Proceedings of the American Physical Society

MINUTES OF THE STANFORD MEETING, DECEMBER 15–16, 1933

THE 188th regular meeting of the American Physical Society was held at Stanford University, Stanford, California, in the main lecture room of the Physics Department on Friday, December 15th, and Saturday, December 16th, 1933. Professor David L. Webster, Chairman of the Physics Department, Stanford University, presided.

The sessions lasted on Friday from 9:00 until 12:30 and from 1:30 until 5:00. The session on Saturday morning began at 9:15 and terminated at 12:00 noon. There was a luncheon for members of the society at the Stanford Union on Friday noon.

The sessions were attended by some sixty members of the society covering the territory ranging from Los Angeles to San Francisco. At 10:00 on Friday, December 15th, there was a short business session at which the following matters were brought up.

It was voted, in conformity with previous announcement, to hold the 192nd regular meeting of the American Physical Society on the Pacific Coast at Berkeley, California, during the week, June 18–23, 1934, in affiliation with the Pacific Coast meeting of Section B of the A.A.A.S. The decision as to details of the arrangements of the meetings at this time was left in the hands of the secretary who will early in 1934 request a committee to act in formulating plans for the meeting.

It was further voted to empower the representative of the Pacific Coast group of physicists delegated to the affiliations committee of the Pacific Division of the American Association for the Advancement of Science to be free to vote a change in the date of the 1935 meeting of the Pacific Division of the A.A.A.S. which had originally been set tentatively as September, 1935, if in the eyes of the Pacific Division a June meeting in 1935 at Southern California would be preferable to the September meeting. This vote was necessary in view of the fact that the Physical Society had unofficially committed itself to the September date at the Pullman meeting of the Society in consultation with the executive committee of the Pacific Division. Circumstances connected with the convention of the American Chemical Society in San Francisco in September, 1935, and the commitment of the Pacific Division to hold the 1935 meeting in the Los Angeles area have necessitated a change in plans as regards the 1935 Pacific Division meeting to prevent a serious conflict with the Chemical Society meetings. The vote taken thus enabled the representatives of the Physical Society on the affiliations committee of the Pacific Division to use their judgment in assisting the Pacific Division to arrive at a proper solution of the present complications concerning the time of the 1935 meeting.

There were forty papers on the regular scientific program of the Society. The abstracts of these papers are given in the following pages.

LEONARD B. LOEB,
Local Secretary for the Pacific Coast

ABSTRACTS

1. The Ratio of Fluorescence Yields of the L_{11} and L_{22} Sub-Series of Lead. B. E. FOSTER, *Stanford University.*— The intensity of an x-ray line depends upon the probability of excitation and the fluorescence yield of the series to which the line belongs. The ratio of total intensities, then, of the L_{11} and L_{22} groups equals the ratio of the products of their probabilities of excitation by their respective fluorescence yields. If one can obtain a comparison between the total fluorescence intensities of the L_{11} and L_{22} groups, the ratio of fluorescence yields of the two sub-series can be ob-

tained, since the comparative excitation probabilities can be gotten from the heights of the absorption discontinuities of the fluorescence material, provided the primary wave-length is near that of the L_{11} limit. This condition was satisfied here with Pb irradiated with Mo $K\alpha$-rays filtered through ZrO_2. The determination of the intensity of the L_{11} and L_{22} groups may be made by measuring a representative line or two in each sub-series and computing the total intensity from known relations existing between the lines in each sub-series. In this experiment $L\beta_6$ and $L\beta_5$ of the L_{22} group have been compared photographically with $L\beta_4$ of the L_{11} group. Rough preliminary measurements give the ratio of the total number of quanta coming from these two series as: $L_{11} : L_{22} = 6 : 70$. Data taken from unpublished work of C. G. Patten indicate that the ratio of the absorption discontinuities is: $L_{11} : L_{22} = 0.185 : 0.490$. This gives for the fluorescence yields: $L_{11} : L_{22} = 2 : 9$.

2. Relative Probabilities of the Ionization of K and L Electrons of Equal Ionization Energy. B. G. EATON, *Stanford University.*—The L_{22} excitation potential of thallium being 12.6 kv and the K of bromine being 13.4 kv, the compound TlBr has in it a K level and an L level which have approximately the same ionization voltage. Likewise in $Th(MoO_4)_2$ the L_{21} voltage of Th is 19.7 kv and the K of Mo is 20.0 kv. The relative probabilities of the ionization, by impact, of K and L electrons of equal ionization energy can be determined by measuring the relative numbers of quanta emitted from these levels when such a compound is bombarded by cathode rays. The x-ray spectra of these compounds were photographically recorded, and the ratio of the intensity of the $K\alpha_1$ of Mo to that of the $L\beta_1$ of Th was found to be about 1 : 1. This means that there are about 4/3 as many quanta in the K series altogether as in the L_{21}. The $K\alpha_1$ of Br was about 3/10 the intensity of the Tl $L\alpha_1$. Here the K level gives off 1/3 as many quanta as does the L_{22}. Since Allison's relative intensities in the Th L series give 100 to 40 as the ratio of the numbers of quanta emitted in L_{22} and L_{21} respectively, the ratio for equal numbers of electrons would then be about 1 : 0.8 for L_{22} and L_{21}. The relative intensities of TlBr and $Th(MoO_4)_2$ reported here therefore give 2/3 as many quanta emitted per K electron as per L_{21}. The number of quanta emitted divided by the fluorescence yield ϕ gives the number of ionizations taking place. ϕ for Mo K is given by Compton as 0.68, and for U L_{22} by Stephenson as 0.67; and the yield for Th L_{22} is probably about the same as for U L_{22}. As the K and L value are the same the relative numbers of quanta coming off are the same as the relative numbers of ionizations. Thus under cathode-ray bombardment any K electron is $\frac{1}{2}$ as likely to get ionized as any L_{22}.

3. Polarization of General X-Rays from Thick Targets. YEE FUNG CHENG, *Stanford University.*—The method applied in this experiment is that of 90° scattering combined with the balanced filter method. Bands of the x-ray spectrum between K-absorption limits of columbium and molybdenum, of palladium and rhodium, and of tungsten and tantalum from different targets of tungsten, copper and aluminum have been tested for polarization, using voltage from about 20 kv to 100 kv. From results so far obtained the following conclusions have been drawn. First, the polarization increases as the voltage decreases and increases very rapidly as the quantum voltage of each band is approached. Second, while the maximum experimental value of polarization obtained was not over 60 percent, the polarization at the quantum voltage of the band, obtained by extrapolation, is nearly complete. Third, the polarization of x-rays from the targets of lower atomic number is higher than from the targets of higher atomic number, except near the quantum voltage where they approach 100 percent.

4. X-Ray Line Intensities in Thick Targets of Nickel. L. T. POCKMAN, PAUL KIRKPATRICK AND D. L. WEBSTER, *Stanford University.*—$K\alpha$ line intensities of thick nickel have been measured as functions of voltage up to 180 kv for rays emerging from the target at various angles, by methods previously used for silver. (Phys. Rev. **44**, 258 (1933).) When the intensities are expressed as functions of U, the ratio of tube voltage to excitation voltage, the results are very much like those for silver up to its limit, $U=7$, but the limit for nickel is $U=21.6$. The effect of target absorption (estimated by Kulenkampff's method) is less for nickel than for silver at any given value of U, but greater at any given voltage. Intensities and emission efficiencies for nickel reach maxima as follows: for rays emerging at 1° from the target face, at 40 kv and 20 kv, respectively; 2°, 53 kv, 25 kv; 6°, 75 kv, 40 kv; 11°, 100 kv, 50 kv; 16°, 140 kv, 55 kv; 21°, 160 kv, 60 kv; 26°, 180 kv, 65 kv, with target absorption eliminated, over 180 kv, 110 kv. Beyond the maxima the intensities at all angles decline very slowly.

5. The True Absorption Coefficients for the Elements from Gold to Bismuth in the Neighborhood of the L-Absorption Edges. C. G. PATTEN, *University of California. (Introduced by R. B. Brode.)*—Thin films of thallium, lead and bismuth were made by evaporation of the metals onto very thin sheets of mica. Oxidation of the films was prevented by coating with a thin layer of aluminum. Effects due to possible irregularities in the films were averaged out by keeping the film in constant motion before the slits. The ionization currents were measured with a F.P. 54 Pliotron vacuum tube amplifier and the readings were constant within one percent. The true absorption coefficients τ_1, τ_2, and τ_3 corresponding to the photoelectric absorption by the three types of L electrons were found to vary approximately as $\lambda^{2.6}$ for each of the five elements gold to bismuth. The data for gold were obtained by Uber and Patten (Phys. Rev. **42**, 229 (1932)) and for mercury by Uber (Phys. Rev. **38**, 217 (1931)). With this relation the τ's were computed for a given wave-length. Their ratio $\tau_1 : \tau_2 : \tau_3$ (which is therefore independent of the wave-length) was found to be constant over the range 0.5 to 1.5A and to have approximately the same value for each of the five elements. The value of the ratio $\tau_1 : \tau_2 : \tau_3$ was found to be 19 : 32 : 49. This ratio also gives the relative numbers of photoelectrons ejected from the three L shells by radiation of a given frequency. Ratios of τ_1, τ_2, and τ_3 which are evaluated at their respective absorption edges L_{I}, L_{II}, and

L_{III} were also determined. This ratio of τ_2/τ_3 was found to be approximately 0.45 for each element and is in very good agreement with the value predicted by relativistic theory. (See abstract No. 6.) The ratio $\tau_1/(\tau_2+\tau_3)$ has been found theoretically only by means of a non-relativistic treatment of absorption. The experimental value, 0.163, is not in good agreement with the predicted value.

6. Theoretical Ratio of L_{II} and L_{III} X-Ray Absorption Coefficients. MELBA PHILLIPS, *University of California.*—On the assumption of a Coulomb field for the narrow range of the $2p$ electrons the relativistic radial wave functions may be used to calculate the ratio of the absorption coefficients for the L_{II} and L_{III} x-ray edges. Thus a correction for the coupling of spin and orbit is introduced. $\tau_{L_{II}}/\tau_{L_{III}}$ was found to have the value $1-0.35(\alpha Z_{eff})^2$ per electron, giving a correction to the "sum rule" ratio, 1 : 2, which holds for light elements. A reasonable choice of the effective nuclear charge for the elements Au to Bi makes $\tau_{L_{II}}/\tau_{L_{III}}=0.45$, in agreement with the observations of C. G. Patten.

7. A New Method of Measuring Doublet Separations with a Fabry-Perot Interferometer. WILLIAM V. HOUSTON, *California Institute of Technology.*—When the orders of interference of the two lines differ by Δp, the wave-number difference is $\Delta p/2d$, where d is the distance between the plates. The principal uncertainty in the ordinary method is due to the uncertainty in the location of the point on the fringe which should be measured. If one tries to find the plate separation, d_0, for which $\Delta p=1/2$, the accuracy can be much increased. The separation d_0 is characterized by the fact that all the minima of intensity are the same. This point can be located by means of interpolation by the following equation. If M_1 is the intensity of the minima between the members of the doublet, and M_2 is the intensity of the minima between the adjacent orders, $(1/\alpha)$ log (M_1/M_2) is a function of d which is zero for $d=d_0$, and is a linear function of d in the neighborhood of this point. The quantity α is given by

$$(L_1+L_2)/(M_1+M_2)=(1+2e^{-\alpha/4})/2e^{-\alpha/16},$$

where L_1 and L_2 are the intensities of the two maxima.

8. The Doublet Separations of the Balmer Lines. W. V. HOUSTON AND Y. M. HSIEH, *California Institute of Technology.*—An analysis of the theoretical shapes of the components of the Balmer doublets shows that, with the exception of $H\alpha$, they should be essentially symmetrical about the centers of gravity. Hence if the separation is measured by the method described in the previous abstract, the result will give the separation of the centers of gravity of the components. For $H\alpha$ a correction of about 1 percent must be applied. These measurements have been made on the first five members of the series. The source was a discharge-tube cooled in liquid air and operated under such conditions that the intensity ratios of the components were those expected theoretically. The results indicate that all of the doublets are about 3 percent narrower than is to be expected theoretically. This large discrepancy cannot be attributed to an uncertainty in the fine structure constant, and so must be attributed to a deficiency in the theory when this degree of precision is required.

9. The Spectrum of Fluorine, F II, F III, F IV. I. S. BOWEN, *California Institute of Technology.*—The spectrum of fluorine extending from 125A to 620A has been obtained with a two-meter grazing-incidence spectrograph. By using these new determinations and the previous measurements in the longer wave-length region made by Dingle and by the author, it has been possible to classify 37 additional lines in F II. The newly classified lines are largely due to transitions to the singlet and triplet terms of the s^2p^4 and sp^5 configurations. In F III, 96 new identifications have been made including 14 intercombination lines. These consist largely of transitions to terms of the s^2p^3 configuration, and of transitions between terms based on the ^1D state of the core. 21 new lines have been classified in F IV. These new identifications include most of the strong lines that had not already been accounted for. These analyses yield the following ionization potentials: F II 34.81 volts, F III 62.35 volts, F IV 87.34 volts.

10. Hyperfine Structure in the Arc Spectrum of Lanthanum. O. E. ANDERSON, *University of California.*—The hyperfine structure analysis previously reported for the arc spectrum of lanthanum has been extended to include a number of new lines and energy levels. These measurements afford a convenient experimental check on the formulas of Goudsmit and Bacher as applied to electron configurations involving three electrons. The spectrum was excited in a liquid-air-cooled Schüler tube and photographed with a three-meter flint prism spectrograph crossed with Fabry-Perot etalons. By setting the prisms off from minimum deviation a relatively high dispersion, sufficient to eliminate the troublesome overlapping of many of the lines, was obtained. Of particular interest in the measurements are the overall separations of the hyperfine structure terms arising from $5d^2\,6s$, $^4F_{3/2,\ 5/2,\ 7/2,\ 9/2}$. Both the hyperfine structure and the fine structure follow the Landé interval rule, and the overall separations are in good agreement with Goudsmit's and Bacher's equations.

11. Isotope Displacement in the Arc Spectrum of Tungsten. KENNETH R. MORE, *University of California.*—W I lines were excited in a liquid-air-cooled Schüler tube operated at 2000 volts with currents from 0.07 to 0.4 amp. The spectrum was photographed with a three-prism glass spectrograph crossed with silvered Fabry-Perot etalons. Invar etalon separators up to 30 mm were used. Several of the stronger W I lines in the region 4000 to 5600A show three components which are roughly equally spaced and are of the same order of intensity. The greatest overall splitting observed is 0.17 cm^{-1}. Aston (Nature **126**, 913 (1930)) reports four isotopes of tungsten of mass and abundance 182, 22.6%; 183, 17.2%; 184, 30.1%; 186, 30.0%. Since the components observed are roughly equally spaced they are attributed to the three even isotopes. The intensity ratios of the three components vary somewhat from line to line. This latter suggests that the odd isotope is present and is

showing a narrow hyperfine structure which is masked by the components due to the even isotopes. The electron configurations are known only for the ground states of W I. They are $5d^4\ 6s^2$, ^5D and $5d^5\ 6s$, ^7S. Most of the lines that show isotope displacement arise from transitions to the levels $5d^4\ 6s^2$, ^5D.

12. The Spectrum of Magnesium Fluoride. F. A. JENKINS AND RAFAEL GRINFELD (*Fellow of the Rockefeller Foundation*), *University of California.*—Measurements of the rotational structure and of the band heads of the three band systems observed in the absorption spectrum of MgF have been made on plates taken with a 21-foot grating. In the $^2\Sigma$, $^2\Sigma$ system at λ2689, wave numbers of 29 resolved lines of the R branch of the 0,0 band, combined with those of the band head and of the band origin (which appears as a sharp minimum at $\nu_{00}=37{,}187.4$), are used to determine the constants $B_0'=0.537$ cm^{-1}, $B_0''=0.518\pm0.010$ and $r_0''=1.75\ 10^{-8}$ cm. In the $^2\Pi$, $^2\Sigma$ system at λ3594, starting with the value of B_0'' found above, measurements of the P_1, P_2 and Q_2 heads, of a minimum at 27,829.4 cm^{-1}, and of some outer lines of the Q branch, the following constants are derived: $B_0'=0.529$, $\nu_{00}=27{,}846.5$, $A=-34.3$ cm^{-1}. The $^2\Pi$ state is assumed to be inverted, as in BeF. If it is normal, $A=+38.3$. By using these constants in the Hill and Van Vleck formula for $^2\Pi$ terms, good agreement is obtained with the measured wave numbers of the heads. In the newly-discovered system at λ2275, the data are insufficient for the determination of constants. The isotope effect of Mg is observed with definiteness for the first time in this spectrum.

13. Electronic and Vibrational Absorption in O_4 and O_2 Molecules. JOSEPH W. ELLIS AND HANS O. KNESER (*Fellow of the Rockefeller Foundation*), *University of California at Los Angeles.*—We have studied the infrared, visible and near ultraviolet absorption spectrum of liquid oxygen. At wave numbers 793, 943 and 1088 mm^{-1} a progression of bands occurs which we identify with the $^1\Delta+v\omega$ ($v=0$, 1, 2) system predicted by Mulliken for O_2 in the infrared. The wave numbers of the three well-known visible and ultraviolet progressions (1587, 1730, 1874, 2020, 2164), (2094, 2235, 2387, 2548) and (2621, 2765, 2896, 3040) we find to be expressible by $\nu=m\,^1\Delta+n\,^1\Sigma+v\omega$, in which $(m, n)=(2, 0)$, (1, 1) and (0, 2) respectively, $^1\Sigma$ represents the wave number of the electronic term of the red "atmospheric" system for O_2 at 1307 mm^{-1}, and ω is the average of the nearly equal vibration terms of the $^1\Delta$ and $^1\Sigma$ systems. These progressions we believe arise from simultaneous excitations of the two loosely coupled O_2 systems which constitute the O_4 molecule. The slight degradation toward the violet of the individual bands is probably caused by the unresolved vibrational terms of the O_2-O_2 molecule. The assumption that the infrared $^1\Delta$ system is primarily a characteristic of the O_2 molecule rests upon its appearance in the solar spectrum of Abbott and Freeman, although we could not detect it with a 64-meter atmospheric path.

14. Dissociation, Excitation and Emission in Condensed Sparks at High Pressure. WOLFGANG FINKELNBURG (*Fellow of the Rockefeller Foundation*), *California Institute of Technology.*—In the spectrum of condensed sparks at high pressure one gets broadened lines of normal and ionized atoms, especially of highly excited levels. The probability of such excitations, especially of dissociation and ionization by single electron collisions, is extremely small, because the potential difference per mean free path of an electron is only a few volts. In hydrogen, where all excitation conditions are known very well, one is able to prove that the emitting H-atoms (molecular spectra do not appear) cannot be formed in one collision, but by a series of two or more successive excitations. Generally in condensed sparks the probability of re-excitations during the lifetime of an excited atom is high because of the high current density. In the hydrogen spark studied one atom suffered 10^3 electron-collisions during the mean lifetime of 10^{-8} sec. Consequently excitation, dissociation and ionization will be a result of re-excitations, and the normal excitation rules do not apply. The enormous broadening of lines usually described as the result of a Stark effect produced by the inhomogenous field of the ions is explained more accurately by interactions of the single particles.

15. Band Spectrum of Nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles.*—Further study of the unusual discharge tube described last December has led to several interesting nitrogen band spectra. In the present tube, the first negative bands are much more intense relative to the first positive bands than on the plates obtained last year. One of the most remarkable properties of the tube is the enhancement of bands which originate on high vibrational states of the molecule. This is shown by the discovery of at least a dozen new members of the Lyman bands of nitrogen. These bands arise in the $a\,^1\Pi-X\,^1\Sigma$ transition. In the first positive group, bands which arise on very high vibrational levels are also remarkably enhanced. The second positive group is nearly completely absent and the fourth positive group is present. The presence of the fourth positive group in an uncondensed discharge, as is the case in these experiments, is a rather unusual phenomenon. Two types of intensity distribution in the first negative bands are shown and their relationship to the spectrum of the aurora borealis is pointed out.

16. Analysis of the Infrared Bands of Formaldehyde. ARNOLD NORDSIECK, *University of California.*—The theoretically expected structure of the infrared bands of H_2CO, a slightly asymmetric coplanar molecule, has been worked out on the basis of Wang's theory of the asymmetric rotator (S. C. Wang, Phys. Rev. **58**, 730 (1929)), the calculations being modelled after those of D. M. Dennison (Rev. Mod. Phys. **3**, 289 (1931)) and H. H. Nielsen (Phys. Rev. **38**, 1432 (1931)). Four of these bands were resolved by J. R. Patty and H. H. Nielsen (Phys. Rev. **39**, 957 (1932)) and a larger number has recently been investigated under improved experimental conditions by Nielsen at Ann Arbor. Account being taken of the alternating intensities due to the presence of two H atoms, the structure seems to be explained satisfactorily. The moments of inertia found agree well with those deduced from the ultra-

violet spectrum by Dieke and Kistiakowsky (Proc. Nat. Acad. Sci. **18**, 367 (1932)).

17. The Value of e/m from the Zeeman Effect. L. E. KINSLER AND W. V. HOUSTON, *California Institute of Technology.*—The measurements of e/m by means of the Zeeman effect of the red singlet lines of Cd and Zn have been repeated with careful attention to all of the sources of experimental uncertainty. All apparatus has been duplicated and interchanged in such a way as to very much reduce the probability of instrumental errors. The magnetic field used in the solenoid was measured under the actual conditions of operation in order to determine the effects of the temperature rise and the mechanical stresses. The solenoid constant was found to decrease by about 1/1500 when the current was increased from 1 amp. to 190 amp. The field determination is believed to be correct to one part in three thousand. The results of the spectroscopic measurements, which were made with a Fabry-Perot interferometer, give $e/m=1.7570\pm0.0010$ e.m.u. The interpretation of these results in terms of e/m depends, of course, upon the theory of the Zeeman effect. If this theory should be incorrect these measurements would give the splitting of these two lines, but would not necessarily give this value of e/m.

18. Anomalies in the Zeeman Effect of Helium. L. E. KINSLER AND W. V. HOUSTON, *California Institute of Technology.*—Measurements of the Zeeman splitting of three singlet lines of helium have shown that they differ among themselves by much more than the experimental error. If e/m is taken as 1.7570 e.m.u., the splitting of λ4921 is 1.0016 times the expected value. This is just at the limit of the experimental uncertainty, and its difference from 1.0000 may not be real. However, on the same plates, λ5015 shows 1.0055 and λ6678 shows 1.0106 times the normal splitting. These differences are much larger than can be accounted for by the ordinary theory of perturbation by the triplet levels, and they point to an inadequacy of the theory of the Zeeman effect when results of this precision are desired.

19. Hyperfine Structure in the Solar Spectrum. EDWIN MCMILLAN (*National Research Fellow*), *University of California.*—The possibility of observing hyperfine structure (including isotope shifts) in the solar spectrum has been investigated. This is of interest since it may give some evidence concerning the isotopic constitution of elements in the sun. Because of the large intrinsic breadths of solar lines, it is impossible to resolve any hyperfine structures; only a broadening of the lines can be observed. This has been studied on a number of plates taken in the third order of the grating belonging to the Astronomy Department of the University. Information has also been obtained from Rowland's Table of Solar Spectrum Wave-Lengths, where many broad lines are listed as double. Studies of the isotope shift in the solar lines of H and Ti have been published by Menzel (J. Astron. Soc. of the Pacific **44**, 33 (1932)) and McMillan (Phys. Rev. **44**, 240 (1933)) respectively. In the present work the following additional lines have been found to show observable evidence of hyperfine structure in the sun:

Element	Listed as double by Rowland	Photographed by author	Correlation with known hyperfine structures
Mn I	11 lines	9 lines	Complete
Cu I	3 lines	3 lines	
Ba II	1 line	2 lines	
La II	2 lines		
Co I	12 lines		Probably complete
Sc II	8 lines		No laboratory data on hyperfine structure
Ti II	9 lines		
Ce II	1 line		

The laboratory data on cobalt, obtained by N. S. Grace in this laboratory, are not complete. Seven of the above lines are found to have large structures, and the others will undoubtedly be found to have also when the work is completed. The case of titanium is interesting, as it would not be expected to have large structure, but nothing further can be said until this is examined in the laboratory. The question of correlation with terrestrial data was also approached from the other side; all lines known to have large structure were examined in regard to their occurrence in the sun. None were found with sufficient intensity or freedom from overlapping for observation of structure, except those listed above. Thus, as far as the observations go at present, there are no differences between the solar and terrestrial hyperfine structures.

20. An Absolute Determination of the Efficiency of Production of Silver $K\alpha$ X-Rays as a Function of Voltage. J. C. CLARK, *Stanford University.*—Ross' method of balanced foils was used with foils of Rh and Mo to isolate a small region of the x-ray spectrum from thin silver targets (about 1400A), the Ag $K\alpha$ lines being included. The ratio of line energy to the continuous for this region was calculated from data taken by Webster, Hansen and Duveneck (Phys. Rev. **43**, 839 (1933), and **44**, 258 (1933)). Preliminary measurements give the ionization cross section per atom as about 5.6×10^{-23} cm^2 at 70 kv. Rosseland's theory would predict 4.6×10^{-23} cm^2 and a more complete classical theory 7.1×10^{-23} cm^2. The departure of these measurements from the theories is of the same order as that of Smith's measurements (Phys. Rev. **36**, 1923 (1930)) on helium. The ionization cross section per atom can be determined as a function of voltage by using the value here obtained in the work of the above reference (Phys. Rev. **44**, 258 (1933)).

21. Compton Effect. P. A. ROSS AND PAUL KIRKPATRICK, *Stanford University.*—The Compton effect has been studied with a double-crystal spectrometer and a special x-ray tube. An annular target and cathode distributed the focal energy over a ring 3 inches in diameter. A small scattering block was placed so that a cone of x-rays from the ring focus converged upon it. Scattering to the spectrometer took place along the axis of the cone. By

turning the tube through 180° supplementary angles were used with each position of the scattering block. This eliminated a large part of the error due to uncertainty in scattering angle, since for supplementary angles $\theta+\theta'=\pi$, $\Delta\lambda=(h/mc)(1-\cos\theta)$, $\Delta\lambda'=(h/mc)(1-\cos\theta')$ and by addition $\Delta\lambda+\Delta\lambda'=2h/mc$. We believe that we have obtained a more accurate value of the "Compton constant" than has hitherto been experimentally obtained and that this accuracy is sufficient to give a value of m (in terms of e, h and c) comparable in accuracy with that obtained by spectroscopic and deflection methods. Curves showing the modified and unmodified components from beryllium, carbon, aluminum and sulphur have been taken at scattering angles between 30° and 150°. Modified widths from carbon and beryllium agree well with DuMond's theory (Rev. Mod. Phys. **5**, 1 (1933)). Radiation scattered by aluminum and sulphur shows a narrow modified line and evidence of some complex structure. The study of the variation of the modified line shape and width is being continued.

22. Determination of h by X-Rays. PAUL KIRKPATRICK AND P. A. ROSS, *Stanford University.*—A determination of the Planck constant has been performed by the method of measuring the minimum potential required to produce continuous spectrum x-rays of specified wave-length. The wave-length employed was that of the $K\alpha_1$ line of silver, a radiation which has been measured with precision by many investigators. No wave-lengths were measured in this research. A double spectrometer was adjusted to receive the $K\alpha_1$ line from a silver target after which isochromats from a tungsten target were observed without disturbing the spectrometer adjustment. X-ray tube potentials were measured by a potential divider and potentiometer system, and the potential during a single observation could be held effectively constant to about 0.01 percent. Though experimental work is complete, the final numerical result must unfortunately be withheld pending action by the Bureau of Standards upon our standard cells and resistances. It is certain at this time that the probable error to be assigned to our final value of $h/e^{4/3}$ will be much smaller than that associated with the presently accepted value. Methods for the attainment of further precision are indicated.

23. A 400 Kilovolt X-Ray Tube for Therapy. R. R. NEWELL, F. B. DUVENECK AND A. W. HACKNEY, *Stanford University.*—The anode end of the tube is a large, grounded, water-jacketed brass cylinder, 80 cm of which is designed to project horizontally into the treatment room. The x-rays come through a belt thinned to three millimeters near the free end. A roof-shaped target with two 45° gold surfaces, water-cooled, and two cathode filaments permits the use of the rays downward, upward, horizontally or at any intermediate inclination. The cathode is a long steel pipe extending axially through a large thick porcelain tube into the brass cylinder to within about 15 cm of the target. In order to make use of a Villard potential-doubling arrangement a valve is built into the tube itself by setting a kenotron filament, at ground potential, into that part of the brass cylinder which will be behind the wall. The plate for this valve is the cathode pipe. The tube is assembled with lead gaskets and is run on the pump.

24. The Crystal Structure of Cadmium Hydroxychloride, CdOHCl. J. L. HOARD AND J. D. GRENKO, *Stanford University.*—The closely related structures of cadmium chloride and cadmium hydroxide, each representative of a large class of halides or hydroxides of bivalent elements, are built up by the superposition of neutral layers of composition MX_2. The crystal structure of a compound of intermediate composition, cadmium hydroxychloride, was determined in order to investigate further the factors determining the order of succession of these layers. Laue and oscillation photographs fix the symmetry as hexagonal with $a_0=3.66$A, $c_0=10.27$A, and the space-group as $C_{6v}{}^4-C\,6mc$. The structure, uniquely determined by semiquantitative but rigorous arguments, places the two molecules of CdOHCl as follows: Cd at $\frac{1}{3}$, $\frac{2}{3}$, 0; $\frac{2}{3}$, $\frac{1}{3}$, $\frac{1}{2}$, Cl at $\frac{1}{3}$, $\frac{2}{3}$, u; $\frac{2}{3}$, $\frac{1}{3}$, $u+\frac{1}{2}$ with $u=0.337\pm0.010$, OH at 0, 0, v; 0, 0, $v+\frac{1}{2}$ with $v=0.100\pm0.010$. The structure is seen to be built up from neutral layers of composition CdOHCl. The order of succession of atomic layers is accounted for by considering the degree of polarization of each type of anion, and these criteria suffice to determine whether the $CdCl_2$ or the $Cd(OH)_2$ type of structure will be assumed by a compound MX_2. Certain slight peculiarities of interatomic distances and the absence of a pronounced basal cleavage in CdOHCl are correlated with the presence of the proton in each hydroxyl group.

25. Spray Electrification of Liquids. SEVILLE CHAPMAN, *University of California.* (*Introduced by Leonard B. Loeb.*)—The problem of spray electrification of aqueous solutions and pure water has been extensively investigated by Lenard and his school. While the phenomenon is known to be applicable to other liquids, little is known of the nature of the phenomenon in these cases. This work represents an attempt to make a more quantitative study of the phenomena by using the Millikan oil drop method, with a view to correlating if possible drop size, sign of charge, magnitude of charge, surface tension, and dielectric constant. A brass-nozzled atomizer operated by clean compressed air was used. Difficulties were encountered due to evaporation and the measurements covered only drop sizes from 3×10^{-5} cm to 7×10^{-4} cm. The results on specially purified liquids are best represented in the table. The data on water are in order of magnitude only, owing to the evaporation of the droplets. It is seen that the larger drops in general have the larger charges, that no

Substance	Dielectric constant	Surface tension in dynes/cm	Smallest Drops: Average charge in electrons	Smallest Drops: Radius in cm	Smallest Drops: Predominating sign of charge	Largest Drops: Average charge in electrons	Largest Drops: Radius in cm	Largest Drops: Predominating sign of charge
Ameroil	1.9	27	2	4×10^{-5}	neither	2	1×10^{-4}	neither
Nitrobenzene	35.7	46	150	1×10^{-4}	neither	800	4×10^{-4}	neither
Aniline	7.3	44	100	1.5×10^{-4}	neither	450	5×10^{-4}	neither
Glycerine	56.2	65.2	40	5×10^{-5}	neither	500	2.5×10^{-4}	neither
Water	80	72.8	125	1.5×10^{-4}	neither	600	5×10^{-4}	neither

preference in sign attaches to drop size in this range, and that higher dielectric constants in general give higher charge values.

26. The Elastic Scattering of High Velocity Electrons by Mercury Atoms and the Agreement with Mott's Theory. EDWARD B. JORDAN, *University of California.*—The angular distribution of electrons scattered elastically by single mercury atoms has been studied for electrons of 900, 1160, 1600 and 2000 volts energy. The angle range was 8° to 48°. The values of the scattered intensities have been plotted and compared with the corresponding theoretical curves computed in accordance with Mott's theory. The theoretical and experimental curves for 900 volt-electrons differ markedly in shape. The slope of the experimental curve is much greater for small angles than that of the theoretical curve. The departure from Mott's curve decreases progressively for electron velocities corresponding to 1160, 1600 and 2000 volts energy. The 2000 volt curve shows good agreement with the corresponding theoretical curve.

27. The Measurement of Natural Alpha-Particles Ejected from Solids. ROBLEY D. EVANS (*National Research Fellow*), *University of California.*—Exact expressions for the ionization due to the emission of alpha-particles from radioactive solids are set up and the results of their graphical integration are given. The total ionization per cm^2 of surface, both with and without absorbers; the variation of ionization with height above the radioactive surface; the ionization from thin films; the ionization from substances containing all members of the U, Th and Ac series, both with and without absorbers; and the counting rate for alpha-particle counting chambers, are given in equations accompanied by appropriate graphs and tables. The older approximate theories break down for actual alpha-particles, particularly those of short range. If q is the number of ion pairs per cm^2 per sec. formed above the surface of a radioactive solid; N, the number of alpha-particles per sec. per cm^3 emitted in the solid; k, the number of ion pairs per alpha-particle of range R in air; and R', the alpha-particle range in the solid: then $q=\epsilon NkR'$, and the numerical coefficient ϵ has values between 0.114 and 0.150 for the alpha-particles from all known radioactive substances.

28. The Crystaldiamagnetism of Single-Crystalline Solid Solutions of Bi. A. GOETZ AND A. B. FOCKE, *California Institute of Technology.*—Previous work on polycrystalline material has shown large influences by metallic admixtures when within the solubility limits. The effect of the type of insertion is found to be non-existing in case of complete insolubility (Bi–Cu), to be random for macroscopic solubility (eutectic) (Bi–Ag) and large and directional for atomic solubility, no matter whether the admixture enters the crystal as atom (Sn, Pb and probably Ge) or as intermetallic compound (BiSe, Bi_2Te_3). The effect is smallest for an isomorphous admixture (Sb) with complete atomic solubility. The dependence of the susceptibilities parallel and normal to [111] on the concentration and the type of the foreign atom shows a critical concentration N_c for low temperatures which exists only in one direction of the crystal: normal to [111] for an atom with an electropositive, parallel to [111] for an atom with an electronegative valency configuration. An isomorphous atom has an electropositive effect normal to [111] and an electronegative parallel to [111]. N_c has the following values for: Te = 0.01%; Sn = 0.03%; Pb = Se = 0.09%. These phenomena contradict any assumption based on a volume effect; however, by introducing a superstructure of planes according to previous suggestions of the authors with a parameter of 10^3–10^4A on which the admixture is adsorbed and accepting the Ehrenfest-Raman hypothesis of crystal-diamagnetism the entire phenomenology can be accounted for. The parameters obtained from N_c are in good agreement with the results of etch figures and the "critical" sizes of colloidal crystals.

29. The Maximum Range of Cosmic Rays. PAUL S. EPSTEIN, *California Institute of Technology.*—As was pointed out by Zwicky, the astronomical red shift seems to indicate that cosmic rays can travel only a finite distance before completely losing their energy. A closer investigation shows that the problem of their travel time is the same as that of the time scale of the universe. It can be generally shown that the types of expansion of the universe discussed by Friedmann and Lemaitre for a special model are the only possible ones under all circumstances. If the cosmological constant is zero or negative, the maximum range of light quanta and material particles is below $2\cdot10^9$ years; if the constant is positive, it can have any value, up to infinity. The difficulties pointed out by Zwicky form, therefore, an additional argument in favor of a finite, positive cosmological constant.

30. On the Production of Positives by Nuclear Gamma-Rays. L. NEDELSKY AND J. R. OPPENHEIMER, *University of California.*—A gamma-ray emitted by a nucleus may be absorbed by the creation of an electron and positive. The probability of this process does not depend essentially on the electrostatic field of the nucleus, and is, for light elements and high energies, very much greater than the probability of internal conversion by the ejection of an atomic electron. The probability that a dipole gamma-ray of energy γmc^2 should eject a positive of energy ϵmc^2 and an electron of energy $\epsilon' mc^2$ (with $\epsilon+\epsilon'=\gamma$) is then

$$d\epsilon\,\frac{2e^2}{hc\gamma^3}\left[2(\epsilon^2-1)^{\frac{1}{2}}(\epsilon'^2-1)^{\frac{1}{2}} + (\epsilon^2+\epsilon'^2)\ln\frac{\epsilon\epsilon'+1+(\epsilon^2-1)^{\frac{1}{2}}(\epsilon'^2-1)^{\frac{1}{2}}}{\gamma}\right]; \qquad (\epsilon,\ \epsilon'>1).$$

The total probability that a pair be created increases with $\ln\gamma$. For $\gamma=12$, which corresponds roughly to the radiation emitted by disintegrating Be, the probability is 0.003. Almost identical results are obtained for a quadripole gamma-ray. The positives observed by Curie and Joliot when Be was disintegrated by Po alpha-particles may be accounted for by this theory. The positives observed in disintegrating Al are far too numerous, and high energy electrons far too infrequent to admit this explanation.

31. Production of High Energy Electron Pairs. W. H. FURRY (*National Research Fellow*) and J. F. CARLSON, *University of California.*—The production of a high energy electron pair (electron and positive) by a γ-ray traversing the field of a nucleus was first discussed by Oppenheimer and Plesset (Phys. Rev. **44**, 53 (1933)). This problem has now been studied in considerable detail and by a more rigorous method. The production of pairs by five million volt γ-rays is reasonably consistent with the experimental results obtained with artificial γ-rays from beryllium. For energies above twenty million volts the predicted pair production is even greater than that computed by Oppenheimer and Plesset, and hence even more irreconcilable with experiment. It seems possible to connect this discrepancy with the fundamental inadequacies of quantum electrodynamics.

32. The Nature of Statistical Fluctuations. ROBLEY D. EVANS (*National Research Fellow*), *University of California.*—I. The square of the mean deviation, D, of the combined effect of several random processes releasing an average of $x, y, z \cdots$ particles per unit time, and producing $a, b, c \cdots$ ion pairs respectively per particle, is $D^2=a^2x+b^2y+c^2z+\cdots$, regardless of whether the separate effects are added or subtracted by the experimental arrangement. For tube-counters, point-counters, scintillation screens, and particle counting chambers, $a=b=c=1$; for ionization chamber $a, b, c \cdots$ are unequal. II. From the standpoint of statistical fluctuations, the use of two identical instruments in a differential circuit is inferior to the use of a single instrument. III. The natural observation limit for the measurement of x particles against a background of y particles is $x=0.67(y)^{\frac{1}{2}}$. IV. The statistical fluctuations in the ionization produced by cosmic rays in a spherical ionization chamber are treated rigorously, and the fluctuations due to heterogeneity of range and to showers are derived. V. Application to existing data shows that the showers observed in cloud-chamber photographs of the penetrating radiation are also present in the ionization chamber, in about the same frequency and multiplicity as indicated by the cloud-chamber results. The tube-counter investigations of the cosmic-ray flux are also in agreement with the deductions from the statistical fluctuations in the ionization chamber. An upper limit of 70 ± 10 ion pairs per cm in air at 1 atmosphere is set for the total ionization along the path of an individual cosmic-ray secondary. The size and the relative frequency of occurrence of showers is several times greater at 14,700 feet elevation than at sea level. These showers are quite distinct from the ionization bursts or "Stösse" observed by Hoffmann, Steinke and others.

33. Radium Content of the Lavas of the Lassen Volcanic National Park, California. ROBLEY D. EVANS (*National Research Fellow*) AND HOWEL WILLIAMS, *University of California.*—Joly and Piggot have determined the radium content of lavas from Vesuvius and Hawaii respectively. The present authors chose the lavas of the Lassen region for study because of their wider range of chemical and mineralogical composition. One of the authors (H. W.) has already described the petrographic characters of these rocks in detail (Univ. Calif. Publ. Bull. Dept. Geol. Sci. **21**, 195 (1932)). The direct-fusion method of radium analysis was employed (Evans, Rev. Sci. Inst. **4**, 223 (1933)). Within the silica range of 47.43 percent and 70.93 percent, the radium content varies from 0.30 to 1.14×10^{-12} g Ra per g rock. There is a strict correlation between these constituents, irrespective of the age or mode of occurrence of the rocks. Experiments are now being made to determine the extent to which the radium is concentrated in certain definite minerals.

34. The Mass of the Neutron. R. M. LANGER, *California Institute of Technology.*—The reaction $Li^7+H^2\rightarrow 2He^4+n$ has been studied by Oliphant, Kinsey and Rutherford (Proc. Roy. Soc. **141**, 722 (1933)) who find all energies up to 8.3×10^6 volts for the resulting alpha-particles. These data can be used to calculate the mass of the neutron with less error than is involved in any other case known. The result is 1.0062 with an error less than 0.001. This means that the binding in the case of H^2 is of the order of 5×10^5 volts and if the proton consists of a neutron and a positive electron (Science **76**, 294 (1932)) its ionization potential is very small. This value of the neutron's mass is apparently in disagreement with disintegration experiments of Kurie (Phys. Rev. **43**, 771 (1933)). However, if Kurie's data (which he has kindly furnished) are computed on the assumption that the neutron is not captured, it turns out that there is no difficulty with the conservation of energy with the mass 1.0062. Moreover, it can be shown that while the evidence for non-capture disintegrations with neutrons in nitrogen is good, that for capture disintegrations is very weak, because the usual criterion for capture applies in this case almost as well for non-capture. Further, only those exceptional neutrons are able to disintegrate nitrogen without capture which have almost their maximum energy. The more abundant kind below 8×10^6 volts play no part in such disintegrations.

35. The Interaction Between Neutrons and Protons. R. M. LANGER, *California Institute of Technology.*—The scalar product $(\mu\cdot\sigma)$ (where μ is the magnetic moment and σ the mechanical moment) seems, according to Bacher (Phys. Rev. **41**, 1001 (1932)) to have about the same numerical value for the neutron and the proton but the sign is opposite. This may be taken as an indication that the interaction between the neutron and the proton is mainly magnetic. In fact two bar magnets free to rotate would be in their lowest energy state when their moments were opposite in direction. In the case under discussion it would follow that the spins would add. The H^2 nucleus in its lowest state should then have a spin of one unit and a magnetic moment close to zero. If the He^4 nucleus is a closed shell the same should apply to Li^6. If O^{16} is a closed shell then N^{14} lacks one neutron and one proton and the same conclusion holds for it as well as for O^{18}. Other results can be obtained for certain more complex nuclei. The expectations are in agreement with all available

experiments. Without the hypothesis here proposed it is hard to see why N^{14} for example should have a spin of 1 instead of 0.

36. Theory of the Origin of Cosmic Radiation. R. M. LANGER, *California Institute of Technology.*—The radical assumption that nuclear charges can disappear slowly has no valid experimental or theoretical evidence against it. If this is a general property of matter it follows that in our portion of the universe there should be a negative space charge which would accelerate positive charges from the outside. Even for exceedingly low rates of annihilation, the total drop could be sufficient to account for cosmic-ray positive particle energies. At the same time the difficulties raised recently by Swann and Zwicky disappear. The primary charged particles shown by the latitude effect have higher energy than the average because they have fallen through the whole field. The more abundant secondaries of lower energy are either parts of showers involving many particles or result from photons formed part way in. The east-west differences seem to indicate that all of the primary charged particles are positive as would be required if the radiation is due to a cosmical field as here supposed. The lack of a dependence on sidereal time is however surprising. Of course the otherwise mysterious atmospheric electrical currents are immediately accounted for as already discussed by Swann (Phil. Mag. **3**, 1088 (1927)). Certain puzzling properties of the aurora also find explanation. In fact a whole series of cosmic and terrestrial phenomena can be interpreted with the help of this single harmless lapse from conservatism.

37. Active Nitrogen. JOSEPH KAPLAN, *University of California at Los Angeles.*—The afterglow in the nitrogen tube described in abstract No. 15 has been photographed in the visible on panchromatic and astronomical green plates and in the ultraviolet on Eastman 33's. In addition to a very unusual intensity distribution in the first-positive group, different from that in normal nitrogen afterglows, this afterglow contains the first-negative and second-positive bands. The two latter groups of bands have never before been reported in nitrogen afterglows. In the present afterglow the first-negative and the first-positive groups are more intense relative to the second-positive group than they are in the exciting discharge itself. It was for this reason that the second-positive bands were not observed on my first afterglow plates, since these were in the visible and there the second-positive bands are very weak. This intensity relationship between the three systems is very similar to that in the aurora spectrum. This fact, together with the experiment performed by me at Princeton, in which the green aurora line was produced in the nitrogen afterglow without the simultaneous excitation of any other oxygen lines, shows that it is possible to produce the entire aurora spectrum in an afterglow.

38. Supernovae and Cosmic Rays. W. BAADE, *Mt. Wilson Observatory,* AND F. ZWICKY, *California Institute of Technology.*—Supernovae flare up in every stellar system (nebula) once in several centuries. The lifetime of a supernova is about twenty days and its absolute brightness at maximum may be as high as $M_{\text{vis}}=-14^{M}$. The visible radiation L_ν of a supernova is about 10^8 times the radiation of our sun, that is, $L_\nu=3.78\times10^{41}$ ergs/sec. Calculations indicate that the total radiation, visible and invisible, is of the order $L_\tau=10^7L_\nu=3.78\times10^{48}$ ergs/sec. The supernova therefore emits during its life a total energy $E_\tau\geq10^5L_\tau=3.78\times10^{53}$ ergs. If supernovae initially are quite ordinary stars of mass $M<10^{34}$ g, E_τ/c^2 is of the same order as M itself. In the *supernova* process *mass in bulk is annihilated.* In addition the hypothesis suggests itself that *cosmic rays are produced by supernovae.* Assuming that in every nebula one supernova occurs every thousand years, the intensity of the cosmic rays to be observed on the earth should be of the order $\sigma=2\times10^{-3}$ erg/cm² sec. The observational values are about $\sigma=3\times10^{-3}$ erg/cm² sec. (Millikan, Regener). With all reserve we advance the view that supernovae represent the transitions from ordinary stars into *neutron stars,* which in their final stages consist of extremely closely packed neutrons.

39. The Motion of Electrons Near a Plane Photo-Electrode in the Presence of a Gas. AUSTIN M. CRAVATH, *University of California.*—When electrons leave a photoelectric cathode in the presence of a gas, some are reflected back to the cathode and only a fraction i/i_0 escapes to the anode. The mean energy and density of the electrons vary with distance from the cathode, approaching constancy at large distances if the field is uniform. Previous theoretical calculations of i/i_0 (Bradbury, Phys. Rev. **40**, 980, 1932; Young and Bradbury, Phys. Rev. **43**, 35, 1933) have been found to be not even approximately valid. The differential equation for the current involves diffusion and thermal effusion as well as mobility. The energy equation involves *flows* of energy due to thermal conductivity of the electron gas, diffusion, and electric field, as well as the energy gained from the field and that last in collision. These equations have been solved numerically. None of the above terms can be neglected under all conditions. $i_0/i=0.25(V_c/W_\infty)(N_c/N_\infty)+0.5$ where V_c is the average speed with which the electrons leave the cathode, W_∞ the drift velocity in terminal state of motion, and N_c and N_∞ the electron densities at and far from the cathode. For most of the range covered by Bradbury's experiments, N_c/N_∞ is nearly unity, giving practically the equation which he found to fit his results.

40. About the Origin of the Mosaic Structure in Metal Crystals. A. GOETZ, *California Institute of Technology.*—In order to explain the appearance of periodicities of higher orders (secondary or mosaic structures) it is suggested that an aggregation of groups takes place during an interval of temperature of a few degrees *above* the melting point. These aggregates ("groups") are of approximately equal size and their existence is essential for the formation of a solid crystal. If their formation is prevented, undercooling results down to a temperature at which the group formation is more probable. The support of this hypothesis is partly found in experiments of the author concerning

the "survival" of crystalline qualities of single crystals beyond the melting point, partly in the experiments about the phenomena of undercooling as function of previous overheating by Webster, partly by the fact that the x-ray analysis of liquid metals whose structure in the solid state deviates much from close-packed arrangements does not give an indication of a statistical distribution of the molecules in the liquid. The mosaic structure in solids is suggested to be caused by the slight structural deformation which the molecules at the surface of the groups possess in the moment of the transition into the solid state. The variation in the size of these groups as well as slight inaccuracies of their packing may serve for explaining the failure to observe diffraction patterns of such structures and also the dependence of such structures on the methods of growth of the crystal.

AUTHOR INDEX TO ABSTRACTS OF THE STANFORD UNIVERSITY MEETING