated in the range from 14°K to 300°K. Intensity distributions (rocking curves) of the Mo $K\alpha$ doublet were obtained with a recording ionization spectrometer of the Bragg type. The crystal was mounted in a cryostat, previously described,[1] and could be maintained at constant temperature anywhere between the triple point of hydrogen and room temperature. Evaluation of the records enables one to determine the relative integrated intensities of reflection as well as the changes in lattice spacing. Measurements were made on planes perpendicular and parallel to the hexagonal axis for different orders of reflection. Characteristic temperatures (Θ_{II}, $\Theta_{\perp}$) and coefficients of thermal expansion (α_{II}, $\alpha_{\perp}$) were calculated and a discussion is given of their relation to data[2,3] (obtained by other methods) on thermal and electrical properties of single crystals and polycrystalline material.

[1] A. Goetz and A. Dember, Phys. Rev. **56**, 857 (1939).
[2] H. Ebert, Zeits. f. Physik **47**, 712 (1928).
[3] P. W. Bridgman, Proc. Am. Acad. **66**, 255 (1931); **67**, 29 (1932).

25. An Absolute Intensity Determination in the Continuous X-Ray Spectrum of Nickel. EDWARD SMICK AND PAUL KIRKPATRICK, *Stanford University.*—A sheet of nickel 506A thick, backed only by a film of cellulose acetate, was bombarded normally by 60 microamperes of electrons of 15.0-kev energy. X-rays leaving the target in a direction making a mean angle of 88° with the direction of motion of the electrons were analyzed with Ross filters of copper and nickel having a pass band at 1.431A and were then absorbed in a large standard ionization chamber filled with air. Absolute charge measurements were made with a calibrated electrometer. Corrections for absorption and other disturbing effects were applied. Taking the energy per ion pair as 33 electron volts these measurements give for the stated wave-length, emission angle, electron energy and target element a radiation output at the target of 2.2×10^{-50} ergs per unit frequency interval per steradian per bombarding electron per atom-per-square-centimeter of

target area. No quantitative theory fully applicable to these conditions is known, but Sauter's[1] treatment with a slight modification predicts the value 2.9×10^{-50}, agreeing with the experiment within the uncertainties of the two values.

[1] F. Sauter, Ann. d. Physik **20**, 408 (1934).

26. Further Experiments Concerning the Determination of h/e by the Short Wave-Length Limit of the Continuous X-Ray Spectrum. J. W. M. DuMond, W. K. H. Panofsky and A. E. S. Green, *California Institute of Technology.*—Recently, new results regarding the value of h/e as obtained by x-ray methods were obtained by Bearden and Schwarz[1] and Per Ohlin.[2] The experiments of Bearden and Schwarz reconfirm the value of h/e as obtained previously which lies about 0.2 percent lower than the value computed from indirect determinations. The value of Ohlin agrees with the preliminary results obtained by us and the indirectly computed values. In order to investigate the cause of these discordant results the influence on the shape and position of short wave-length limit isochromats of the following factors was noted: (1) the effect of deposits on the target was investigated by installing a device in the x-ray tube to clean the target in vacuum. (2) The effect of the slow decline of the monochromator pass band "wings" was investigated further by using a 2-crystal monochromator in conjunction with a set of balanced filters and by changing the wave-length separation between the filter edges and the crystal monochromator peak. The conclusion was reached that both factors will profoundly influence the value of h/e as obtained by short wave-length limit measurements.

[1] Bearden and Schwarz, Bull. Am. Phys. Soc., Washington Meeting, May 1–3, 1941.
[2] Per Ohlin, Arkiv Mat. Astro. Fysik, 27B, No. 10 (1940).

27. The Polarization of X-Rays from Thin Targets. Brewer F. Boardman, *Stanford University and Fresno State College* (*Introduced by Paul Kirkpatrick*).—The polarization of x-rays from thin nickel, silver, and lead targets is measured as a function of tube voltage for the wave-length band between 0.176 and 0.184A. The targets are thinner than 1000A, made by vacuum evaporation onto thin plastic films. The method is that of 90° scattering from paraffin as used in a previous study,[1] but the x-ray tube is redesigned to eliminate stray radiation at voltages above 110 kv and to use targets of large area. Corrections are calculated for secondary and tertiary scattering in the paraffin. The rays from silver show the same complete polarization at the quantum limit as those from Piston's 1700A foil, have slightly higher polarization between 70 and 90 kv and lower beyond 90 kv. Nickel gives similar results; and of two nickel films the thinner gives somewhat more polarized rays. X-rays from lead are apparently only three-quarters polarized at the limit, and depolarize more rapidly with increasing voltage than those from films of lower atomic number. The polarizations decrease more rapidly than is called for by Elwert's theoretical work.[2]

[1] Piston, Phys. Rev. **49**, 275 (1936).
[2] Elwert, Ann. d. Physik **34**, 178 (1939).

28. Extended X-Ray Absorption Fine Structure in Solutions. S. T. Stephenson, *State College of Washington.*—The extended K absorption structures of Cu and Se in $CuSeO_4$ solutions of about $1N$ concentration have been studied. Se shows a definite structure which is similar to that for the solid state.[1] This substantiates the view[1] that the immediate surroundings of the atom from which the K electron comes are more important in determining extended fine structure than the crystal lattice itself since Se still has its four O neighbors while in solution, but is no longer in a crystal lattice. Cu showed no extended fine structure pronounced enough to be observed. This can be expected because the Cu ion in solution lacks the close neighbors which it had in the solid state.

[1] S. T. Stephenson, Phys. Rev. **58**, 873 (1940).

29. Relative Intensities in the Nickel Continuous X-Ray Spectrum. Keith Harworth and Paul Kirkpatrick, *Stanford University.*—A sheet of nickel 199A thick, prepared by condensation upon a thin film of cellulose acetate, was bombarded normally with electrons in the energy range from 10 to 180 kev. X-radiation leaving the target in a direction making a mean angle of 93.5° with the direction of motion of the electrons was analyzed with Ross filters and an ionization chamber. (The apparatus resembled that of abstract 25 but was an entirely separate outfit.) Wave-length bands centered at 0.497A (Ag-Pd), 1.01A (Se-As) and 1.431A (Cu-Ni) were isolated by the filters and intensity measurements performed at voltages within the above range. The data were corrected for electron retardation and scattering in the target, for slight effects due to the backing film and other matter near the target, and for various absorptions to which the radiation was subject. Isochromats and spectrum curves for the independent nickel atom are in partial agreement with theoretical curves.

30. New Spectra in Nitrogen. Joseph Kaplan and Sidney M. Rubens, *University of California at Los Angeles.*—A tube, containing nitrogen at 50 mm and conditioned to produce a strong auroral afterglow when properly excited, has been studied when the discharge is weak. The weak discharge resembles the ozonizer used by Wulf and Melvin to excite the Vegard-Kaplan bands at atmospheric pressure. The green line is strong in the continuous "ozonizer" discharge and it is accompanied by the Vegard-Kaplan bands and by a set of five bands between 5000A and 6100A, one of which falls under the green line. The new bands and the green line disappear when enough oxygen is added to quench the auroral afterglow. The bands persist as the oxygen cleans up. The weak discharge is the most auroral-like source of the green line so far observed. The addition of helium reduces the intensity of both the green line and the new bands. The presence of these bands as well as the high efficiency of the green line excitation may thus be due to chemical action in the discharge, the green line due to excitation and dissociation of ozone and the new bands to N_3 or to a triatomic oxide of nitrogen.

31. Resonance Broadening of Homogeneous Caesium Vapor in Absorption. CHRIS GREGORY, *California Institute of Technology.*—The resonance broadening of homogeneous Cs vapor in absorption was studied by means of the contour method. The intensities were obtained via the method of "astigmatic photometry" by utilizing the astigmatism of the Rowland grating. The pressure of the homogeneous absorbing vapor ranged from 10^{-2} to 17.5 mm Hg. The half-breadth varied rather linearly with the number of atoms per unit volume, with $(\gamma_1/N)\times 10^7 = 1.45$, $(\gamma_2/N)\times 10^7 = 0.84$ for the $^2P_{3/2}$ and $^2P_{1/2}$ components, respectively, of the resonance lines. The average value of the ratio of half-breadths γ_1/γ_2 was found to be 1.8. The experimental half-width γ is found to be about $1\frac{1}{2}$ times larger than that predicted by Professor Houston. Below pressures of 10 mm Hg the lines exhibited symmetrical broadening according to the "dispersion" formula. At higher pressures indications of a violet and red asymmetry are present for the $^2P_{3/2}$ and $^2P_{1/2}$ components, respectively. A definite band on the red side of the $^2P_{3/2}$ and one on the violet side of the $^2P_{1/2}$ was observed.

32. The Quadrupole Moment of the Deuteron and the Range of Nuclear Forces. JULIAN SCHWINGER, *University of California.*—The quadrupole moment is a unique property of the deuteron, for its very existence demands a finite range of the forces. This is a simple consequence of the observation that the D wave function must vanish in the limit of zero range, for being of the form $e^{-\alpha r}(1+3/\alpha r+3/(\alpha r)^2)$, it possesses inadmissible singularities. This fact, combined with the upper limit to the amount of D state provided by magnetic moment measurements, sets a lower limit to the range of nuclear forces. This limitation can be placed in quantitative form with the aid of the approximate equations:

$$w_D=\frac{5}{3}\frac{\alpha r_0}{1+\alpha r_0}\chi^2, \quad Q=\frac{2^{\frac{1}{2}}}{6}\frac{r_0^2}{1+\alpha r_0}\chi,$$

which express the D state probability and the quadrupole moment in terms of the force range and the quantity χ, the ratio of the D to S wave function at the boundary of the well. Hence, $w_D=30\alpha r_0(1+\alpha r_0)(Q/r_0^2)^2$, an equation which is practically independent of any details of the interaction other than that both ordinary and tensor interactions possess the common range r_0. Thus the limitation $w_D<5$ percent implies $r_0>2.6\times 10^{-13}$ cm.

33. On the Internal Pairs from Oxygen. J. R. OPPENHEIMER, *California Institute of Technology.*—Because the pair producing fields are here limited to the interior of the nucleus, the energy and angle distribution of the internal pairs from excited O^{16} is quite different from that for pairs made by gamma-rays and by internal conversion. In deriving the distribution we can neglect the Coulomb field and the ratio of nuclear radius to wave-length. We then find, if $E\pm$, $p\pm$ are energy and momentum of positron and electron, and ϑ is the angle between them,

$$dN=dE_+d(\cos\vartheta)p_+p_-(E_+E_--m^2c^4+p_+p_-c^2\cos\vartheta).$$

34. On a Modification of Planck's Quantum Theory with Special Reference to an Explanation of His Oscillators. SAMUEL R. COOK, *Sacramento, California.*—A statement of Planck's quantum theory in the light of the tenets of the radiant energy theory of the geneses and absorption of primary x-rays is given and it is shown that, if the processes of geneses and absorption, as given in the radiant energy theory, be substituted for Planck's oscillators, Planck's quantum theory is very simply explained. It is also shown that the quantum concept is applicable both to geneses and absorption and that, with the modification of Planck's quantum theory, by the substitution of the radiant energy theory *processes* for Planck's *oscillators*, a quantum theory for all forms of radiation may be simply and scientifically explained.

35. An Automatic-Recording Vacuum Spectrograph for the 2μ to 27μ Region. R. ROBERT BRATTAIN, *Shell Development Company, Emeryville, California.*—An infra-red vacuum spectrograph, of the Wadsworth-Littrow type, which incorporates the following features, is described: (1) A double bilateral slit is opened automatically and continuously by a cam arrangement in such a manner that the energy remains constant when either the 2μ to 15μ or 14μ to 27μ region is mapped. (2) The prism is turned by another cam arrangement at such a rate that regardless of the variation of spectral slit-width with prism position and regardless of the variation of actual slit-width necessary to maintain constant energy, the prism turns through each spectral slit-width in constant time. (3) As a result of (1) and (2) an approximately constant spectral slit-width is maintained over a large part of the 2μ to 27μ region. (4) Absorption spectra are recorded directly and automatically in terms of percent transmission *versus* wave-length.

Author Index to Abstracts of Papers Presented at the Pasadena Meeting