

PROCEEDINGS
OF THE
AMERICAN PHYSICAL SOCIETY
MINUTES OF THE WASHINGTON MEETING
APRIL 23 AND 24, 1926

The 139th regular meeting of the American Physical Society was held at the Bureau of Standards, Washington, D. C. on April 23 and 24, 1926. The presiding officers were Professor Dayton C. Miller, President of the Society, and Professor K. T. Compton, Vice-President. The attendance was about three hundred.

On Friday evening there was a dinner at the Raleigh Hotel, attended by two hundred and thirteen members and guests. The speakers at this dinner were Professor M. I. Pupin, Dr. S. W. Stratton, Dr. G. K. Burgess, and General G. O. Squier.

Meeting of the Council.—At the meeting of the Council held on April 23, 1926, seventeen were elected to membership: Martin J. Connoly, Kenneth Cole, Austin M. Cravath, C. del Rosario, Karl G. Emeleus, Hugh Farrell, Sylvan Harris, L. G. Hector, D. W. Morehouse, Leonard J. Neuman, Nicolas P. Rashevsky, P. N. Rhodes, Clarence Rockwell, John L. Rose, Shou Chin Wang, George P. Welch and Harvey A. Zinszer.

The regular program of the American Physical Society consisted of ninety-four papers, Numbers 2, 7, 9, 61, 73, 86, 87, 89, 90, 91, 92, and 95 being read by title. The abstracts of these papers are given in the following pages. An **Author Index** will be found at the end.

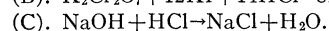
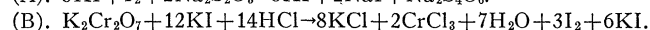
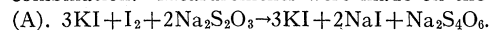
HAROLD W. WEBB,
Secretary.

ABSTRACTS

1. **A precision study of the K absorption limit.** F. K. RICHTMYER and J. B. BISHOP, Cornell University.—A series of careful measurements of *observed* absorption coefficients taken through the K absorption limit of silver yields data which, after correcting for the finite width of the slits, are in agreement with the assumption that the λ^3 law holds up to the limit from both directions and at the same time furnishes a method for determining, with comparatively high precision, the magnitude of the absorption discontinuity.

2. **The effect of chemical combination on the absorption of x-rays.** W. B. MOREHOUSE, Cornell University.—The x-ray absorption by aqueous solutions was measured

before and after chemical reaction, employing a differential null method similar to that described by Becker (Phys. Rev., **20**, 134, 1922), and using the direct beam from a water cooled Molybdenum Coolidge tube, operating at 30 kv peak. Cells having equal compartments were used, so that the same elements were in the beam before and after combination. Measurements were made on the following reactions:



Corrections having been made for changes in density the results indicate: Reaction (A). The mass absorption coefficient of the solution after reaction is approximately 0.25 percent less than before reaction. Reaction (B). 0.25 percent greater. Reaction (C). No appreciable change. Since iodine, sulphur and chromium are the only elements changing valence and since computations from known absorption coefficients show that the absorption by the iodine in the beam is several times that by either the sulphur or the chromium, it seems probable that the absorption by iodine in the free state is greater than its absorption in the combined state.

3. X-ray absorption in heated silver. H. S. READ, National Research Council Fellow at Stanford University.—Previous research (Phys. Rev., April, 1926) has suggested that Al, Fe, Ni, Cu, Ag, and Pb have slightly larger absorption coefficients at higher temperatures. Total radiation from a tungsten target tube was used. Continued work with Ag indicates that the transmission is a complicated function of the wave-length (0.2 to 0.7A used) increasing with temperature at some wave-lengths and decreasing with temperature at others. The largest change was a 1.5% decrease in transmission at the K-limit when the Ag strip was heated to 830°C. If this were due to a shift of the K-limit the shift corresponds to +0.00021A which corresponds in turn to -11. volts. This result suggests that energy of thermal agitation may add to x-radiation energy or that heat prepares the atoms in some way to absorb slightly smaller quanta, at the K-limit, than is possible when cool. An equal shift of the whole absorption coefficient curve does not appear to account for the changes of transmission at some of the other wave-lengths. A correction was made for the effect of thermal expansion. A detailed account of the method and results will be published.

4. Conditions for the disappearance of the unmodified line in the Compton effect. G. E. M. JAUNCEY and R. A. BOYD, Washington University. The method previously described by Jauncey and DeFoe (Phys. Rev., **27**, 102, (1926)) for measuring the ratio of the modified to total scattering coefficients when a wave-length of 0.41 A is scattered by carbon at various angles has been used. The ratio becomes practically unity at 87° and continues unity for angles out to 120° (we did not test it further out). However, at angles less than 87° there is a rapid decrease of the ratio as the angle decreases. It seems therefore that unmodified scattering disappears at 87° when $\lambda = 0.41$ A. On Jauncey's theory, unmodified scattering disappears at 82°. There is thus good agreement with theory.

5. Measurement of x-ray scattering coefficient. PIERRE MERTZ, Cornell University.—The mass scattering coefficient was measured directly by collecting the scattered radiation in an ionization chamber surrounding the scatterer, comparing its intensity with that of a portion of the primary beam going through an auxiliary ionization chamber of equal length along the ray path. The primary beam consisted of the continuous radiation from a Coolidge tungsten tube, filtered through Al and Cu until the spectral width between the half-maximum intensity points was about 25% of the mean wave-length. Corrections were made for internal absorption in the scatterer and for the increased absorption of the scattered beam in the ionization chamber due to the Compton effect. The latter could not be estimated very accurately and is probably one

of the largest sources of error in the determination. The values of mass scattering coefficient (σ/ρ , in cm^2/gram) as determined are given below:

λ	.32	.43	.54	.66	.79 A.
Scatterer			σ/ρ		
C	.166	.182	.194	.214	.234
H ₂ O	.198	.206	.210	.216	.228
Na	.173	.191	.248		
Li	.133	.165	.157	.169	.200
B	.154	.162	.169	.165	.179

6. Intensity of x-ray reflection from solid and powdered sodium chloride. J. A. BEARDEN, University of Chicago. (Introduced by Arthur H. Compton.)—The experiment of the intensity of x-ray reflection by Bragg, James and Bosanquet has been repeated using monochromatic x-rays ($K\alpha$ line of Molybdenum reflected from rock-salt crystal) for all orders of reflection thereby reducing the uncertainty in choosing a base line. The values of the structure factor F are in satisfactory agreement with the values obtained by the previous experimenters. The most uncertain elements entering in these experiments are: (1) the linear absorption coefficient and (2) the extinction effects. Measurements of the intensity of reflection from powdered crystals have also been made with monochromatic x-rays, using both the transmission and the reflection methods. Both powder methods gave the same values for the structure factor F for several samples of sodium chloride of different history. Except for the (100) plane, however, the values were consistently higher than the corresponding values obtained by the solid crystal method.

7. Refraction of x-rays by method of total reflection. RICHARD L. DOAN, University of Chicago.—The critical angle of total reflection of x-rays from polished surfaces is related to the index of refraction by the expression $\theta_c = (2(1-\mu))^{1/2}$, θ being the glancing angle of incidence. Since this critical angle has been found experimentally to be sharply defined, this method furnishes a simple means of determining indices of refraction with a relatively high degree of accuracy. The line $\text{MoK}\alpha_1$, isolated by means of a calcite crystal and suitably placed slits, was allowed to fall on optical surfaces of speculum metal and glass, the reflected beam being received on a photographic plate one meter distant. Approximately one hundred one-minute exposures were made as the mirror was turned at intervals of a few seconds of arc through a total range of about $7'$. Measurements, accurate to 1%, gave for speculum, $\theta_c = 10'52''$, $1-\mu = 4.96(10)^{-6}$; for glass, $\theta_c = 6'18''$, $1-\mu = 1.67(10)^{-6}$. Attempts were made to use sputtered gold films for reflecting surfaces but the reflection was surprisingly weak and the critical angle not sharply defined. An accurate measurement of the index of refraction of $\text{MoK}\alpha_1$ in gold would be valuable as a check on the Drude-Lorentz dispersion formula because of the expected large resonance effect due to the L-electrons.

8. Refraction of x-rays in prisms. BERGEN DAVIS and C. M. SLACK, Columbia University.—A continuation of measurements of refraction of x-rays by means of a double x-ray spectrometer (Phys. Rev. **27**, 18, (1926)). The double x-ray spectrometer is well suited to this purpose, since the position of the peak of the rocking curve is not affected by unsymmetrical absorption in the prism. Measurements of δ , ($\mu = 1 - \delta$) were made in substances tabulated below with the observed value in brackets. Using $\text{Mo K}\alpha$ ($\lambda = .7078$) the values of $\delta \times 10^6$ are: Ag (5.85), Cu (5.95), S (1.39), Al (1.68), Carbon (graphite) (1.23), celluloid (.98) and paraffin (.7). Using $\text{CuK}\alpha$ (1.537), the values of $\delta \times 10^6$ are: Al (8.4), celluloid (4.78) and paraffin (3.28). These results agree well with the values calculated. *Broadening of rocking curves.*—The rocking curves were much broadened when the rays passed through granular substances such as graphite, grated paraffin, etc.

This effect, which appears to be due to refraction by the successive particles, has been treated theoretically by Dr. R. van Nardroff. A formula has been obtained which permits the calculation of the size of the particles from the observed broadening.

9. The refraction of x-rays applied to the determination of the diameters of small particles. ROBERT VON NARDROFF, Columbia University.—The divergence introduced into a beam of x-rays on passing it through a mass of refracting particles is investigated mathematically. It is found that a plane beam would be scattered by a single sphere of index of refraction $\mu = 1 - \delta$ so that the fraction of the energy in a cone at an angle between ω and $\omega + d\omega$ with the original direction is $8\delta^2\omega d\omega / (4\delta^2 + \omega^2)^2$. For a large number of spheres, if n is the average number of spheres passed through by a ray, the root mean square bend produced is $\alpha_0 = 2\delta[n(\log 2/\delta + 1)]^{1/2}$ and the fraction of the energy lying in a cone between α and $\alpha + d\alpha$ is $2\alpha(\exp(-\alpha^2/\alpha_0^2))/\alpha_0^2$. For a beam originally having a width at half maximum W_0 as measured on the rocking curve of the second crystal of a double x-ray spectrometer, the width after passing through the refracting material will be $W = (W_0^2 + 2\alpha_0^2)^{1/2}$. This gives a means of determining the number, and, if the total mass is known, the size of particles which could not be measured by other methods. The method is applied to rocking curves obtained by Davis and Slack for beams passed through different thicknesses of graphite. The variations of curve width with thickness of graphite are found to be in agreement with the theory, and, assuming the particles acted like spheres, their approximate diameter is found to be .0035 cm.

10. The theory of x-ray dispersion. R. DE L. KRONIG, Columbia University.—The quantum theory of dispersion as developed by Ladenburg and Kramers is extended so as to apply to the refraction of x-rays, where the number of atoms in a wave-length cube is no longer large, and the absorption forms a continuous band. A general formula for the index of refraction in terms of the atomic absorption coefficient α and the critical frequencies is given. From the condition, experimentally verified, that the electrons in the atom for impressed frequencies, large compared to their natural frequencies, shall act like free electrons as far as the index of refraction is concerned, a relation is obtained for α . The theory is in accord with Heisenberg's quantum mechanics. Some considerations on the origin of the Compton shifted radiation are added, from which it appears that in the wave description this radiation must be regarded as coming from all the atoms and as being coherent with the incident waves; a result suited to stress the difficulty of harmonizing the wave picture with that of quantum processes in the atoms.

11. The polarization of characteristic x-rays. J. B. BISHOP, Cornell University.—An investigation to determine a possible state of polarization of the alpha lines of molybdenum was undertaken in the following manner: A molybdenum target water-cooled Coolidge tube was so mounted that it could be rotated about an axis perpendicular to the cathode stream and passing through the focal spot. A carbon block was placed in the path of the x-ray beam and the intensity of the radiation from it was measured parallel to and perpendicular to the cathode stream respectively as the tube was rotated. A second ionization chamber receiving a portion of the direct beam was used in order to detect a possible variation of intensity of the incident radiation due to improper alignment and fluctuations of the current through the tube. When a zirconium filter, which is relatively transparent to the alpha lines, was used; it was found that the ratio of the intensity of radiation scattered parallel to the cathode stream to that scattered at right angles to the cathode stream was about 0.74. On using a strontium filter, which strongly absorbs the alpha lines, this ratio was about 0.84. One concludes from these results that the alpha lines are at least partially polarized.

12. An electron lattice theory of metals. BERTRAM E. WARREN, Massachusetts Institute of Technology.—Metallic crystals are built up of positive ions and of electrons,

both the ions and the electrons arranging themselves in a definite space lattice. The particular type of lattice utilized must represent a minimum of potential energy, and therefore depends on the number of valence electrons given up by each atom. The heuristic rule is laid down that atoms with one or two valence electrons will lose them, while atoms with more than two will lose only those in excess of two. The metals of Group I and III should utilize a complete lattice of the rock salt type, the sub-lattice of the positive ions being face centered cubic. In exception to this, the sub-lattice of the alkalis must be considered as face centered tetragonal. The sub-lattice of the metals of Groups II and IV should be either face centered cubic or hexagonal close packed. Groups V and VI should utilize a sub-lattice of the body centered cubic type. The lattice of a Group VII metal should not be of any of the simple types. These predictions are in very good agreement with the results of x-ray determinations. Such physical properties as the good ductility and conductivity of the face centered metals, and the high melting points of the body centered metals would be expected. The metals of Group VIII have not been classified.

13. The carbon atom model and the structure of the diamond. R. B. LINDSAY, Yale University.—Using a method similar to one previously described by the writer the $2p$ orbitals in neutral carbon are approximately computed, introducing the assumption that the four orbital planes are arranged in tetrahedral symmetry. The atoms are then distributed in the diamond lattice and the field on any electron due to its own atom and neighboring atoms is calculated as a function of the distance from the nucleus assuming that: (1) the orbital plane of the electron is oriented in a certain symmetrical way relative to the lines joining its nucleus to those of the neighboring atoms; (2) for a first approximation only the four nearest atoms may be considered as effective; (3) the effect of the electrons in the neighboring atoms is that due to a time distribution of their charges in their orbital planes, disregarding definite phase relations such as have been assumed by previous writers. An approximate expression for the increase in energy of the electron orbit due to the neighboring atoms is developed, and the calculation of the lattice energy per electron for various values of a , the lattice constant, is carried out. The equilibrium value of a comes out between 1.10Å and 1.60Å (nearer the latter). In fact the heat of sublimation for $a=1.50$ Å is found to be 161 calories per mol. The accepted experimental values for these quantities are $a=1.54$ Å and $Y=168$ to 177 calories per mol. Compressibility calculations for this model are being undertaken.

14. The crystal structure of zirconium oxide. WHEELER P. DAVEY, General Electric Company.— ZrO_2 appears to crystallize in several forms. Using the powder method, diffraction patterns of two of these have been interpreted. One type shows that ZrO_2 may exist in a face-centered cubic lattice of ZrO_2 , $a=5.098$ Å. The strong lines of the pattern taken alone show a diamond cubic pattern, indicating that the Zr^{++++} and $2 O^{--}$ are situated in the lattice like Ca^{++} and $2 F^-$ in CaF_2 . The second type of diffraction pattern shows that ZrO_2 may exist in a triangular close-packed lattice of ZrO_2 , $a=3.598$ and $C=1.633$. This structure is closely related to the face-centered cube. Both structures give a density of 6.13 which is to be compared with 5.75 given in 1860 by Nordenskiöld.

15. Nickel-chromium solid solutions. F. C. BLAKE and A. E. FOCKE, Ohio State University.—A complete series of nichrome alloys has been studied by the powder method of x-ray analysis and the amount of distortion of the nickel lattice by chromium substitution and of the chromium lattice by nickel substitution has been determined.

The influence of impurity due to the crucible in which the melt is made has been studied and the correct lattices free from such influence have been determined. Inter-metallic compounds and allotropic forms have been the subject of special study.

16. **The ultra and extra-ultraviolet spectrum of iron as developed by the inverse photo-electric effect.** OTTO STUHLMAN, JR., University of North Carolina.—A three element vacuum tube of the commercial form VT-I, with platinum filament and iron grid and plate, was used. In series with the grid was a sensitive galvanometer and a variable potential whose negative terminal was connected to the negative end of the filament. A second circuit with the positive end of a battery connected to the plate and its negative terminal connected to the galvanometer served to keep the plate at a constant positive potential higher than the positive potential of the grid. As a result of critically accelerating electrons, emitted by the filament, towards the grid monochromatic radiations are emitted, which are reabsorbed by the grid resulting in photo-electric emission. Such emission and absorption interpretations are given the discontinuities which appear in the potential-current curves. They are evaluated by the usual $V\lambda = 12344$ relation. Using a work function for iron equal to 5.000 volts the following spectral regions were reproduced. Spark spectrum of iron (Exner-Haschek, Spectren Tabellen) pronounced lines between 2456 and 2213. New lines between 2211 and 2154. Millikan, Bowen and Sawyer's spark spectrum, including the spectral region investigated by Bloch, from 2152 to 880A. The spectrum is being extended beyond 200A.

17. **The extreme ultra-violet spectrum of titanium.** R. C. GIBBS, Cornell University.—Using one of the vacuum spectrographs at the Norman Bridge Laboratory of Physics, California Institute of Technology, photographs of the hotspark spectrum of titanium were obtained over the region from 192 to 1718A. By comparison with the data of previous workers in this part of the spectrum, it was possible to identify many of the lines obtained on the plates as due to other elements such as oxygen, carbon and silicon, many of which are present with every element used as electrodes. By placing a plate for titanium and one for some other element obtained with the same setting of the spectrograph face to face on the comparator it was possible to determine with considerable accuracy, by taking relative intensities and structure of line also into consideration, what lines were not due to titanium. All of the twenty-five lines reported within the above limits by Lang were found and about ninety additional lines. Careful focussing and the use of a very narrow slit made it possible to fix the wave-length to within .05A in the case of many lines obtained in the second order. On one plate it was possible to observe in the second order all seven components of the 834 oxygen line.

18. **On the spectrum of argon.** F. A. SAUNDERS, Harvard University.—The spectrum of argon in the extreme ultraviolet obtained by T. Lyman shows a very strong pair at $\lambda\lambda 1048.26$ and 1066.72 , and many other lines, some as yet unidentified. Following Paschen's neon notation, this pair is a combination between a $1p$ level ($j=0$) and $2s_2, 2s_4$. The known frequency-differences in the rest of the argon spectrum yield the terms $2s_3$ and $2s_5$, and many $2p$ terms are readily obtained, some of which combine with all four s terms, others with s_2, s_4 and s_5 only, as in neon. Three of the latter (presumably p_4, p_6 and p_8) are unexpectedly found to combine with $1p$, and produce strong lines ($\lambda\lambda 941.39, 932.09, 919.80$). The same combinations also produce lines, (though weaker) in neon ($\lambda\lambda, 662.84; 665.30; 667.46$), not previously identified. For these lines j must change from 0 to 2; they are thus quite unconventional. They are produced with a mild excitation. Other pp combinations seem to be present, but are not yet firmly established (e.g. Argon $\lambda 946.95$). Many other terms in the argon spectrum have also been found, and photographs have been taken in the ultrared, which are yielding data for a complete analysis of this spectrum.

19. **The quantum theory of the Zeeman effect for band lines.** E. C. KEMBLE, Harvard University.—Assuming an electronic angular momentum with fixed components σ and ϵ along and perpendicular to the axis of figure of a diatomic molecule,

the application of Bohr's postulates to the precessional motion in a magnetic field leads to the Zeeman term formula

$$E = E_0 + r\hbar\Delta\nu_n(\sigma^2 + \epsilon(j^2 - \sigma^2)^{\frac{1}{2}})/j^2,$$

where r is the magnetic quantum number, subject to the usual selection principle, $\Delta\nu_n$ is the Larmor frequency, j is the total angular momentum. The following qualitative inferences may be drawn: (a) The Zeeman pattern for lines adjacent to a band origin will normally be simple and the scale may be similar to that for an atomic line. (b) The outer lines of a band will have very complicated patterns, usually on a scale entirely too small to detect. (c) If the initial and final values of ϵ are different, the outer lines of a band will seem to be diffusely broadened in a magnetic field. (d) The direction of rotation for the Faraday effect in the neighborhood of a band line will frequently be different for the P and R branches of the same band. The theory agrees with the meagre experimental facts only in general qualitative features.

20. On the continuous spectrum of hydrogen. W. H. CREW and E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—In a discharge tube filled with dry hydrogen at a moderate pressure (1 to 3 mm Crookes dark space) the striations near the negative end of the positive column have quite different colors, widths and spacing; the first is a vivid blue and narrow, the second or third is pinker and wider, the third or fourth bluer again, the remainder being pinker or whiter for the most part. Spectrograms showed that the first blue striation, i.e. the one next to the Faraday dark space, emitted the continuous spectrum of hydrogen in great purity, the Balmer and molecular lines being relatively feeble. In the other striations the continuous spectrum was weaker than the line spectra, and in the cathode glow, Crookes dark space, negative glow and Faraday dark space was absent. The intensity decrement of the Balmer lines appeared to vary in different parts of the discharge. With moist hydrogen the Balmer lines were bright and the continuous spectrum dim in the striations. These facts together with the positive ray analyses of the ions in a hydrogen discharge by Smyth and Brasefield support the conclusion that H_2 is the source of the continuous spectrum of hydrogen.

21. The structure of the hydrogen molecule. H. C. UREY, Johns Hopkins University.—Recently Dieke and also Takahashi have arranged the Fulcher bands of hydrogen into single band systems with each band consisting of a zero branch. To these Dieke has added positive branches for the red bands and incomplete branches for the green bands. A study of these positive branches shows that they may be rather doubtful. Witmer has shown that the Lyman bands in the far ultraviolet have a similar structure. Since only one band system appears in each group it seems most reasonable to assume that the vibration quantum number does not change in these transitions and that therefore the molecule is symmetrical about the median plane. Since the bands have only zero branches the molecule must have no angular momentum in the electron system for otherwise the frequency of rotation of the nuclei would appear in the Fourier expansion of the electron motion and therefore positive and negative branches would appear. It seems necessary to assign the steady states involved to the *vibration* electron orbits of the median plane. This would give no first order Zeeman effect as required and a diamagnetic model for the normal state.

22. The structure of the hydrogen molecule ion. H. C. UREY, The Johns Hopkins University.—The energy levels of the vibrational model of the hydrogen molecule ion have been calculated including the energy contributed by the vibration and rotation of the nuclei. The calculated spectroscopic term is

$$\nu = -134899/n^{*2} - 9.37/n^{*4} + 5358n_4/n^{*2} + 107.6m_1^2/n^{*4} - 0.1767m_1^4/n^{*6},$$

where n^* , n_4 , and m_1 are the quantum numbers conjugate to the electron coordinate, and the vibrational and rotational coordinates of the nuclei respectively. The applica-

tion of the correspondence principle to the model requires that $\Delta n^* = 1, 3, 5, \dots$, $\Delta n_4 = 0$ and $\Delta m_1 = 0$ for transitions emitting light. Bands emitted from such a molecule should consist of single band systems, each band having a zero branch only. Exact agreement between theory and experiment has not been found.

23. P, Q, R combinations in the sodium hydride many-lined molecular spectrum. E. H. JOHNSON, University of Chicago.—A study has been made of the many-lined spectrum obtained from sodium arc in hydrogen in the region from $\lambda 5500$ down to $\lambda 3800$. Direct comparison of high dispersion plates shows an arrangement wholly different from that of the hydrogen secondary spectrum. Though at first sight there is little evidence of band structure, several groups of P, Q and R branches have been traced out by means of the combination principle. The $\Delta F(m)$ relations indicate the presence of a Kramers and Pauli effect. Preliminary values of $2B$ lead to a final moment of inertia of about 5.5×10^{-40} gm cm², which gives a nuclear separation of about 1.8×10^{-8} cm for a sodium hydride dipole. A detailed quantum analysis of the bands is included.

24. Half-integral vibrational quantum numbers and rotational energy data for the MgH bands. WILLIAM W. WATSON, University of Chicago.—The magnitude of the isotope effect in the $\lambda 5211$ band is shown to agree exactly with the assumption that $n' = \frac{1}{2}$ and $n'' = \frac{1}{2}$, as demanded by the new quantum mechanics. The "zero-points" of this band system can be represented by the equation

$$\nu = 19217 + (1603.5 n' - 34.75 n'^2) - (1493.5 n'' - 31.25 n''^2)$$

where n' and n'' take on half-integral values from $\frac{1}{2}$ to $3\frac{1}{2}$. For the final state in the $\lambda 5211$ band, the rotational energy can be represented by $F = Bm^2 + Dm^4 + Fm^6$ where $m = j + \frac{1}{2} - \epsilon$, ϵ having the approximate value 0.47. Kemble's formula, $\omega = (-4 B^3/D)^{\frac{1}{2}}$ gives the vibrational frequencies in the ν_0 formula to within the experimental accuracy of the data. The values of ΔF for the initial state indicate the presence of a Kramers and Pauli effect. The results of a least square solution and the question of missing lines lead to the approximate value $\epsilon = 0.43$ for the initial state. A comparison with rotational energy data for the C+H bands is made.

25. Nitrogen Series in the ultraviolet. J. J. HOPFIELD, University of California.—Four new series, namely, two series of triplets probably converging to a common head and belonging to the quartet system, and two series of doublets also having a common limit and belonging to the doublet system, have been observed in nitrogen. The short wave-length lines of one of the triplet series are given accurately by the equation

$$\nu = 117353 - 109677(m + 0.845685 - 0.022749/m^2 - 0.026562/m^4)^{-2}$$

in which $m = 1, 3$ and 4 correspond to terms already observed by Kiess. $m = 2$ gives a new triple term, and $1S = 117353$ (14.48 volts) is the lowest energy level yet observed in neutral nitrogen. The two doublet series which begin with the previously known lines at $\lambda 1742$ and $\lambda 1592$ respectively have each been observed to three members. Their common limit is 98100 cm⁻¹ (12.11 volts). The terms representing these series are linked to the doublet terms already observed through the lines at $\lambda 1742$. The resonance and ionizing potentials of neutral nitrogen are contained in the data given above. Inter-series and other relations are now being studied.

26. The infrared spectra of brucite and some sulphates; isotopic effect. E. K. PLYLER, University of North Carolina.—By means of an infrared spectrometer the structure of the absorption band of brucite $[\text{Mg}(\text{OH})_2]$ was studied. The region of greatest absorption was found to be at 2.48μ . Besides this maximum there were small maxima of absorption located at 2.40μ , 2.30μ , 2.14μ . The maxima at 2.48μ , 2.40μ , and 2.30μ correspond approximately in position and absorption to the isotopes of Mg^{24} , Mg^{25} ,

and Mg^{26} as found by Aston. The small band at 2.14μ , corresponds in position to Mg^{28} . However this isotope is not given. The work of Coblenz has been examined for the isotopic effect. In the reflection spectrum of nickel sulphate in solution there are two maxima located at 9.15μ , and 9.50μ . The second is more intense. These maxima are probably due to Ni^{58} and Ni^{60} . In the spectrum of potassium sulphate there are two maxima, one at 9.00μ , and the other at 9.40μ . The maxima at 9.40μ is much more intense. These two maxima are probably due to K^{39+41} and K^{39} taken twice. Other sulphates in solution only showed one maximum.

27. The intensities of the lines in the HCl absorption band at 3.5μ . D. G. BOURGIN and E. C. KEMBLE, Harvard University.—Measurements of the absorption curves for the HCl band at 3.5μ have been made by the writers with tube-lengths varying between 0.1 cm and 3 cm . From plots of the areas of the individual lines against tube-length the areas of the corresponding absorption coefficient curves have been determined. The measurements cover all lines between the tenth of the R branch and the sixth of the P branch. The results are in harmony with the formula previously derived by one of us (Phys. Rev. **25**, 1, (1925)) provided that the statistical weight series 1, 3, 5, 7, . . . is used as suggested by Fowler and Dieke (summation rule). The agreement between the results and the theory was within three percent of the intensity of the strongest line for all but two of the lines measured. From the shapes of the area-tube-length curves it may be inferred that the lines are very sharp, the center of the strongest lines being completely absorbed in the first few millimeters of absorption path. The variation in the shapes of the curves from line to line shows definite evidence of a rotational isotope effect.

28. Analysis of Wood's iodine resonance spectrum. E. C. KEMBLE and E. E. WITMER, Harvard University.—The resonance spectrum of I_2 excited by the broadened green mercury line consists of several series of doublets. According to Lenz each doublet is due to molecular transitions from a definite initial excited state to two different final rotational states. The different doublets in a series are due to different final vibrational states, the different series to a variety of initial states present because the exciting line covers a number of absorption lines coming from different absorption bands. Mecke has partially analysed some of the absorption bands in the red and has worked out empirical formulas for the frequencies of the resonance series. Kratzer and Sudholt have written out theoretical formulas for the resonance series in harmony with the observations and from Mecke's data have evaluated the moment of inertia of the molecule. Assuming that the nuclear rotational quantum numbers of the final states associated with each doublet differ by exactly two, the authors have revised and extended the work of Kratzer and Sudholt. We obtain the values $7.9 \times 10^{-38} \text{ gm cm}^2$ and $11 \times 10^{-38} \text{ gm cm}^2$ for the moments of inertia in the normal and excited states respectively. The large difference between these values locates the origin within three lines of the head.

29. The fluorescent and absorption spectra of iodine. F. W. LOOMIS, New York University.—The four series without linear terms found by Mecke (Ann. d. Phys. **71**, 104, (1923)) in Wood's spectrum of fluorescent iodine excited by the broad green mercury line are due to four lines of the band (26, 0); those with positive doublet interval to lines in the P branch. The P and R branches are the absorption series Ia and Ib found by Mecke in this region. The fluorescent lines are identified. This makes it possible to pick out a series of pairs of lines with common m' , and another with common m'' and hence to find $B_0'' = 0.03835$, $B' = 0.02480 \text{ cm}^{-1}$, $J_0 = (7.21 \pm .03) \times 10^{-38}$ and the absolute values of m which turn out half-integral. Similarly, lines of Mecke's series II belong alternately to the P and R branches of band (27, 0) and the fluorescent lines are identified as are also the main lines in three of the four remaining fluorescent series. Wood's measurements of the magnetic rotation of six absorption lines show in every case the

"normal" direction of rotation for lines here assigned to a P branch and the opposite for R lines. These results demonstrate the existence of P and R branches in absorption, which Mecke has doubted, and confirm the Lenz theory.

30. On the polarization of fluorescent light from colloid solutions. PAUL FRÖHLICH, University of Chicago, (introduced by William W. Watson).—The partial polarization of fluorescent light from aqueous solutions of fluorescein, eosine, magdala-red, rhodamine 5 G, and rhodamine B extra, produced by dissolving in them more and more gelatine, gum arabic, or agar-agar; and in acetone solutions of the same substances by dissolving in them successively more celluloid, has been investigated. Three different wave-lengths of the plane polarized exciting light were used. It is found that the percent of polarization is successively increased from zero or a low value to a maximum, by dissolving in the solution a colloid. The maximum value will be reached in some cases with 60 percent, in others with 100 percent colloid in a solid film. The percent of polarization in the case of colloid solutions shows the same effects as in the case of non-colloid solutions with a high viscosity, such as glycerin or oils. It is increased by lower concentration of the dye, and by longer exciting wave-length. With dyes having shorter wave-length absorption bands (fluorescein, eosine), the wave-length effect proceeds at a slower rate than with solutions having longer wave-length absorption bands (magdala-red, rhodamine). By suitable choice of concentration and exciting wave-length, the maximum value of the polarization is about 35 to 40 percent.

31. Fluorescent exciting power and black-body radiation. E. H. KENNARD, Cornell University.—Suppose one quantum number n of an atom has normally the value n_1 while another m is statistically distributed by thermal agitation. Let absorption at frequency ν_x change n to n_2 and m from m_1 to m_2 ; and suppose that after this process thermal agitation is either (a) ineffective (then $m_2 = m_3$ below) or (b) completely effective in re-distributing m statistically. Suppose fluorescent emission of frequency ν_y then occurs while n changes back to n_1 and m changes from m_3 to m_4 . Then the Einstein theory (1917) leads to the equations

$$\phi_{yx} = k_x \alpha_y u_y, \quad \phi_{yx} / \phi_{xy} = \nu_y u_y / \nu_x u_x,$$

where ϕ_{yx} = fluorescent emission of frequency ν_y per unit volume excited by unit energy density at ν_x , α_y = absorption coefficient and u_y = black-body density of radiation for ν_y , and the factor k_x depends on ν_x but not on ν_y . These equations should hold for iodine fluorescence, n referring to the electron jump and m either to the rotation of the molecule or to the atomic vibration. For the second equation, restrictions (a) and (b) are probably unnecessary. Perhaps the equations will hold also for fluorescent solids and liquids; experiments are in progress.

32. Transformation spectra and the principle of essential identity. E. L. NICHOLS and H. L. HOWES, Cornell University.—At their transformation points many incandescent bodies, particularly certain oxides, emit light over and above that due to their thermal state. The effect, although reversible, is most readily seen as a temporary flash up when a small mass of the substance is cooling. Through the spectroscope it may be seen to be selective. When the incandescent body contains a rare earth in solution, as activator, the *transformation spectrum* consists of narrow bands which appear suddenly in the field of view and melt away as the temperature falls below the transformation point. *These coincide with the fluorescence bands characteristic of the activator* or where that is not the case are members of the sets of equidistant components of which the fluorescence spectrum is composed. In other words, the fluorescence spectrum and transformation spectrum for a given activator are essentially identical and the principle of *essential identity*, hitherto applied to luminescence at ordinary temperatures is extended also to the luminescence of incandescent substances. (Nichols and Howes, Phys. Rev. **19**, 304 (1922).)

33. The form of the absorption bands in solutions of the organic dyes, and a relation between absorption and fluorescence. ERNEST MERRITT, Cornell University.—It is assumed that the active molecule behaves as an electric doublet whose moment changes from μ_0 in the normal state to μ_1 when excited. In the field E due to the solute molecules the frequency for absorption, or emission, is then ν instead of ν_0 , where $h\nu = h\nu_0 + (\mu_1 - \mu_0)E$. If thermal equilibrium is assumed the absorption coefficient α , which is determined by the distribution of the normal molecules, and the fluorescence F , determined by the distribution of the excited molecules, will be

$$\alpha = V(E)\exp(-\mu_0 h(\nu - \nu_0)/kt(\mu_1 - \mu_0)), \quad F = F_0 h\nu V(E)\exp(-\mu_1 h(\nu - \nu_0)/kt(\mu_1 - \mu_0)),$$

$$F/\alpha = F_0 h\nu \exp(-h(\nu - \nu_0)/kt),$$

where $V(E)$ is the volume within which the field (in the direction of μ_0) lies between E and $E + dE$, and F_0 depends on the duration of the excited state. If the solvent molecule is also a doublet, $V(E)$ is shown to be independent of ν through a considerable range, so that α is exponential on the long wave side of the band. This result is confirmed by experiment with uranine in water. Measurements, not yet of high accuracy, indicate agreement with the theory to within 10 percent in the value of F/α .

34. Gyromagnetic electrons and a classical theory of atomic structure and radiation. LOUIS VESSOT KING, F.R.S., McGill University.—A charged sphere in rotation with spin Ω_1 is deformed by translational velocity v into an ellipsoid of revolution, and as a result acquires the properties of a gyrostator in so far as precessional oscillations are concerned. The electrodynamic coefficients of inertia (A, C, C) are rigorously determined by integrating the magnetic energy throughout the space, within and without the ellipsoid whose deformation is considered to be physically real. It is shown that the frequency ν of precessional oscillation is given by

$$2\pi\nu = \Omega_1(C - A)/C = \Omega_1(c_1 - a_1)\beta^2(1 + b_1\beta^2 + b_2\beta^4 + \dots), \quad (1)$$

and leads to the formula $h\nu = \frac{1}{2}m_0v^2(2)$ for moderate velocities, where $m_0 = \frac{2}{3}e^2/a$ and $\beta = v/c$, the velocity of light being denoted by c . Remembering that a precessing electron has the properties of a small magnet, and therefore can radiate electromagnetically, equation (2) is the well-known photo-electric equation, while h becomes a fundamental constant of a rotating electron expressed in terms of spin by the relation $h\Omega_1 = \pi c^2 m_0 / (c_1 - a_1)$ (3) where $(c_1 - a_1)$ is a numerical constant equal to $\frac{2}{3}$ for the simple model considered. The spinning deformed electron leading to equation (2) appears to give, on classical mechanics and electrostatics, the key to radiation problems generally, and in the corresponding theory of atomic orbits yields the principal fundamental series formulae, as well as an adequate account of fine structure, Zeeman and Stark effects.

35. Light quanta and interference. A. J. DEMPSTER, University of Chicago. Experiments by W. Wien and by the author have shown that after 5×10^{-8} seconds the process of light emission from a radiating atom is practically complete. The energy from a glow discharge radiated in the helium line 4471 (decay constant 5.42×10^7) was measured by comparison with the intensity of the spectrum from a black body at a known temperature. The glow discharge was made so faint that 8.4×10^{-11} ergs or 19 quanta fell on the end of an echelon diffraction grating per second. With this intensity each light quantum must pass through the echelon separately. Interference patterns were photographed, showing the same appearance as with bright sources. In particular the characteristic double order image was photographed, indicating interference of rays that have passed simultaneously through the fifteen different steps of the echelon.

36. Effect of an electric field on the radiation from hydrogen atoms. K. L. HERTEL, University of Chicago. (Introduced by A. J. Dempster).—Canal rays were allowed to pass from a discharge tube through a small hole into an observation chamber which was kept at a very low pressure (.0005 mm of mercury). The luminosity from the rays died out rapidly as found by other observers. The light from the canal rays on first

entering the low pressure chamber was observed to be partially polarized, the component parallel to the bundle being the stronger. It was found that the polarization decreased with increasing distance from the opening, the rate of decrease of the polarization being greater than the rate of decrease of the intensity of the rays. When an electric field was applied across the bundle the polarization observed at right angles to the field behaved quite differently. The initial polarization altered very rapidly, and, at two millimeters beyond the opening, was reversed so that the component polarized parallel to the bundle was weaker than the other. This partial polarization then gradually decreased in the field at about the same rate as a polarization then gradually decreased in the field at about the same rate as a polarization observed without the electric field.

37. The effect of changing the conditions of excitation upon the time of appearance of certain spark lines of cadmium and zinc. J. W. BEAMS, National Research Fellow, University of Virginia.—The appearance of the spark lines of cadmium and zinc was studied in the two spectra produced when the same spark discharge passed between metallic electrodes in air and through the ionized vapor of the metallic arc, by a method previously described (Brown and Beams, *J.O.S.A. & R.S.I.*, **11**, 11, (1925)). Each of the spark lines 4924, 4912 ($4d_{1,2}-4f$); 6103, 6021 ($4p_1-5d_1$), ($4p_2-5d_2$) of zinc and 5378, 5338 ($5d_1-4f_1$), ($5d_2-4f_2$) of cadmium were observed to appear simultaneously in both spectra. From this it is concluded that the sequence in the appearance of spectrum lines in the spark is predominantly an atomic phenomenon and practically independent of the characteristics of the spark discharge.

38. Intensities in spectra and the new quantum mechanics. FRANK C. HOYT, National Research Fellow, University of Chicago.—On the basis of the new quantum mechanics of Heisenberg and Born it becomes possible for the first time to obtain exact expressions for the intensities of spectral lines. If the intensities for the linear oscillator as given by Born (*Zeit. f. Phys.* **34**, 858 (1925)) are compared with those calculated on the basis of the older form of the theory it is seen that no one of the possible expressions which were previously proposed can be regarded as exact, provided the new theory is accepted. Computations from the new theory are shown to be in agreement with the relative intensities of the (01) and (02) bands in HCl.

39. The use of a cathode-ray tube for the transmission of speech. C. W. VAN DER MERWE, Washington Square College, New York University, (Introduced by H. H. Sheldon).—One of the chief defects of the "speaking arc" as used by H. Th. Simon in 1898 was its comparative failure to reproduce in a satisfactory manner high-pitched tones. This failure was obviously due to the thermal inertia of the arc. The minuteness of the mass of the electron, and for that matter of the atom, suggested the substitution of an ordinary discharge tube for the electric arc. A tube of special construction containing a trace of a mixture of helium and neon was used and the substitution met with marked success, the high notes coming through much more clearly than in the case of the arc, sibilants like "s" and "c" being distinguishable from one another and voices being recognizable. Quantitative comparisons confirmed the superiority of the tube over the arc, and with a current of only 10 milliamperes flowing through the former, it was possible to telephone a distance of 60 feet with the greatest ease. The key to the success of the "speaking tube" is the luminosity of the discharge, since the light from the glow has to be reflected to the receiver. The success of this essentially wireless telephone will therefore depend on the efficiency with which discharge tubes carrying large currents can be built.

40. Experiments on cathode sputtering. E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—Experiments with the flying metallic particles sputtered from a cathode have yielded the following facts. The side of a glass plate away from the

cathode receives a film of metal as well as the near side. There is no critical relation between the position of the glass plate with reference to the boundary of the cathode (Crookes) dark space and the film received. Shadows on the metallic film, in some cases geometrical and in others more complex, are cast by diaphragms and obstacles. No evidence of the reflection of the particles from glass or metal plates was obtainable. The particles enter open-ended glass tubes only to a distance roughly equal to the diameter of the tube. Some of the particles leave the cathode surface normally and therefore may be focussed on to a glass plate by a concave (spheroidal surface) cathode. The circular film thus formed, however, had an unexpected hole in the center. Likewise a cylindrical cathode, which should concentrate the film into a strip, did so, but the strip had a central line of no deposit. The explanation of the various effects is perhaps to be found in the different sizes, velocities and charges of the flying particles combined with the many complexities of the interior of a discharge tube. Experiments with twenty-two metals enable them to be classed according to their relative ease of sputtering.

41. Normal arc characteristic curves depend on the absolute temperature of the anode. W. B. NOTTINGHAM, Princeton University.—The characteristic curves for normal arcs in air have been found to follow $V=A+B/I^n$ where V is the potential drop, I the arc current, A , B , and n constants with n directly proportional to the temperature of the boiling point of the anode material. Since the publication of this equation (Trans. A.I.E.E. Jan. 1923, p. 12) it has been verified by Anderson and Kretchmar (Phys. Rev., **26**, 33, (1925)) for short platinum and tungsten arcs of small current intensity. Recent measurements on tungsten arcs 2.0 mm to 10.0 mm in length and for currents 1.0 to 10.0 amperes show the average value of n to be 1.38 indicating a temperature of 5250°K while for the six arc characteristics of lengths between 5.0 mm and 10.0 mm the value of n was found to be 1.34 which corresponds to a temperature of 5100°K and agrees exactly with the Langmuir calculation. (Phys. Zeit., **14**, 1273, (1913)). The ten points now located along the straight line $n=2.62(10)^{-4}T$ are

Anode	W	Pt	C	CuO	Al ₂ O ₃	NiO	Ag	Pb	Sb	Bi
T° K	5100	4180	3770	2580	2480	2450	2370	1850	1710	1690
n	1.34	1.15	0.985	0.67	0.65	0.64	0.624	0.48	0.46	0.445

These observations indicate that there may be something more significant to the equation $V=A+B/I^n$ than simply a convenient empirical formula and should be recognized as an experimental fact to be explained by any comprehensive theory of the electric arc.

42. Collisions between electrons and gas molecules. IRVING LANGMUIR and H. A. JONES, General Electric Co.—By a method already described (Science, **59**, 380 (1924)) the volt-ampere characteristic of a cylinder surrounding a coaxial cathode in a gas at low pressure gives quantitatively the probability P (per cm of electron path) that the electron, of 50 to 250 volt energy, will make a collision of a specified type. Thus the collisions may be elastic (P_e) or inelastic (P_k) and the inelastic collisions include those that ionize (P_i) and those (P_r) that make the electron lose a definite energy corresponding to a resonance potential (E_r volts). The electrons that make elastic and resonance collisions are scattered by each such collision only through small angles distributed according to probability laws, θ_e and θ_r being $2/\pi^{\frac{1}{2}}$ times the most probable angle of deflection in degrees. The results for 100 volt electrons calculated for a gas pressure of 1000 bars at 20°C are

Gas	P_e	P_k	P_r	θ_e	θ_r	E_r
Hg	19.	33.	10.	14	14	6.7
A	10.	14.	1.3	14	14	13.
He	1.4	2.7	0.9	26	20	20.
N ₂	7.8	12.2	3.6	14	18	13.
H ₂	4.8	7.1	2.8	14	15	12.

43. Collector characteristics in neon and helium. R. RUDY, Nela Research Laboratory.—After having passed for variable distances through neon at pressures from .01 to 1 mm Hg, 70-volt electrons were received upon a disk. With a retarding field of over 100 volts, only positive ions reached the filament; their number remained nearly unchanged as the collector was moved away for a distance of several cms, and then started to decrease. When the collector was given the potential of the cathode, it began to receive primary electrons, which caused a break in the characteristic. From the slope, their average energy could be determined for different positions of the collector and compared with the results deduced from the theory of the scattering of electrons. Even in inert gases, the loss of energy is considerable besides excitation and ionization, whereas it is often neglected in the work on activation and disappearance of gases in the electric discharge. As the pressure was increased, the break disappeared entirely; the collector was now in the "positive column" of the discharge; a strong increase in current occurred only when the anode potential was approached. With heavier discharge currents space charges (e.g. near the collector) disturbed the field and discontinuous changes were noted.

44. Hydrogenation of ethylene by excited mercury atoms. A. R. OLSON and C. H. MEYERS, University of California.—In a previous article, (*J. A. C. S.* **48**, 389 (1926)), we have shown that ethylene and hydrogen react to form ethane under the influence of excited mercury atoms. The rate of the reaction was found to be proportional to the square root of the partial pressure of molecular hydrogen when all other factors are kept constant, and therefore the primary reaction is $H_2 = 2H$. The atomic hydrogen then diffuses from the illuminated region into the body of the gaseous mixture where hydrogenation occurs. The addition of an inert gas such as nitrogen should lower the diffusion rate. This effect is in qualitative agreement with the increased brightness of the thallium lines in the presence of nitrogen as observed by Loria, and in the decreased reaction rate of water formation from oxygen and hydrogen in the presence of nitrogen as observed by Mitchell. In the present set of experiments a gaseous mixture composed of 2.5 mm of N_2 , 4.5 mm of H_2 and 1.2 mm of C_2H_4 were circulated past the illuminated window. The rate of reaction was found to be the same, within experimental limits, as the rate for the same mixture without the nitrogen. Under these conditions any increase of reaction rate due to metastable mercury atoms, must be offset by a decrease of rate due to diffusion. The broadening of the absorption line of mercury due to the added nitrogen was investigated by an external filter containing mercury vapor and found to be negligible.

45. Measurement of the increase of metastable atoms in mercury with accelerating voltage. HELEN A. MESSENGER and HAROLD W. WEBB, Columbia University.—The "radiation" from mercury vapor excited in a four-electrode tube by electrons from an equipotential cathode was measured by the "photo-electric" current from the nickel plate which was not sensitive to $\lambda 2537$ radiation. A quartz or a calcite window could be lowered at will into the space between the grids to cut off metastable atoms from the plate. With no window typical Frank and Einsporn curves were obtained showing all the breaks which they found. With quartz a similar curve was obtained above 5.2 volts although the current was reduced to 10% or less. Below 5.2 volts there was no measurable current. With calcite the currents were still smaller; the 5.7, 6.7, 8.05 and 8.35 breaks were missing. The difference between the "photo-electric" currents in the open tube and those obtained with quartz interposed measures the increase of metastable atoms with accelerating voltage. The difference between the quartz and the calcite curves shows the presence of $\lambda 2140$ radiation and further shows that the $\lambda 1849$ radiation increases linearly from 6.7 volts.

46. The formation of negative ions in mercury vapor. WALTER M. NIELSEN, Duke University.—The method used is similar to that of Mohler (*Phys. Rev.* **26**, 614, (1925))

Electrons, projected along the axis of a tube between two plates were prevented from scattering by a magnetic field of 350 gauss parallel to the axis of the tube. Negative ions formed by the attachment of an electron to a molecule or to an atom were removed by suitable potentials applied to the side plates. The remainder of the current reached a circular plate at the end of the tube. With a small field between the side plates, the negative ion current was just barely observable (1×10^{-10} amperes). With higher fields the ion current increased enormously, approaching saturation when the potential difference between the side plates was increased to between 3 and 4 volts. The negative ion current was of the order of 9×10^{-9} amperes. The total current was of the order of 1×10^{-7} amperes. The ratio between the negative ion and total current decreases with increase in the driving potential for low voltages, but increases at 2.7, 4.7, 5.5, and 8.8 volts. The cause of the break at 2.7 volts is not known. The breaks at 4.7, 5.5, and 8.8 volts are believed to be associated with the electronegative properties of the mercury atom having an electron in a metastable orbit. The total current increases rapidly with increase in the driving potential and decreases at 4.9 and 6.7 volts.

47. Resonance and ionization potentials in mercury vapor. C. W. JARVIS, Ohio Wesleyan University.—Measurements on the critical potentials in mercury vapor were made with two types of tubes: (1) a three-electrode tube by which both total and partial currents were observed; (2) Hertz differential tubes of several different sizes. The table shows the values obtained together with those calculated from the relation $Ve = h\nu$ and those reported by Franck and Einsporn.

Calc.	F. & E.	Author	Calc.	F. & E.	Author	Calc.	F. & E.	Author
1.26		1.23	5.28	5.32	5.22	7.69	7.73	7.74
2.26		2.21	5.43	5.47	5.37		8.05	8.02
2.83		2.80	5.73	5.76	5.70		8.35	8.33
3.37		3.44		6.04	6.05	8.81	8.86	8.82
3.70		3.80		6.30	6.46	9.32	9.37	9.33
4.16		4.21	6.67	6.73	6.79	9.52	9.60	9.58
4.66	4.68	4.53		7.12	7.13	9.80	9.78	9.90
4.86	4.90	4.97		7.46	7.41			

A number of critical potentials below 4.68 volts were observed. The interpretation of these is much in doubt, as they imply that in normal mercury vapor the valence electron is in a higher energy level than that corresponding to the ground orbit of the valence electron. Perhaps they may be attributed to the molecule of mercury.

48. The ionization potentials of hydrogen and nitrogen on an iron catalyst. GEORGE KISTIAKOWSKY, Princeton University, (Introduced by K. T. Compton).—By the method of electron bombardment, Gauger and Wolfenden showed that hydrogen adsorbed on nickel has radiation and ionization potentials characteristic of atomic hydrogen. Nitrogen adsorbed on a promoted iron catalyst has now been studied by an improved method. The catalyst was prepared by reduction in hydrogen and contained residual hydrogen. Ionization potentials in presence of nitrogen were found at 11.1, 13.0, 16.0, 17.1 corrected volts. The two highest doubtless belong to molecular hydrogen and nitrogen. 13.0 volts is slightly different from the ionization potential of gaseous atomic hydrogen, but evidently the energy required for ionization of an adsorbed gas atom is not necessarily the same as that for a free atom. This energy is compounded of the ionization energy of a free atom plus its adsorption energy minus the energy of adsorption of a free electron by the metal. The last two terms are not necessarily equal, though they are known for hydrogen to be not very different. The ionization at 11.1 volts was only observed when catalyst and nitrogen were both present and belongs, probably, to atomic nitrogen, whose gaseous ionization potential has been estimated spectroscopically as about 11 volts. Catalytic poisons were found to suppress the critical potentials at 11.1 and 13.0 volts.

49. Direct determination of the ratio of Planck's universal constant to the charge on the electron. ERNEST O. LAWRENCE, National Research Fellow, Yale University.—The precision of the method for critical potential measurements described at the Montreal meeting has been developed to a greater degree. The most recent determinations of the ionization potential of Hg vapor with assigned "weights" are:

Volts	Weight	Volts	Weight
10.46	8	10.36	5
10.32	4	10.40	4
10.42	10	10.44	4
10.37	10	10.39	10

Calculating in the usual way the mean value and probable error we have for the ionization potential 10.399 ($\pm .007$) volts. Applying the quantum postulate to the series limit there results for the ratio h/e the value $1.3735 (\pm .0009) \times 10^{-17}$. Using Millikan's determination of e we have for h the value $6.550 (\pm .006) \times 10^{-27}$, in which the error presumably is concerned with the uncertainty in e . These results are tentative pending the outcome of a thorough investigation of possible sources of systematic error.

50. On the threshold sensitivity of photographic emulsions to low speed electrons. KENNETH COLE, Cornell University, (introduced by F. K. Richtmyer).—A new design of magnetic dispersion electron spectrograph has been used in an investigation of the sensitivity of photographic emulsions to electrons of speeds below 100 volts. With commercial emulsions, the lowest speed that will produce a perceptible effect depends upon the emulsion and is usually in the neighborhood of 30 volts. It has been found however that a very thin film of lubricating oil on the surface of the emulsion enormously increases its electron sensitivity and at the same time lowers the threshold speed. With both oiled and unoled emulsions, the photographic action seems to be due to fluorescence excited at the surface by the electron impact.

51. Secondary emissions from metals due to bombardment by high speed positive ions. WILFRID J. JACKSON, Princeton University, (introduced by K. T. Compton).—A beam of K^+ ions from the iron catalyst source discovered by Kunsman was collected in a Faraday cylinder. A target could be interposed at the mouth of the cylinder by a magnetic control. The difference in current measured in these two cases gave the amount of the secondary emission. A transverse magnetic field could be applied at the target to prevent emission of electrons and thus separate electron emission from positive ion reflection. On bombardment of a molybdenum target which had been baked in *vacuo* to 1000°C and then exposed to air before final evacuation of the apparatus, secondary emission was inappreciable if the energy of the bombarding ions was less than 250 volts, was appreciable (1%) at 350 volts and rose steadily to about 9% at 1000 volts. These values depended somewhat on previous treatment of the target. After heating in position in *vacuo* by induced currents the emission fell to not more than a third of the above values. The secondary electrons were stopped by retarding fields of 0.25 volts. Positive ion reflection did not exceed 2%. Secondary emission from nickel was first detected at about 400 volts and increased to about 7% at 1000 volts.

52. Long wave length limit of mercury. WAYNE B. HALES, California Institute of Technology.—Kazda made the first definite and satisfactory determination of the critical potential and long wave-length limit for a clean flowing mercury surface, locating this critical frequency at 2735A with an uncertainty of $\pm 10A$. Sophie Taubes' recent determination made on mercury drops suspended in argon was very much higher, namely, $3043 \pm 20A$. I have, with completely new apparatus and new working conditions, found this long wave-length limit to be 2735A and have succeeded in getting a stationary surface so clean that the critical frequency has been found for it, namely, $2735 \pm 10A$ which is in entire agreement with Kazda for flowing mercury.

53. A new effect in the photo-electric emission from oxide-coated filaments. W. H. CREW, Naval Research Laboratory, Washington, D. C.—Total radiation from a quartz mercury arc was directed on to the oxide-coated platinum filament of a two-electrode quartz vacuum tube. Current-voltage curves were obtained with and without the light shining in the tube; and from these was determined the electron current due to the light alone. This current, plotted as a function of the plate voltage, increased rapidly to a maximum and thereafter fell off gradually. The position of this maximum was found to shift in the direction of decreasing potentials with increase of the temperature of the filament. Similar phenomena were observed with a filament made of oxide-coated tungsten, but could not be detected for either platinum or tungsten without oxide coating. The photo-electric emission was largely due to light of wave-length below $\lambda 3000\text{\AA}$; for the photo-current was reduced almost to nothing by use of suitable glass absorbing screens, and was enhanced when mercury vapor was removed from the tube and the arc was water-cooled. The explanation of these phenomena is perhaps to be found in the changes in the surface of the filament under the action of the light rather than to space-charge effects.

54. The theory of thermionics. N. RASHEVSKY, Westinghouse Elec. & Mfg. Co., East Pittsburgh, (introduced by Dayton Ulrey).—The expression for the free energy of a metal is derived by computing the "Zustandsumme." Account is taken especially of the fact that the thermionic phenomena are essentially surface phenomena. The expression for the free energy thus obtained is substituted in the general formulas for thermionic emission previously derived. The final formula thus obtained gives indications for the understanding of the fact that while for pure metals the " A " constant of Richardson's equation has almost exactly the universal value postulated by Dushman, it has a largely different value for oxides and adsorbed films. The question as to the existence of an electric double-layer on the surface of a metal is discussed, as well as the influence of such a layer on thermionic emission. It is shown that while the existence of such a layer follows from Schottky's "Equilibrium Theorems," the same theorems lead to the conclusion that the temperature change of the moment of such a layer is relatively small. Its value may be approximately estimated.

55. Measurement of electronic charge by shot effect in aperiodic circuits. N. H. WILLIAMS and H. B. VINCENT, University of Michigan.—The theory of the probability variations of thermionic currents and their relation to the charge on the electron was investigated by Schottky. Hull and Williams measured the charge on electrons produced by thermionic emission, by photo-electric emission and by ionization of a gas. They worked with the high frequency currents set up in a tuned circuit by the Brownian fluctuations of the electron currents in a tube. The work here presented makes use of a five stage amplifier similar to the one they have described. The screen grid tubes were furnished by the General Electric Company. A pure resistance is substituted for the tuned circuit in which the shot effect is measured and an expression for the electronic charge in terms of the high frequency potential difference between the terminals of this resistance is developed. Both the mathematical derivation and the experimental procedure are considerably simplified. The results thus far obtained are in close agreement with the accepted value of the electronic charge. Measurements of shot effect have already thrown some light upon the nature of ionization and the mechanism of secondary emission and it is believed that this modification of the former method of measurement will increase the range of such investigations since the effects are larger and more easily measured.

56. Velocity distribution among thermionic electrons in vacuum and in hydrogen atmosphere. C. DEL ROSARIO, Yale University, (introduced by W. F. G. Swann).—The thermionic current from a tungsten filament to a coaxial cylindrical electrode was

measured for different retarding potentials first in vacuum and then in hydrogen, keeping the temperature of the filament constant. The heating current was made intermittent to eliminate potential drop along the filament when the thermionic current was being measured, and its effective value was kept constant to 1/20 percent by a Wheatstone bridge arrangement of which the filament was made one arm. The filament temperature, determined from data of Forsythe and Worthing ranged from 1800°K to 1990°K, and the pressure of hydrogen was varied from 0 to 0.22 mm Hg. The distribution of velocities among the electrons was found to follow Maxwell's law, contrary to the experience of other observers, for a gas in thermal equilibrium with the filament for both vacuum and hydrogen atmosphere.

57. The adsorption of caesium on tungsten and oxidized tungsten. JOSEPH A. BECKER, Bell Telephone Laboratories, Inc.—By means of a method previously described it is possible to determine the number of caesium atoms and ions that evaporate from a cm² of tungsten at various temperatures when the tungsten is covered to various extents. The results are exhibited by curves showing rates of evaporation versus fraction of the surface covered. A typical isothermal rises sharply at the origin, reaches a maximum for 1 percent of covering, then decreases exponentially until the covering is 20 percent when it again rises steeply. The first rise and fall are due to ions, the second rise to atoms. These curves show that as more caesium is adsorbed ions evaporate less readily while atoms evaporate more readily. They explain (1) why positive ion emission versus temperature curves show a steep rise at an upper critical temperature at which the filament cleans off spontaneously, and a steep decline at a lower critical temperature; (2) the lack of discontinuities in the electron emission at these same temperatures; (3) why the filament may be covered to two different extents separated by a dividing edge; (4) why this edge travels along the filament; (5) how changes in the caesium vapor pressure affect these characteristics.

58. A new theory of ionic mobilities. A. P. ALEXIEVSKY, University of California, (introduced by Leonard B. Loeb).—Recently, Loeb has shown in HCl gas that the ions are probably clusters of molecules about a charged molecule. Previous theories have accounted for the mobility of ions assuming that the clusters consist of but a few molecules. In this paper it is shown that it is possible to account for the mobility of these ions by assuming that the ion consists of a droplet of liquid HCl, condensation being caused by the electrical forces of the charged molecule. Assuming that the force of attraction between ion and molecule is given by $f = (D-1)e^2/2\pi Nr^5$ where D is the dielectric constant, e is the electron, N the number of molecules per cm³ and r the distance of the HCl molecule from the charge, one can calculate from the expression $vd\phi = ((D-1)e^2/2\pi r^5 N)dr$, using Van der Waal's equation, the radius R of the droplet which would be in equilibrium with any pressure of the gas. Placing the value of the radius so calculated in Epstein's equation for the mobility of a charged spherical droplet in an electrical field the mobility of the HCl ion is computed and found in good agreement with observed values. The equations also enables one to calculate the variation of the mobility with concentration in HCl air mixtures.

59. Molecular structure and the relative mobilities of positive and negative gaseous ions. LEONARD B. LOEB and A. M. CRAVATH, University of California.—Recently it has been shown by Loeb that the mobility of the negative ions in HCl gas is less than that of the positive ion. Condon made the suggestion that this was due to the presence of the H nucleus in the molecule which lay closer to the molecular surface than in most molecules. In a recent paper by Hund it is shown that both H₂O and H₂S exhibit the same general characteristics as HCl in the placing of the H nuclei. Mobility measurements have been made in these gases using the Franck modification of the Rutherford alternating current method. The mobilities of the positive ion in H₂S was 0.61 cm/sec per

volt/cm and that of the negative ion was 0.55 cm/sec per volt/cm. In water the mobilities were 0.62 and 0.56 cm/sec per volt/cm respectively. It is seen that these results are in agreement with the anticipation. The mobility values are relative to air, assuming 1.4 for positive and 1.8 for negative ions in cm/sec. per volt/cm.

60. Ether-drift experiments at Mount Wilson in February, 1926. DAYTON C. MILLER, Case School of Applied Science.—In February 1926, the ether-drift experiments were continued at Mount Wilson under very favorable conditions of weather. This series, consisting of 101 sets of observations involving 34000 readings, is the most extensive yet made for any one epoch. This epoch was chosen because, when combined with the epochs of 1925, it gives observations well distributed throughout the year. The new observations entirely confirm the results of the 1925 observations as announced at the Kansas City meeting. There is a periodic displacement of the interference fringes which is clearly systematic and cosmical in character; it is such as would be produced by a relative motion of the earth and the ether of 10 kilometers per second, the apparent apex of the earth's motion being a point in space having the right ascension of 255° and a north declination of 68° . The definitive values of the coördinates, from all available observations, are not yet determined. Causes for the observed phenomena other than relative motion are to be considered.

61. Faraday tubes and amperes rule. R. C. COLWELL, West Virginia University.—A new theory of Faraday tubes is outlined in which each tube is supposed to be made up of a succession of double doublets. These doublets have both electric and magnetic polarity. In a Faraday electric tube the electric poles are placed end to end and the magnetic poles are then perpendicular to the tube. In a Faraday magnetic tube, the electric poles are perpendicular to the tube. A Faraday tube always extends from a positive to a negative pole and shortens by an elision of the double doublets. When these doublets are elided they go out with a right hand twist thus giving rise to a closed electric or magnetic line of force. A lengthening of a Faraday tube reverses the direction of the closed magnetic (or electric) line of force. The single rule that "a shortening Faraday tube gives a right hand twist, a lengthening Faraday tube a left hand twist" is then sufficient to cover all cases of induced currents. It is also shown that this rule is equivalent to Ampere's rule regarding the attraction between two conductors which have currents in the same direction, so that Ampere's rule alone may be substituted for the many rules that are now given to determine the direction of an induced current.

62. The electric field of a charged wire and a slotted cylindrical conductor. CHESTER SNOW, Bureau of Standards.—The potential is found which is due to a fine wire (charged) in the presence of an outer shield at potential zero. This shield consists of a thin cylindrical shell, concentric with the wire, whose trace on a plane perpendicular to the latter consists of n equal, equally spaced circular arcs of a common circle. The problem is first simplified by a complex transformation $Z^n = z$, reducing it to that of a line charge in the presence of a single (incomplete) circular arc (a part of the circular arc $r = \alpha$). This problem is solved for any position of the line charge, the solution being effected first by a transformation $z = \alpha(i - z') / (i + z')$ which transforms the interior of this circle into the entire upper half of the z' -plane. The circular boundary then corresponds to the real axis of z' . This problem (that of a line charge in the presence of a finite straight line at zero potential) is again simplified by the transformation $z' = c \cos w$ which represents the entire z' -plane upon a semi-infinite strip in the w -plane. The proper (periodic) solution due to a line charge in this strip is then built up by an infinite series of images and their effect summed. By retracing the steps of the transformation, a solution in finite form is obtained for the original problem.

63. A new type of contact rectifier. L. O. GRONDAHL, Research Department, Union Switch and Signal Co.—A piece of copper with a layer of copper oxide formed on it at a high temperature is an unsymmetrical conductor of electricity. Ratios between high resistance and low resistance as high as 20,000 have been obtained. The unit consists of the oxidized piece of copper with a contact on the outer copper oxide surface made by means of a piece of lead or other soft metal applied under pressure. In a 1-1/2" disc, the low resistance may be a small fraction of an ohm and it is therefore capable of carrying comparatively high current. The capacity of such a disc is represented by a d.c. output of 5 watts. Cuprous oxide is an electronic conductor and the rectifier is therefore permanent. The effects of voltage and of pressure on resistance are similar to the corresponding effects in contact rectifiers, the principal difference being in the magnitude of the resistances. The voltage characteristic results in a very slight distortion of the rectified wave. No forming is necessary so the rectifier is immediately operative when the alternating voltage is applied. The units may be assembled like cells in a battery to supply higher voltages or greater currents.

64. Electrolytic conduction of potassium through glass. V. ZWORYKIN, Westinghouse Elec. & Mfg. Co., East Pittsburgh.—Burt has reported the successful introduction of sodium into a thermionic vacuum tube by electrolysis, the filament of the tube being connected to the negative terminal of a d.c. supply while the positive terminal is connected to a crucible containing molten sodium nitrate into which the tube is immersed. Attempts to duplicate the experiment with potassium were unsuccessful, the failure being attributed to the smaller mobility of potassium ions. The author has repeated Burt's experiments with different glasses and finds that for a soda potash glass immersed in KNO_3 the metal introduced into the tube is primarily sodium while the glass itself is enriched in potassium at the expense of sodium and becomes unusually brittle. When a potash glass, free from sodium, is used, potassium of high purity passes into the tube without corroding or embrittling the glass. This seems to show that Burt's negative results with potassium were due primarily to the difference in dimensions and molecular forces of potassium and sodium ions.

65. The sodium voltameter. ROBERT C. BURT, California Institute of Technology.—This voltameter, mentioned in recent publications, using the electrolysis of Na through glass, has been modified in form by using metal contact with the glass instead of thermionic emission. The voltameter not only possesses a large advantage over the silver voltameter because of the simplicity of the operation involved and reproducibility under ordinary working conditions where the limit of refinement is not demanded, but it has also been shown to yield results which are certainly correct to 1 part in 2000, and probably to 1 part in 6000.

66. Contact electromotive force of carbon. BRIAN O'BRIEN, Buffalo Tuberculosis Association, Perrysburg, N. Y.—The carbon surface was prepared by depositing a thin layer of soot from pure benzol on a platinum ribbon. The contact e.m.f. was measured against cupric oxide by the Kelvin method with a precision of 0.01 volt. Freshly smoked surfaces in air before outgassing were positive to CuO by about 0.40 volt, with some variation between different surfaces prepared alike. Reduction of pressure from atmospheric to less than 10^{-6} mm mercury without heating made carbon slightly less electropositive, reaching a steady state. Outgassing carbon at successive temperatures up to 1400°C (the CuO at all times cool) made the carbon less electropositive, finally becoming negative to the CuO by 0.11 volt. The outgassing-contact e.m.f. curves were fairly reproducible on a number of surfaces. An outgassed surface allowed to stand in air became more electropositive, but did not return to initial value. There was no evidence of a final value characteristic of a completely denuded carbon surface, as further heating at higher temperatures rendered the carbon progressively more electronegative.

Effect of mercury vapor. Allowing mercury vapor at a pressure of 0.001 mm in the tube did not affect the contact potential difference between the carbon and the CuO.

67. Dielectric constant of an electrolyte. EDWARD M. LITTLE, University of Illinois, (introduced by Jakob Kunz).—Dielectric constant is related to electric moment per unit volume just as permeability is to intensity of magnetization. The electric moment of an electrolytic solution decreases with ionization, and the dielectric constant for 100% ionization of the solute equals that for the pure solvent (corrected for volume change). A critical value of dielectric constant, k_c , is assumed, above which the molecular binding forces in the solution are weakened sufficiently to allow all molecules to ionize. For values of k below this, thermal agitation together with the dielectric constant, occasionally ionizes a solute molecule. In general, for initial values of k less than k_c and also for some values greater, there is less than 100% ionization of the solute. A relation between n (ionized molecules per cc) and the concentration, c (molecules of solute per cc) is found, and as a relation between k , n , and c is known (because of the relation between k and intensity of electrification) the relation between k and c is then obtained. It is approximately a hyperbola. The initial drop in the experimental curves is due to grouping of molecules around ions, thus decreasing the intensity of electrification and therefore the dielectric constant.

68. Piezoelectric quartz oscillators coated with metallic films. E. O. HULBERT, Naval Research Laboratory, Washington, D.C.—Recent experiments have demonstrated that a quartz piezoelectric crystal with the sides coated with films of platinum, copper, or other metals, may be used in a suitable electron tube radio circuit as an *oscillator*, i.e. a *generator* of sustained current oscillations. Electrical connection was made to the metallic films by soldering small wires to the films or by a brush contact. The natural frequency of the crystal was changed but slightly by the addition of the metallic film. This frequency change with the weight of the film, the effect of the films on the other frequencies and harmonics, the effects of temperature, gas pressure, etc., are being investigated in detail. W. G. Cady has shown that a piezoelectric crystal coated with chemically deposited silver will serve as a resonator in a radio frequency circuit; its use as an oscillator, however, appears to have been unsuspected. In fact previous experience would suggest that a metallic film adhering to the crystal may destroy its oscillating properties, just as an oil film is known to do.

69. A new phenomenon dealing with the action of electrostatic fields upon electric currents. PALMER H. CRAIG, University of Cincinnati.—If the Hall effect is caused by a magnetic deflection of the free electrons within a metal, an analogous effect should be produced by an electrostatic field. An electrostatic potential of 17,000 volts was applied to the edges of a bismuth film 7.5×3.0 cms in area and 0.045 cms thick, by means of copper rods separated from the bismuth by sulphur or plate glass insulation. When a current of one ampere flowed through the strip longitudinally, a net transverse potential difference of about 40 microvolts was measured between point contacts at the edges midway between the ends of the film. This was a net effect after correction had been made for thermal effects, leakage currents and other causes masking the true effect. The transverse potential decreased with decreasing electrostatic field, longitudinal current and thickness of the film, and was measured by a potentiometer arrangement sensitive to 0.01 microvolt. Moving the point contacts towards the end of the strip also decreased the effect. No effect was observed in copper, silver and aluminum and it was therefore concluded that if the phenomenon exists in these metals it is of very much smaller magnitude than that in bismuth. The magnitude of the Hall effect is approximately 611 times that of the new effect when comparing the magnetic effect at 1000 gauss with the electrostatic effect at 17,000 volts, the same bismuth film and a longitudinal current of one ampere being employed in both cases.

70. Wave form of free electrical oscillations: self-capacity effect in multi-layer coils. ALLEN ASTIN, New York University. (Introduced by J. C. Hubbard).—Observations have been made of the wave form of the free oscillations of a section, or sections of a multilayer coil by itself, and with added capacities, using the drop chronograph method developed by J. C. Hubbard (Phys. Rev., 9, 529, (1917)). From the results periods, self capacities and damping factors of the coil are determined. Periods are determined to less than 1/10 per cent. The resistance is determined from the decrement. From a calibration of the contacts of the instrument, using a constant potential, the oscillation potentials are found to be in excellent agreement with those calculated from the constants of the circuits. With a coil of rectangular cross section of winding, with layer windings in several sections, but with the unused sections disconnected, the free periods are approximately independent of the number of sections used.

71. The inductance of a helix made with wire of any section. CHESTER SNOW, Bureau of Standards.—A formula has been derived for the inductance of a single layer helix which is to be used in absolute measurements of precision. It takes account of the helical nature of the winding and hence of the axial component of current in it. It is derived for any shape of wire section and is especially simple if this is symmetrical about each of two axes passing through its center of gravity. It is correct to the second order inclusive in small quantities like the ratio of the dimensions of the wire section to the radius of the cylindrical form. The current density is not assumed to be uniform but the formula applies (to the second order) to any current distribution which is developable by Maclaurin's theorem over the section of the wire. The formula is specialized and simplified for the cases of wires having circular or rectangular section. For windings of ordinary dimensions a precision is claimed of at least one part in a million.

72. The resistance of condensers at radio frequency. R. R. RAMSEY, Indiana University.—The condenser was placed in a "differential thermometer" made of two 800 cc pyrex glass beakers inverted on and sealed to two glass plates. Through each glass plate three holes were drilled. In two of these, electrical connections were placed and through the third a glass tube was sealed. To the glass tubes was fastened a U-tube filled with water. The height of the water in the tubes served to indicate the relative pressure in the two beakers. The radio condenser, which was an eleven plate variable condenser of "low loss" construction, was placed in one of the beakers and connected to the electrical connections which extended through the glass plate. In the second beaker a second condenser exactly like the first was placed, but this condenser was not connected to the terminals. A short piece of resistance wire was connected to the electrical terminals. The first condenser was connected into a radio frequency circuit and the resistance wire was connected to the electrical terminals. The first condenser was connected into a radio frequency circuit and the resistance wire was connected to a D.C. circuit. Then assuming that both beakers are exactly alike thermally when the pressures as indicated by the water in the U-tube are the same, we have I^2R in the high frequency side is equal to i^2r in the D.C. side. The average of a number of determinations at a frequency of 10^6 cycles, was .098 ohms. The individual results varied from .05 ohms to .15 ohms, the condenser being set so that the capacity was .00008 microfarads.

73. Establishment of radio standards of frequency by the use of a harmonic amplifier. C. B. JOLLIFFE and GRACE HAZEN, Bureau of Standards.—One method used by the Bureau of Standards in establishing radio standards of frequency consists in the "stepping up" from a known standard audio frequency to a radio frequency by the use of harmonics. The low-frequency output is carried through an amplifier arranged to distort and so produce harmonics. By means of tuned circuits a harmonic is selected which in turn serves as a fundamental for further distortion and amplification to give the desired frequency with sufficient power to operate the frequency meter under standardization.

A fixed radio-frequency generator such as a piezo oscillator, or a fixed audio-frequency generator such as an electric-driven tuning fork, can likewise be standardized by the use of the harmonic amplifier with the addition of a sonometer for measuring an audio-frequency beat note produced by a harmonic from the standard audio-frequency source and the fundamental or harmonic from the fixed-frequency generator. The frequency of the beat note is impressed on the steel wire of the sonometer by means of a telephone receiver magnet. The vibration frequency of the wire is calculated by means of the constants of the wire and the tension applied.

74. Cooperative investigation of radio fading. J. H. DELLINGER, C. B. JOLLIFFE and T. PARKINSON, Bureau of Standards.—Signal intensity fluctuation is one of the chief barriers to reliable long distance reception of broadcasting and of the higher radio frequencies. With a view to securing quantitative data on this phenomenon the Bureau of Standards invited a number of university and other laboratories to engage in a cooperative program of fading measurements. This report summarizes the progress made in 1925 when five series of simultaneous observations were made on certain specially arranged transmissions from broadcasting stations. Twenty laboratories in the eastern half of the United States were engaged in the work. The measurements consisted of recording graphically variations of deflection of a galvanometer connected to radio receiving apparatus so as to indicate directly variations in the received field intensity. These records were supplemented in some cases by absolute measurement of the field intensity and by simultaneous continuous records of direction variation. The measurements yielded data of value on the characteristic radio wave phenomena during a solar eclipse, during the sunset period and the variations throughout the whole diurnal cycle.

75. Reception currents from a loop antenna. R. C. COLWELL, West Virginia University.—If the oscillations in the four sides of a loop antenna are regarded as made up of the oscillations of a succession of vibrating doublets, an integration around the loop will give the resultant electric vector for any point in space. For the two vertical sides of the loop, the electric intensity takes the form $E_{\theta} = (2I \tan \theta / cr_0)(1 - \cos 2\pi h \cos \theta / \lambda r_0)^{\frac{1}{2}}(1 - \cos 2\pi aX / \lambda r_0)^{\frac{1}{2}}$. This equation shows that a loop has a directional effect high up in the air as well as along the ground. If the integration is taken over one vertical and one horizontal side, we have the electric intensity due to a bent antenna. The resulting equation is in the form

$$E_{\theta}' = (Ic/r_0) ((A + B \cos \alpha)^2 + (C + D \cos \alpha)^2)^{\frac{1}{2}}$$

The $\cos \alpha$ changes sign when the azimuth is 90° in such a way as to give a directive effect to the wave sent out from this antenna; the intensity being greatest for azimuth 180° and least for azimuth 0° .

76. A ballistic galvanometer as an integrating instrument. H. L. CURTIS and C. MOON, Bureau of Standards.—The formula for the capacitance when using Maxwell's absolute bridge is derived assuming that the time integral of the current through the galvanometer is zero. This paper shows the conditions which must be fulfilled by a galvanometer in order that it will correctly integrate the current. With all integrating galvanometers the torque produced by the current through the coil shall at every instant be proportional to this current. This will be the case only if the coil is non-magnetic and if the current through the coil does not affect the field of the permanent magnet. This last condition can be experimentally realized by finding the position of the coil where the reversal of the applied electromotive force does not change the galvanometer reading. A second requirement applies only to conditions similar to those in a Maxwell bridge. These conditions are such that the curve of motion of the galvanometer coil as a function of time is a series of parabolas. In order that the time integral of current shall be zero, the time integral of deflection must also be zero. This requires that the

excursions shall be on both sides of the galvanometer zero, but not an equal amount on the two sides. The ratio on the two sides is as two to one.

77. Magnetostriction in permalloy. L. W. MCKEEHAN and P. P. CIOFFI, Bell Telephone Laboratories, Inc.—The specimens examined were well-annealed 1 mm wires, 40 cm long, of iron, nickel, and permalloys containing from 46 to 89 percent nickel. Changes in the magnetization were measured ballistically. Changes in the length of part of the specimen were multiplied two million times by a mechanical lever, an optical lever, a multiple slit, a photo-electric cell and a sensitive galvanometer. Measurements were made with or without tension. The rate of increase in magnetostriction with magnetization, at zero magnetization, was zero in all cases. Permalloys with less than 81 percent nickel expanded, those with more than 81 percent nickel contracted when magnetized. Tension reduced the expansions and increased the contractions. The theory of atomic magnetostriction (Phys. Rev. **26**, 274, (1925)), explains the new results and suggests that orientation of the magnetic axes of iron and nickel atoms, precisely like that due to the application of magnetic fields, may be effected by mechanical stresses within the elastic limit. Changes in electrical resistance (Phys. Rev. **23**, 114, (1924)) support this view.

78. Hall effect in mono-crystalline copper. P. I. WOLD, Union College.—The Hall effect has been measured in a single crystal of copper in the form of a rod 15 cm long and .55 cm in diameter. The crystal was cubic with an axis nearly coincident with the longitudinal axis of the rod. Transverse contacts were obtained by copper terminals spring pressed against the sides of the rod, the rod being placed in a holder which permitted rotation about the longitudinal axis. The Hall constant varied with rotation, but only by relatively small quantities which were irregular and apparently due to difficulty in maintaining stable transverse contact. If the Hall constant parallel to an edge of the crystal cube is R_1 and that at right angles thereto is R_2 , the results are in agreement with the relation that in intermediate directions the resultant constant is $R = R_1 \cos^2 \alpha + R_2 \sin^2 \alpha$. In the case of a cubic crystal $R_1 = R_2$.

79. The effect of small amounts of silicon on the thermo-magnetic change point "A2" in mild steel. F. C. FARNHAM, New York University (Introduced by H. H. Sheldon).—Tests have been made on samples of steel containing .25 percent carbon with varying silicon content up to 3 percent. It is observed that for small amounts of silicon, up to about .5 percent, the point "A2" is lowered rather rapidly; for added amounts, up to about 2 percent, the lowering of "A2" is much less; and for amounts between 2 percent and 3 percent the rate of lowering of "A2" is again greater. From these results it is evident that the presence of the carbon greatly modifies the effect of silicon as observed in ferro-silicon alloys.

80. Magnetic moments of the alkali metal atoms. JOHN B. TAYLOR, University of Illinois, (introduced by W. H. Rodebush).—The results previously reported on sodium (Kansas City meeting) have been confirmed, showing that the neutral sodium atom possesses a moment closely equal to one Bohr magneton. Potassium has also been investigated and shows, likewise, the single magneton value.

The amounts of deflection or splitting of the atomic rays of sodium and potassium are related inversely as the temperatures of evaporation, in accord with the equations for the effect. Distinct images of the divided rays have been obtained.

81. The Zeeman effect, the Stern-Gerlach experiment and the magneton. JAKOB KUNZ, University of Illinois.—Landé and Sommerfeld have given a classification of the anomalous Zeeman effect, which makes it possible to determine the number of magnetons in an atom if the multiplicity, the ground term of the atom and the inner quantum

number are given. These numbers have been supplied to the writer by P. D. Foote for most of the elements. The number of "lines" to be expected in the Stern-Gerlach experiment, and the number of Bohr magnetons has been calculated. It has been shown moreover that especially for the rare earth elements the agreement between these calculations and recent measurements is satisfactory.

82. Direct absolute measurement of acoustic impedance. G. W. STEWART, University of Iowa.—Advantage is taken of the author's theory of the transmission in an acoustic line with an attached branch which alters the intensity and the pressure phase of the transmitted sound. By the measurement of the relative intensities and phases with and without the branch present, it is possible to obtain the components Z_1 and Z_2 of the impedance, $Z = Z_1 + iZ_2$, of the branch. If S is the area of the conduit, P_0 and P_0' the two pressure amplitudes, ϵ the change in phase, ρ the density of the medium, a the velocity of sound therein, $Z_1 = (\rho a/2S) [A/(A^2 + B^2)]$ and $Z_2 = (\rho a/2S) [B/(A^2 + B^2)]$, wherein $A = (P_0/P_0') \cos \epsilon - 1$ and $B = -(P_0/P_0') \sin \epsilon$. The method involves only the *relative* magnitudes of pressure amplitudes and the direct measurement of phase change, the knowledge of density and velocity being sufficiently accurate. In the present application the pressure ratio is determined by altering a comparison source, and the phase is measured directly. The method involves only one simple absolute measurement and is a strictly acoustic method somewhat analogous to methods of measurement long used in electricity.

83. Effect of amplitude on the frequency of a tuning fork. C. MOON and H. L. CURTIS, Bureau of Standards.—There has been devised a method for the precise rating of a tuning fork by comparison with a pendulum. A series of flashes of twice the fork frequency are obtained by means of slits in a pair of vanes carried by the prongs of the fork giving images on a moving film, formed by two concave mirrors, one attached to the pendulum and the other to the pendulum support. The frequency of the fork is computed from the trace on the film. An accuracy of five parts in a hundred thousand can be obtained from the record over a single second of time. Two 100 cycle forks, one of steel, the other of elinvar were studied. When vibrating freely showed nearly a linear increase in frequency with decreasing amplitude. The elinvar fork increased ten parts the steel fork three parts in a hundred thousand as the amplitude decreased from 1.0 mm to 0.25 mm. With either of the forks maintained at a constant amplitude by a vacuum tube drive, the frequency could be changed by a part in ten thousand by varying the conditions in the tube circuits. Hence there can be no proper discussion of the effect of amplitude on the frequency of a driven fork.

84. Hysteresis due to the Ewing effect in the flexure of bars. G. H. KEULEGAN, Bureau of Standards, (introduced by L. J. Briggs).—Boltzmann's theory of elastic time effects does not always account for the entire hysteresis observed in the deformation of an elastic body during a closed load cycle. The author, therefore, has made an attempt to formulate an additional theory of hysteresis which is independent of time effects and calls such hysteresis the "Ewing effect." The basis of the theory is the assumption that the stress-strain curve of an elastic body, instead of being a straight line, consists of a symmetrical loop. The deductions from the theory as applied to the flexure of bars are as follows: (a) In the flexure of bars the energy lost owing to the "Ewing effect" varies with the third power of the maximum load of the load cycle and with the fourth power of the length of the bar. (b) The distribution of hysteresis is parabolic and is independent of the maximum load and of the length of the bar. Again, a general deduction from the theory is that the loss of energy per unit volume for a tensional stress range σm is $1/3\beta\sigma_m^3$. Experiments gave $\beta = 1.33 \times 10^{-6}$ ergs cm^3 per kg^3 for Armco iron; so that energy loss per cubic centimeter due to hysteresis is 26,000 ergs for a stress range of 3900 kgs per cm^2 .

85. The expansion of copper from absolute zero to the melting-point. THOMAS A. WILSON and WHEELER P. DAVEY, General Electric Company.—Copper bars of rectangular cross-section, $3/8$ inch on a side and approximately 30 cm long, were supported on powdered alumina in an alundum tube wound with a molybdenum heating coil lagged with a wrapping of asbestos $2\frac{1}{2}$ inches thick. The tube extended 2 inches beyond each end of the copper so minimizing end cooling. Two holes $3/8$ inch square drilled through the tube and asbestos permitted reading the position of the ends of the copper with a horizontal cathetometer. The experiments were conducted in a hydrogen atmosphere. The power through the heating coil was increased approximately 100 watts every 24 hours, at the end of which period a reading was made. At temperatures near the melting-point, readings were made quite frequently. Two experiments gave the linear expansion of copper per cm length from room temperature (27°C) to the melting-point as .0257 cm and .0264 cm. With data from Landolt-Bornstein, the calculated expansion from absolute zero to 27°C is .0034 cm per cm length, making the total expansion from absolute zero to the melting-point .0291 cm per cm length.

86. The expansion of crystals from absolute zero to the melting point. WHEELER P. DAVEY, General Electric Company.—In a face-centered cubic crystal each atom lies in a "pocket" formed by three adjacent atoms of a 1 1 1 plane (the slip plane) so that the four atoms form a tetrahedron. At 0°K the "atomic domains" are assumed to be in contact. It seems plausible that, in such a crystal $12\frac{1}{2}$ percent of the tetrahedra must expand $4\frac{1}{2}$ percent along each edge before all the surface atoms can leave the solid. But at any instant $12\frac{1}{2}$ percent of the tetrahedra are 1.7 times the most probable size. A linear expansion of 2.6 percent from 0°K is therefore a prerequisite to melting for a face-centered cubic crystal. Added to this will be the expansion occurring while the atoms take up additional energy to overcome cohesion. Expansions calculated from the literature are Al 2.4 percent; Mg (having an analogous structure), 2.4 percent; Ag 2.3 percent; Cu 2.4 percent; Ni 2.9 percent. These are probably all low because of extrapolations. Recent measurements of Cu (see previous abstract) indicate 2.9 percent. Body-centered cubic crystals require no expansion except what occurs while overcoming cohesion. Na and K become non-crystalline before melting. W expands 2 percent corresponding to its high interatomic attraction.

87. Thermal properties of butane, isobutane, propane, and ethane. LEO I. DANA, Linde Air Products Company, Buffalo, N. Y.—The investigation is intended to cover the thermal properties of these liquids in the saturation region over the range of pressures and temperatures required for the use of these gases as refrigerants. The latent heats of vaporization and the specific heats of the liquids of ethane and propane have been determined from -40°C to $+30^{\circ}\text{C}$; of isobutane and butane from -13°C to $+30^{\circ}\text{C}$. An aneroid calorimeter, enclosed by a vacuum jacket, operating adiabatically and thus avoiding heat leak corrections, was employed. The vapor pressures of the first three have been measured from one half atmosphere absolute to about 6 atm. abs. and the measurements are being extended to higher pressures. The liquid and vapor densities of the first three gases have been measured from 0°C to 60°C . New forms of cryostats have been constructed for the low temperature measurements.

88. Thermal conductivity of lithium, sodium and lead to -250°C . CHARLES C. BIDEWELL, Cornell University.—The bar method of Forbes was modified as follows. The metal rod, centered in a large test tube, was placed in a constant temperature bath and heated by a coil at the upper end. Air convection in the tube was stopped by cardboard disks through which the rod was threaded and which were spaced at short intervals along the rod. Temperature gradient was determined by thermojunctions spaced along the rod. Cooling curves were obtained on smaller lengths of the rod similarly mounted. With mean temperature not exceeding 15° above bath temperature accurate values of

k were obtained. Values for lead from -250°C to $+100^{\circ}\text{C}$ taken to test the method agreed well with the best recorded values. Lithium shows a linear increase in k from 0.15 at 0°C to 0.20 at -200°C , thereafter rising sharply to 1.00 at -246°C . Above 0°C a minimum occurs at $+40^{\circ}\text{C}$ and an increase thereafter to 0.17 at $+140^{\circ}\text{C}$. Sodium shows a linear increase from 0.28 at -40°C to 0.40 at -240°C . Above -40°C an increase occurs to 0.35 at 0°C and thereafter a decrease to 0.28 at $+65^{\circ}\text{C}$. The breaks in these lines correspond to breaks previously reported in electrical conductivity and thermo-electric power lines for these metals.

89. Thermal conductivity of metals at high temperatures. M. F. ANGELL, University of Idaho.—This paper describes a continuation of former work with improved methods. The metal is heated electrically in the form of a long hollow cylinder. In the earlier experiments the heat flow was assumed to be radial at a point midway between ends, but in these experiments this assumption is made for the point of maximum temperature along the cylinder. The thermal conductivity is calculated from the temperature gradient along the radius at this point and from the energy transmitted. Complete curves of the thermal conductivity from 50°C to the melting point are given for copper, zinc and lead. For copper the thermal conductivity was found to be .92 at 50°C , decreasing very slowly to .90 at 500°C , then more rapidly to .8 at 1000°C . The conductivity of zinc decreases from .265 at 50°C to .215 at 400°C . The conductivity of lead decreases from .082 at 50°C .

90. The ratio of heat losses by conduction and by evaporation from any water surface. I. S. BOWEN, California Institute of Technology.—From theoretical considerations it is shown that the process of evaporation and diffusion of water vapor from any water surface into the body of air above it is exactly similar to that of the conduction or "diffusion" of specific heat energy from the water surface into the same body of air. Due to this similarity it is possible to represent the ratio R of the heat loss by conduction to that by evaporation by the formula, $R = .46(T_w - T_a)P / (P_w - P_a)760$, where T_a and P_a are the original temperature and vapor pressure of the air passing over the lake, and T_w and P_w are the corresponding quantities for the layer of air in contact with the water surface. The substitution of R times the evaporation loss for the value of the conduction heat loss in the Cummings equation for evaporation makes it an exact equation for the determination of evaporation from any water surface in terms of the net radiant energy absorbed by the water and the heat stored in the water.

91. Surface tension of sodium. F. E. POINDEXTER, Washington University.—The surface tension of sodium was determined in a high vacuum at a series of temperatures ranging from 105°C to 245°C . A modified flat drop method was used. The values taken from the best mean straight line through the experimental points gave the values of 222 dynes per cm at 100°C and 211 at 250°C . This gives a temperature gradient of .072 dynes per degree. From the Eotvos relation $\gamma v^{2/3} = k(T_0 - T)$ we get upon differentiating with respect to T , $v^{2/3} d\gamma/dT = -k$, where γ is the surface tension, v is the volume of a gram atom, T is the temperature and T_0 and k are constants. Taking the density of sodium as .91 at 100°C , we find $v = 8.6$. This together with the experimental value of .072 for $d\gamma/dT$ gives us $k = .62$. This is taken to mean that the molecules in liquid sodium are polyatomic, since the value of k for non-associated liquids is 2.2.

92. Pressure distribution over airfoils at high speeds. L. J. BRIGGS and H. L. DRYDEN, Bureau of Standards.—The forces exerted on a body by an airstream of speed not greater than a few hundred feet per second depend on the airspeed, V , size of the body as given by a linear dimension, L , air density, ρ , and viscosity, μ , in the manner described by the equation

$$\text{Force} / (\frac{1}{2} \rho V^2 L^2) = \phi(VL\rho/\mu).$$

At high speeds the influence of the compressibility of the air becomes appreciable and the force coefficient is a function of the ratio of the air speed to the speed of sound as well as of the Reynolds number, $VL\rho/\mu$. The variation of force coefficient with Reynolds number is small whereas the variation with speed ratio has been found by the authors, together with G. F. Hull, to be large. The work now described gives a more extensive and systematic series of observations on airfoil sections of 1 inch chord including observations of flow near the surface. The large changes in forces were found associated with a breaking away of the flow from the surface. The pressure distribution furnishes data to the propeller designer regarding the load distribution encountered at high speeds. The paper will be published as a Technical Report of the National Advisory Committee for Aeronautics.

93. Compensation of altimeters and altigraphs for air temperature. W. G. BROMBACHER, Bureau of Standards.—The altitudes of aircraft are usually determined by an altimeter, which is an aneroid barometer calibrated to an altitude-pressure relation containing an arbitrary altitude-temperature assumption. For the accuracy required in aeronautics, altitudes should be determined by both pressure and temperature measurements. It is difficult to take account of the mean temperature term of the barometric formula mechanically in an instrument. The following new relation based on the summer, winter, and yearly averages of observations of upper air temperatures at latitude 40° in the United States is presented as a substitute. Up to 30,000 feet: $dP/dt = A_h$, (1) where P is the pressure and T the absolute temperature at the altitude h , and A_h is a constant for any one altitude. Further, values of A_h give values of K varying from 0.0023 to 0.0038 in the following important relation for instrument work, $A_h/(P_0 - P) = K$, (2) where P_0 equals 760 millimeters of mercury pressure. Altitudes according to relations (1) and (2) can be indicated by using a temperature element ("air temperature compensation") or a manually operated device to modify the multiplication of the mechanism ("ground temperature compensation"). The manually operated device modifies the multiplication according to an average value of K and the temperature dial is graduated in terms of ground level temperatures.

94. The effect of a high temperature in disrupting ice. HOWARD T. BARNES, McGill University.—Our knowledge of the mode of transfer of heat across very steep temperature gradients is practically nil. The author has been experimenting in this field by driving a powerful energy charge into solid ice cooled below the freezing point. An intense exothermic reaction is rapidly generated by burning a mass of aluminum and the temperature is raised in 5 to 8 seconds to 2500°C . The disruption of the ice below 0°C is observed. Ice is, in this way, converted into a high explosive, the atoms being driven out of the molecules without melting the ice. In large masses a slow explosion occurs which resembles the reaction of black powder set off at a low temperature rather than the sudden detonation of dynamite. Ordinary welding thermit has been used conveniently, since that material is not in itself explosive. Application of this method has been made practically, as it offers a powerful means for relieving ice accumulations.

AUTHOR'S INDEX

- | | |
|----------------------------|--|
| Alexeievsky, A. P.—No. 58 | Bishop, J. B.—No. 11 |
| Angell, M. F.—No. 89 | ———see Richtmyer |
| Astin, Allen—No. 70 | Blake, F. C. and A. E. Focke—No. 15 |
| Barnes, Howard T.—No. 94 | Bourgin, D. G. and E. C. Kemble—No. 27 |
| Beams, J. W.—No. 37 | Bowen, I. S.—No. 90 |
| Bearden, J. A.—No. 6 | Boyd, R. A.—see Jauncey |
| Becker, Joseph A.—No. 57 | Briggs, L. J., and H. L. Dryden—No. 92 |
| Bidwell, Charles C.—No. 88 | Brombacher, W. G.—No. 93 |
| | Burt, Robert C.—No. 65 |

- Cioffi, P. P.—see McKeehan
 Cole, Kenneth—No. 50
 Colwell, R. C.—Nos. 61, 75
 Craig, Palmer H.—No. 69
 Cravath, A. M.—see Loeb
 Crew, W. H.—No. 53
 ———and E. O. Hulburt—No. 20
 Curtis, H. L. and C. Moon—No. 76
 ———see Moon
- Dana, Leo I.—No. 87
 Davey, Wheeler P.—Nos. 14, 86
 ———see Wilson
 Davis, Bergen and C. M. Slack—No. 8
 Dellinger, J. H., C. B. Jolliffe, and T. Parkinson—No. 74
 Del Rosario, C.—No. 56
 Dempster, A. J.—No. 35
 Doan, Richard L.—No. 7
 Dryden, H. L.—see Briggs
- Farnham, F. C.—No. 79
 Focke, A. E.—see Blake
 Fröhlich, Paul—No. 30
- Gibbs, R. C.—No. 17
 Grondahl, L. O.—No. 63
- Hales, Wayne B.—No. 52
 Hazen, Grace—see Jolliffe
 Hertel, K. L.—No. 36
 Hopfield, J. J.—No. 25
 Howes, H. L.—see Nichols
 Hoyt, Frank C.—No. 38
 Hulburt, E. O.—Nos. 40, 68
 ———see Crew
- Jackson, Wilfrid J.—No. 51
 Jarvis, C. W.—No. 47
 Jauncey, G. E. M. and R. A. Boyd—No. 4
 Johnson, E. H.—No. 23
 Jolliffe, C. B. and Grace Hazen—No. 73
 ———see Dellinger
 Jones, H. A.—see Langmuir
- Kemble, E. C.—No. 19
 ———and E. E. Witmer—No. 28
 ———see Bourgin
 Kennard, E. H.—No. 31
 Keulegan, G. H.—No. 84
 King, Louis Vessot—No. 34
 Kistiakowsky, George—No. 48
 Kronig, de L. R.—No. 10
 Kunz, Jakob—No. 81
- Langmuir, Irving and H. A. Jones—No. 42
 Lawrence, Ernest O.—No. 49
- Lindsay, R. B.—No. 13
 Little, Edward M.—No. 67
 Loeb, Leonard B. and A. M. Cravath—
 No. 59
 Loomis, F. W.—No. 29
- McKeehan, L. W. and P. P. Cioffi—No. 77
 Merritt, Ernest—No. 33
 Mertz, Pierre—No. 5
 Messenger, Helen A. and Harold W. Webb—No. 45
 Meyers, C. H.—see Olson
 Miller, Dayton C.—No. 60
 Moon, C. and H. L. Curtis—No. 83
 ———see Curtis
 Morehouse, W. B.—No. 2
- Nichols, E. L. and H. L. Howes—No. 32
 Nielsen, Walter M.—No. 46
 Nottingham, W. B.—No. 41
- O'Brien, Brian—No. 66
 Olson, A. R. and C. H. Meyers—No. 44
- Parkinson, T.—see Dellinger
 Plyler, E. K.—No. 26
 Poindexter, F. E.—No. 91
- Ramsey, R. R.—No. 72
 Rashevsky, N.—No. 54
 Read, H. S.—No. 3
 Richtmyer, F. K. and J. B. Bishop—No. 1
 Rudy, R.—No. 43
- Saunders, F. A.—No. 18
 Slack, C. M.—see Davis
 Snow, Chester—Nos. 62, 71
 Stewart, G. W.—No. 82
 Stuhlman, Otto, Jr.—No. 16
- Taylor, John B.—No. 80
 Urey, H. C.—Nos. 21, 22
- van der Merwe, C. W.—No. 39
 Vincent, H. B.—see Williams
 Von Nardroff, Robert—No. 9
- Warren, Bertram E.—No. 12
 Watson, William W.—No. 24
 Webb, Harold W.—see Messenger
 Williams, N. H. and H. B. Vincent—
 No. 55
 Wilson, Thomas A. and Wheeler P. Davey—No. 85
 Witmer, E. E.—see Kemble
 Wold, P. I.—No. 78
 Zworykin, V.—No. 64