PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE NEW YORK MEETING, FEBRUARY 24-25, 1928.

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA.

The 149th regular meeting of the American Physical Society was held in New York City on Friday and Saturday, February 24 and 25, 1928, as a joint meeting with the Optical Society of America. All sessions were held at Columbia University except the joint session on Saturday morning which was held at the Bell Telephone Laboratories, 55 Bethune Street.

The Optical Society held regular sessions for the reading of papers on Friday morning and afternoon. At the special session held on Friday evening Dr. W. F. G. Swann of the Bartol Research Foundation delivered an address on "Recent Theories of the Atom." This was followed by a demonstration of the Baron Sheba fast moving pictures, given through the courtesy of Professor Alexander Klemin of New York University.

On Saturday morning the two societies were the guests of the Bell Telephone Laboratories, Inc. The principal feature of this joint meeting, which was attended by five hundred members and guests, was a demonstration of television by Dr. H. E. Ives. Before the beginning of the formal session the visitors were given a demonstration of talking motion pictures showing the Vitaphone and Movietone. Five papers from the program of the Physical Society were read. Professor K. T. Compton presided.

Regular sessions of the Physical Society were held on Friday afternoon and Saturday afternoon, the latter session being split into two sections. The presiding officers were Professor K. T. Compton and Professor H. G. Gale.

Special Business Meeting. At the Saturday afternoon session of the Physical Society the following resolution was passed:

"Resolved that the By-laws be amended by striking out the whole of Section 4 of Article I—Dues, reading as follows—'Newly elected fellows or members transferred from membership to fellowship shall pay a fee of three dollars. There shall be no entrance fee for newly elected members,' and that this amendment become effective for all those paying fellowship dues for the first time to cover the year 1928."

There was adopted by rising vote the following minute in memory of Professor H. A. Lorentz:

"Hendrik Antoon Lorentz, since 1906 an Honorary Member of the American Physical Society, died at the age of seventy-five on February fourth, 1928.

"All of us well know of his brilliant and long continued contribution toward the advancement of the subject of Physics which he so well loved and served. Many of us found in him as lecturer and teacher on the occasions of his various visits to America a powerful stimulus and source of inspiration. Some of us were privileged to know him well and were continually impressed by the charm of his personality and by his friendliness of manner.

We, members of the American Physical Society, recognize that the death of our distinguished colleague marks the passing of one of the great figures of modern science and it is our wish that there be placed among the minutes of our society this expression of our tribute to his memory."

At the regular meeting of the Council of the Physical Society held on Friday, February 24, 1928, forty-two were transferred from membership to fellowship, and twenty-six were elected to membership. *Transferred from Membership to Fellowship*: Henry A. Barton, Joseph A. Becher, John A. Carroll, Edward Condon, James M. Cork, Harry Clark, John A. Eldridge, Alexander Ellett, Marion Eppley, Alexander Forbes, Hugo Fricke, Lester H. Germer, George R. Harrison, T. R. Hogness, Frank C. Hoyt, J. C. Jensen, Charles F. Kettering, S. M. Kintner, Charles H. Kunsman, Ernest O. Lawrence, George A. Lindsay, Adolph Lomb, F. W. Loomis, J. P. Maxfield, W. H. McCurdy, George S. Monk, Jared K. Morse, Robert A. Patterson, David C. Prince, Chester W. Rice, P. A. Ross, Arthur E. Ruark, A. G. Shenstone, Erwin Schroedinger, John C. Slater, Joseph Slepian, Keith K. Smith, Louis A. Turner, Hugo B. Wahlin, Alan T. Waterman, William V. Watson, Charles T. Zahn. *Elected to Membership*: James T. Adams, Peter P. Alexander, L. W. Blau, Craig M. Bouton, Brooks A. Brice, Gertrude Buggeln, Leslie V. Case, W. C. Ellis, Carl L. Frederick, W. R. Frederickson, G. E. Gates, W. Delmar Hershberger, Frederick R. Hirsh Jr., F. T. Holmes, Joseph Kaplan, C. P. Keim, R. M. Langer, John M. Ort, R. Ronald Palmer, Eugene A. Paulin, William F. Radle, Harold K. Schilling, J. C. Stearns, S. Bradford Stone, William A. Thomas, Glen W. Warner.

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

The Abstracts of the forty-three papers presented before the American Physical Society are given in the following pages. Numbers 7, 8, 11, 14, 35, 38, 39, 40, 41, 42, and 43 were read by title. An Author Index will be found at the end.

HAROLD W. WEBB, *Secretary*

ABSTRACTS

1. Line structure. D. G. BOURGIN, University of Illinois.—The author's previously published data for the HCl fundamental band lines has been approximated by line patterns of (a) a Doppler broadening type or (b) a Stark effect broadened line (admitting a molecular force field) or (c) a Lorentz interrupted absorption type. The modifications attendant on recognition of the isotopic structure are predictable from the calculations for an infinitely separated doublet structure. The component line breadth is about 10^{10} frequency units for a class (c) line. Certain considerations make it improbable that the Stark or Doppler effects are determining influences here. The criterion $dp(r_0)/dr \sim q_0$ is suggested.

Badger's data on the rotational spectrum of HCl has been studied on the assumption of a "coupling," pressure line broadening. The value $\int_0^\infty \mu(\lambda)d\lambda = 1.3\ 10^{-4}$ is in better agreement with theory than Badger's estimate of $1.1\ 10^{-4}$ but the discrepancy is still excessive and indicates the necessity for further experiment.

2. Quantum analysis of the beryllium oxide bands. JENNY E. ROSENTHAL and F. A. JENKINS. New York University.—The three prominent sequences of BeO bands in the blue-green, blue, and violet have been photographed in the first and second orders of the 21-foot grating at Harvard University. The source was a carbon arc cored with potassium beryllium fluoride. Resolution of the bands is complete except for about five lines at the head. Each band has a P and an R branch, the lines of which remain strictly single as far as they are observed (to about $j=70$). A perturbation occurs in the state $n'=1$, $j'=50$, the result being merely a displacement of the corresponding line by 0.45 cm^{-1} toward lower frequencies, with no sign of doubling. Combination relations between R and P lines are found to hold, and the resulting values of $\Delta_2 F$ may be represented by $4BT$, where T is half-integral. There is probably but one missing line at the origin and no evidence is found of weak Q branches. According to these results, the bands may be interpreted as due to a ${}^1S \rightarrow {}^1S$ electron transition. The combination relations show that the band at $\lambda 4708.64$ is the (0, 0) band. Preliminary values for the constants in the equation $B = h/8\pi^2 I_0 - \alpha n$ are: $I_0' = 17.65 \times 10^{-40}$ gm. cm.^{2}, $I_0'' = 16.85 \times 10^{-40}$, $\alpha' = 0.0165$, $\alpha'' = 0.0187$. The internuclear distance of BeO in the final state (probably the normal state) is therefore 1.33×10^{-8} cm.

3. The heat of dissociation of Na_2. F. W. LOOMIS. New York University.—From the writer's formula (Phys. Rev. **27**, 607, (1927)) for the vibrational terms in the blue-green band system of Na_2, the heat of dissociation of the normal molecule is calculated, by the method of Birge and Sponer, to be 1.0 ± 0.1 volts. It is also shown that the dissociation energy of the molecule in the upper level of this band system is 0.6 volt and that this upper level molecule dissociates into one normal atom and one atom in a 3^2P state, whereas the lower level molecule dissociates into two normal atoms. By combining the above results with those calculated from the formula of Fredrickson and Watson (Phys. Rev. **30**, 429, (1927)) for the red band system, it is shown that this system has the same lower state as the green system and that its upper state also dissociates into one 3^2P and one normal atom, but with an energy of dissociation of 1.25 volt.

4. Optically excited iodine bands with alternate missing lines. By R. W. WOOD, Johns Hopkins University, and F. W. LOOMIS, New York University.—The iodine fluorescent bands which develop around the fundamental doublets when iodine is in the presence of helium have been studied with higher resolution than heretofore. They are found to contain only alternate lines of the corresponding absorption bands, namely, those for which m' is even. Now the fluorescent bands are known to be developed by collisions of the second kind between excited iodine molecules and helium atoms, wherein m' is changed from 34, the value originally excited, to various neighboring values. The new data, then, show that the rotational quantum number of an iodine molecule can only change by an even number during a collision of the second kind in which the electronic quantum number does not change. This result is entirely in accord with the new mechanics, which, according to Hund, attributes to the successive rotational states of a symmetrical molecule, such as I_2, eigen-functions which are alternately symmetric and anti-symmetric in the two nuclei; and which requires that transitions between symmetric and anti-symmetric states shall be very rare; so rare that, on Dennison's successful theory of the specific heat of hydrogen, they do not occur, even during the time it takes to measure the specific heat.

5. Electron states in diatomic molecules. ROBERT S. MULLIKEN, New York University, Washington Square College.—Applying Hund's recent theories, and developing suggestions of

Hund and the writer, the ordinary physical and chemical properties of diatomic molecules can be accounted for by assigning a quantum state for each electron, and energies of removal (ionization) for each state. The assignments below are probably in the main correct; the order in which the symbols is given is always that of increasing ease of removal. The two 1*s* and two 2*s* electrons represent *K* electrons of the separated atoms, essentially unchanged except in formal quantum number. Outer electrons are mostly much more firmly bound than the same quantum numbers would indicate for an atom; *e.g.* the 4*s* shell of N_2 (ionization potential 17 volts) is comparable energetically with the 1*s* shell of He. Assignments: Normal LiF, BeO, $(1s)^2(2s)^2(3s)^2(2p)^6$; normal BeF, BO, CO^+, CN, N_2^+, $(1s)^2(2s)^2(3s)^2(2p)^6(4s)$; excited BO, etc., $(1s)^2(2s)^2(3s)^2(2p)^5(4s)^2$; normal CO, N_2, CN^-, $(1s)^2(2s)^2(3s)^2(2p)^6(4s)^2$; excited CO, N_2, $(1s)^2(2s)^2(3s)^2(2p)^6(4s)(x)$ and (or?) $(1s)^2(2s)^2(3s)^2(2p)^5(4s)^2(y)$, x and y variable; NO and O_2^+, $(1s)^2(2s)^2(3s)^2(4s)^2(2p)^6(x)$, with $(x)=(3p)$ for normal state; normal O_2 and F_2, $(1s)^2(2s)^2(3s)^2(4s)^2(2p)^x(3p)^y$ with perhaps $x=y=4$ for O_2 and 5 for F_2. Similarly for analogous higher molecules. The assignments are based mainly on spectroscopic and ionization potential data.

6. A new determination by a photographic method of the water absorption band at 9727 angstroms. J. E. LAMBLY, Cornell University.—A precise determination of the water absorption band in the near infra-red has been made and found to be located at 9727 Angstroms, for a temperature of 22°C. This result, which is the average of three independent determinations, checks with that of Collins (Phys. Rev. **26**, 771, (1925)) at 9740A. Photographic records of spectral intensity from an incandescent lamp, with and without absorption, were made on red sensitive neocyanine plates, hypersensitized with ammonia. Density measurements were made with a photo-electric densitometer, and ratios computed to determine absorption peaks. Care was taken to measure these accurately. Long exposures through heavy filters and a slit of only 40 Angstroms were made. Results were consistent. The average should be accurate to 10 or 12 Angstroms, every precaution having been taken to give the utmost accuracy, both in making the exposures and measuring the plates. Consequently, the result should be considerably more accurate than previous results.

7. The molecular structures of methane. JARED KIRTLAND MORSE, University of Chicago. —The same concepts which were so useful in determining the molecular and lattice structures for ethane (Proc. Nat. Acad. Sci. Jan., 1928) are here used to construct molecular models for methane and the moments of inertia computed from these structures are compared with those obtained by Cooley (Atrophys. J. **62**, 73 (1925)) from the analysis of the infra-red absorption bands. These moments of inertia are found to agree with experiment within the limit of experimental error. Two types of molecules are differentiated, one having a "single electron bond" between the carbon and hydrogen nuclei, the other having two electrons forming this bond. In each of these types, eight "hydrogen positions" are possible, since there are only four hydrogen nuclei available in the molecule, a certain finite number of "dynamic isomers" can be formed determined by the number of ways four nuclei are distributed among the eight positions. The band observed at 7.7μ is due to a symmetrical tetrahedral methane molecule having a "single electron" bond between the hydrogen and carbon nuclei. The band at 3.31μ is due to a symmetrical molecule having a "two electron" bond between them. The weak band at 3.5μ is due to an unsymmetrical "dynamic isomer" of methane with "two electron" bonds.

8. The absorption bands of some hydrocarbons between 1.0μ and .7μ. JAMES BARNES, Bryn Mawr College.—This paper is a continuation of abstract (Phys. Rev. **29**, 922 (1927)). In this region of the spectrum liquid pentane, decane, and tetradecane have each two strong absorption bands which are doublets and their wave-lengths have been measured to an accuracy of $.002\mu$. Their frequencies have lower values than the corresponding bands of the aromatic series and also decrease as the mass of the molecule becomes larger. Their frequency differences are 7 and 8×10^{12} sec^{-1} for the longer and shorter wave-length bands respectively. The shorter wave-length component of all these doublets has the stronger intensity. The densitometer graphs give their relative intensities as 4 to 3 approximately. In addition to the above these substances have weak single bands at $.81\mu$ and $.97\mu$. The strong absorption at $.874\mu$ of benzene and at $.877\mu$ of toluene have also been resolved into doublets. Their frequency differences are the same, 3×10^1 sec^{-1}, within the limit of error.

9. Certain multiplets in the spectra of cadmium III and indium IV. R. C. GIBBS and H. E. WHITE, Cornell University.—Guided by the transitions from $^3PD'F$, $^1PD'F$, $(4d^95p)$ to ^3D, ^1D $(4d^95s)$, already determined for Pd I and Ag II, (data furnished to the authors by A. G. Shenstone in advance of publication), the corresponding lines have been identified in the spectra of Cd III and In IV. The transitions from $^3D'_1$, $^3P_1$ and $^1P_1(4d^95p)$ to $^1S_0(4d^{10})$, the latter being the lowest level in each of these spectra, have also been identified for Ag II, Cd III, and In IV. These combinations account for nearly all of the strong lines in each spectrum. The term values for the four iso-electronic systems Pd I, Ag II, Cd III, and In IV, together with those for the corresponding elements in the first long period, have been plotted on a Mosely diagram which brings out certain similarities and variations between these two sets of spectra. The validity of the irregular doublet law is again confirmed by the almost constant shift in the corresponding radiated frequencies $(4d^95s-4d^95p)$ on passing in succession from Pd I to Ag II, to Cd III, and to In IV.

10. The spark spectrum of silver (Ag II). A. G. SHENSTONE, Princeton University.—The spark spectrum of silver can be based on a set of terms as follows:- $^1S_0$ from the structure $4d^{10}$; ^3D, ^1D from $4d^95s$; ^3P and ^1P, D', F from $4d^95p$; ^3D, ^1D from $4d^96s$; $^{3 \text{ and } 1}S$, P', D, F', G from $4d^95d$. The lowest term $^1S_0$ is from the measurements of H. E White at Cornell in the region λ1100. There is evidence also for the structure $4d^95f$. The intervals and g-values are very irregular. The ionization potential calculated from the two-member series of $^3D_3$ levels is about 21.9 volts from $^1S_0(d^{10})$ to $^2D_3(d^9)$. The limits calculated from the component series of ^3D, ^1D indicates a divergence from theory as in the analogous cases of Ni I, Cu II, Pd I The intervals of the pentad d^9d also indicate a divergence. The $^1S_0$ term is at 39164 wave-numbers below $^3D_3$. This indicates that the hypothetical $^2D(d^9s^2)$ of Ag I should have almost the same value as 2^2P of that spectrum, which in part explains the low intensity of the lines in the spectrum which must be due to it.

11. The arc spectrum of antimony. J. B. GREEN, Ohio State University, and R. A. LORING, Northwestern University.—McLennan and McLay (Trans. R. S. Can. **21,** 63 (1927)) have made a start at the analysis of the spectrum of Sb on the basis of the Hund theory. According to this the lowest levels should be due to the configuration s^2p^3 (hereafter called the a configuration) and are $^4S_2'$, $^2D_{23}'$, $^2P_{12}$. These levels have also been identified in all the other elements of this group. The b levels, due to $s^2p^2\cdot s$ should be $^4P'_{123}$, $^2P_{12}'$, $^2D_2$, $^2S_1$. Of these, only the first two terms have previously been identified. The c configuration, $s^2p^2\cdot d$, should yield $^4(F'DP')$, $^2(F'DP')$, $^2(GF'DP'S)$, ^2D. The d configuration gives $^4(D'PS')^2$, $(D'PS')$, $^2(FD'P)$, ^2P. These authors have been successful in assigning all the low levels of each of configurations, and also that due to Sp^4. In addition, a series of terms yields the value 67579 for a $^4S_2'$ corresponding to an ionization potential of 8.35 volts. Ruark gives 8.5±1.0 volts. The Zeeman effect has been studied for all of the stronger lines in the region 2500–4033 and the g values of the terms computed. The g values do not agree with the theoretical values and not enough lines can be measured with sufficient accuracy to determine whether Pauli's g sum rule is satisfied. A complete report of the work is now in press.

12. Recombination of atom ions and electrons. F. L. MOHLER, Bureau of Standards. A thermionic discharge is maintained in caesium vapor with about 5 volts applied between a fine wire cathode and a cylindrical anode which completely incloses it. Relatively high ion and electron concentrations can thus be obtained and with currents greater than .1 amp. and vapor pressures above .1 mm the spectra show continuous bands extending from each series limit. A paper in press gives photographs and intensity measurements of these continuous spectra. Probe wire measurements have been made in a similar discharge and semilogarithmic plots of the electron current show that the electrons have a strictly random distribution of energy, with unusually low average energies, between .2 and .3 volts. Assuming that the continuous spectra are recombination spectra one can, on the basis of the intensity measurements and the known velocity distribution of electrons, compute relative values of the recombination probability as a function of the electron speed, and of the absorption probability as a function of the frequency. The results of course apply to recombination into a definite energy state or to absorption resulting in ionization of atoms initially in that state.

13. Reflection of electrons by a crystal of nickel. C. J. DAVISSON and L. H. GERMER, Bell Telephone Laboratories, Inc.—A homogeneous beam of electrons is directed against a face of a crystal of nickel cut parallel to a set of its $\{111\}$ atom planes. The angle at which the beam meets the crystal surface can be varied. The angle of incidence is adjusted to a chosen value, and observations are made in the plane of incidence of the intensity of scattering as a function of direction and of bombarding potential. At certain critical speeds of bombardment a sharply defined beam of electrons issues from the crystal in the direction of regular reflection. When the angle of incidence is 10 degrees the regularly reflected beam appears for speeds corresponding to 38, 70, 133, 210 and 320 volts. The values of the critical speeds increase as the angle of incidence is increased. The phenomenon is the analogue of the Bragg type of x-ray reflection with the incident beam exhibiting the properties of a beam of waves of wave-length inversely proportional to the speed of the electrons. The data cannot be used to calculate wave-lengths on account of the effect of the "spacing factor" of the crystal [Phys. Rev. **30**, 704 (1927)] and because the elementary plane grating beam is of zero order.

14. X-radiation from the impacts of electrons against gas atoms. WILLIAM DUANE, Harvard University.—In a paper presented to this Society last year I described experiments on the x-radiation produced by the impacts of electrons against atoms of mercury vapor. All the electrons had substantially the same velocity, and the radiation at right angles to the direction of motion of the impinging electrons (after it came through the window in the apparatus) appeared to have an average, or effective wave-length somewhat longer than the short wave-length limit given by the quantum equation. This paper describes further experiments on the radiation at right angles to the electron stream, in which thinner windows were used, and also experiments on the radiation projected from the impacts forward in the direction of motion of the electrons. The paper contains also a brief discussion of the degree of approximation with which the results of the experiments can be explained by certain theories of the radiation coming from an electron as it approaches an atomic nucleus.

15. The application of the phonodeik in determining the performance of electro-acoustic devices. DAYTON C. MILLER and JOHN R. MARTIN, Case School of Applied Science.—The phonodeik gives a direct photographic record of a sound wave, as received by the ear. A sound reproduced by an electro-acoustic device may thus be compared directly with the original sound. A loud speaker is connected to the output of a transmitting system which may consist of a microphone and amplifier, and any sound energizing the microphone will be reproduced by the loud-speaker and is recorded by the phonodeik. The distortion introduced by the device, together with its associated electrical system, may thus be determined. This method has been used to study the frequency response of radio loud-speakers, microphones, electrical phonographic pick-ups, and amplifying systems. By replacing the loud-speaker with a vacuum-tube voltmeter, the distortion introduced by the electrical system may be determined. A vacuum-tube oscillator with a frequency range of 40 to 6000 may be used as an electrical source, the energy of the output being maintained constant, and the wave form being checked with an oscillograph. This output is used to actuate a loud speaker and the resulting sound is recorded on the phonodeik at the desired frequencies. The method is also applicable to the study of mechanical-acoustic devices.

16. Extreme ultra-violet spectra excited by controlled electron impacts. K. T. COMPTON and J. C. BOYCE, Princeton University.—A vacuum spectrograph having some new features in design has been used in the study of the spectra of helium, neon, and argon in the wave-length region shorter than 1200A. Electrons from a Wehnelt cathode are accelerated by known voltages through a wire grid anode, beyond which they excite the gas. Fast pumps keep the pressure in the spectrograph at about 0.005 of that in the discharge tube, returning the gas to the discharge through a purifying tube. Spectra are photographed with the pressure in the discharge low enough that electrons in their path make on the average only one collision with a gas molecule, and that arcing is impossible. Exposures made at increasing voltages show successive stages of excitation and ionization brought about by single electron impacts, making the interpretation easier than that of those taken at higher pressures where cumulative ionization occurs. In helium ten members of the arc series have been observed from 584 to 507A and five members of the spark series from 303 to 234A. In neon and argon the results of Dorgelo and Abbink have been generally confirmed and many additional lines have been observed.

17. The spark spectra of neon and argon. H. N. RUSSELL, K. T. COMPTON and J. C. BOYCE, Princeton University.—With the vacuum spectrograph described in the previous communication, Neon II shows 15 new lines between 462 and 353A—all of which have been identified as combinations between a low ^2P term of separation 782 frequency units, and higher doublet and quartet terms. Many still higher terms conbine with the latter, giving multiplets in the visible and ultra-violet, some of which have been announced by de Bruin and Kichlu. The corresponding electron configurations have been identified, and the ionization potential fixed at 40.9 ± 0.05 volts. Argon II shows numerous lines between 932 and 487A. The low ^2P term has in this case a separation of 1430—as suggested by Dorgelo and Abbink. The higher terms can be connected with the frequency differences observed in the blue spectrum by Paulson. The ionization potential appears to be not far from 27 volts, supporting the value obtained by Barton by the method of positive ray analysis.

18. On the time required for the photo-electric ejection of an electron by visible light. ERNEST O. LAWRENCE and J. W. BEAMS, Yale University.—We have already reported experiments (Phys. Rev. **29**, 903, (1927)) which indicated that electrons are ejected from a potassium metal surface within $3(10^{-9})$ sec. Although the experimental observations were definite and reproducible, there existed several possible sources of systematic error. We have now completed a more detailed study of the ejection of electrons from a potassium hydride surface which has confirmed the conclusion that the photo-electric effect is instantaneous within $3(10^{-9})$ sec.—and which has eliminated the uncertainties of the earlier research.

19. Photo-electric thresholds and fatigue for iron, cobalt, and nickel. GEORGE B. WELCH, Cornell University.—Preliminary measurements on samples of pure iron, cobalt, and nickel, with surfaces prepared in vacuum, show the photo-electric thresholds for these elements to be 3150, 3150, and 3045A., respectively. With time, the thresholds remain constant within the limits of experimental error. All three elements show photo-electric fatigue. During the course of the experiments, the relation between the photo-electric current and the time is found to be $i = Ct^{-\alpha}$, where α is a quantity which depends upon the substance used and, for a given substance, increases numerically as the threshold is approached.

20. Heisenberg's uncertainty relation and the motion of free particles. ARTHUR E. RUARK, Mellon Institute, University of Pittsburgh and Gulf Production Companies.—In the Nashville program, the author has described (Proc. Am. Phys. Soc., Nashville meeting), an arrangement of apparatus which seemed to make possible simultaneous determinations of the coordinate q and the momentum p of a free particle, so accurately that Heisenberg's relation $\Delta q \cdot \Delta p \sim h$ is violated. It was stated that the violation is only apparent because the precision of measurement of both p and q is limited by statistical fluctuations in the measuring devices. Contrary to this view, the true reason for the validity of the principle is that slight velocity changes occur when the particle passes through a variable slit. The situation is analogous to the frequency changes of light due to modulation. (Breit, Ruark and Brickwedde, Phil. Mag., **3**, 1306 (1927)). Of course, errors due to fluctuations of the measuring devices are also present. Even in the most favorable cases, they are such that $\Delta q \cdot \Delta p \gg h$. Further, the reaction of the measured object on the measuring device introduces an uncertainty similar to that discussed by Heisenberg.

21. A novel optical instrument: spectroscope used as color-filter for telescope. JOHN Q. STEWART, Princeton University.—The slit of any spectroscope is removed from normal position, backed by a mirror, and substituted for the eyepiece of the view-telescope. A condensing lens, as usual, images an object in the focal plane of the collimator. A succession of overlapping images in light of neighboring wave-lengths is thus formed on the slit, after dispersion by prism or grating. The segment of mirror exposed behind the slit reflects back a different part of each image, in light of corresponding color; and thus a complete image of the original object is again formed in the focal plane of the collimator, but in light of a narrow range of wave-lengths, adjustable over the spectrum. A half-silvered mirror, or other means, forms this image off to one side; where it may be magnified by an eyepiece. Thus the original extended object is viewed in light of a narrow band of wave-lengths. This apparatus was set up and tested in various forms, Mr. S. A. Korff assisting. With the help of Mr. J. Bucher the same principle was found to give practicable means of color-photography without the use of colored screens—the camera being used, reversed, to view the plate.

22. An afterglow spectrum of argon. Carl Kenty and Louis A. Turner, Princeton University.—Using a rapidly rotating sectored disc and commutator the arc spectrum of argon is found to persist approximately 0.001 sec. after an arc of 0.5 amp. in pure argon at 0.5 mm pressure is cut off. This spectrum is not caused by direct excitation by electrons since the *D* lines which are strong in the arc itself are absent in the afterglow. Sodium vapor from a properly impregnated oxide cathode is always present. Dropping the voltage to 4–11 volts instead of to zero in the off period brings out the D lines in the afterglow and shortens its duration. Reverse potentials up to 45 volts have no effect. Comparison of photographs of the spectra of the afterglow and of the arc shows that, in the afterglow, lines involving jumps from high s and d states to the $2p$ states are much stronger with respect to $1s-3p$ lines than in the arc. The absence of the D lines, the relative enhancement of lines involving high energy levels and the shortening of the duration of the afterglow by electrons suggest the hypothesis that the afterglow spectrum results from recombination. A search is being made for continuous spectra which would probably accompany recombination.

23. The optical dissociation of iodine vapor. Louis A. Turner, Princeton University.—A cell containing iodine vapor at 18°C absorbs the light of the iodine emission line of wave-length 1830.4A more strongly when illuminated by concentrated light from a carbon arc than when not so illuminated. The line at 1844.5 does not show this effect. The increased absorption is attributed to iodine atoms resulting from the optical dissociation of molecules by the light of the arc. Franck suggested that such a dissociation was connected with the continuous absorption of iodine on the short wave-length side of the convergence limit of the absorption bands. The idea was supported by Dymond's experiments on fluorescence, and by the correctness of the value of the heat of dissociation calculated on the basis of this theory. The present experiment gives a direct indication of the presence of the atoms. The 1830.4 line is very probably the $a^2P_2-k^4P_3$ line, the one of longest wave-length which is emitted as a result of a transition to the ground state (a^2P_2).

24. The absorption and fluorescence of a mixture of mercury and zinc vapors. J. G. Winans, National Research Fellow, Princeton University.—It was observed that light from the aluminum spark of wave-length below 2000 excited vapor distilling from slightly amalgamated zinc, causing the emission of the first triplet of the sharp series of zinc; but excited neither the non-distilling vapor nor that distilling from pure zinc. Vapor distilling from the same kind of mercury zinc mixture showed a continuous absorption, especially strong for wave-lengths below 1860 and extending to 2050. The non-distilling vapor (zinc vapor pressure 37.0 mm) absorbed Hg 1849, width 5A; Zn 2138, width 91A; Hg 2536 and Cd 2288, both narrow; and two unaccounted for bands at 2068, width 7A; and 2001, width 7A. These observations are explained by assuming that HgZn distills from the zinc amalgum and is dissociated into an excited zinc atom in the 2^3S state and a normal mercury atom upon absorption of light of wave-length below 1860. Assuming a very small heat of dissociation, the minimum energy for this process is 6.62 volts, corresponding to a wave length of 1861. The absorption of mercury alone under like conditions was different and appeared the same for distilling and non-distilling vapor.

25. Theory of the excitation of spectra by atomic hydrogen. Joseph Kaplan, National Research Fellow, Princeton University. (Introduced by H. D. Smyth).—An explanation is proposed for the results of Bonhoeffer and of Mohler on the excitation of spectra by atomic hydrogen. The theories advanced by these authors do not completely explain the experimental results. The theory presented here is based on the hypothesis that in a three-body collision two hydrogen atoms can be bound to form a molecule in any one of the vibration states of its normal electronic level. We make use of the principle, used in collisions of the second kind, that the probability of excitation increases as the energy of the exciting body and the energy necessary for excitation approach each other. This is done by postulating that the probabliity of the excitation of the third body is greater, the nearer the energy required is to the difference between the energy of recombination and the energy retained by the hydrogen molecule in one of its vibration states. The theory has been applied successfully to the excitation of Na, K, Cd, Zn, Cs and Mg by atomic hydrogen. The excitation of the 2537 line of mercury, which requires more energy than that available from recombination, is explained on the basis of Bonhoeffer's observations.

26. Certain characteristics of the spectra of mercury at the higher radiating potentials. L. R. MAXWELL, National Research Fellow, Bartol Research Foundation.—Electrons in mercury vapor with velocities greater than 150 volts were confined in a beam by a magnetic field. Perpendicular to the beam an electric field withdrew positive ions before they recombined. The arc lines emitted showed no increase in density on removing the electric field. This indicates that recombination contributes very little to the production of these lines which is contrary to the explanation given for the complete arc spectrum appearing above the ionization potential. Consequently the arc spectrum is explained in the following two ways: (1) as being due to inward transitions of one or both of the valence electrons after being removed to outer orbits, (2) due to the return to the 1^1S state by an electron which has been displaced from a soft x-ray level to a virtual orbit, while simultaneously a valence electron falls in to fill the vacancy of the inner level. Resonance radiation exists for lines produced by transitions ending in the 1^1S, 2^3P_0, 2^3P_1 and 2^3P_2 states, but much less for those terminating in the 2^1P state. Several spark lines due to Hg^{++} appear unique in that they show a distinct shift in the direction of motion of the positive ions. This presents a new method for distinguishing this type of spectrum.

27. Photographic determination of the temperature of the tungsten cathode in the electric arc. ERNST K. G. STUECKELBERG, Princeton University.—By means of the blackening of a photographic plate, the value and distribution of the cathode temperature of a tungsten arc in nitrogen were measured. As a fixed point for the scale the black temperature of the carbon arc anode was taken. Its value was found by Henning and Heuse to be 3700°K. The emission power for tungsten was taken from Zwikker. The arc burned in carefully purified nitrogen between small spheres of tungsten (diameter 0.18 to 0.29 cm) on wires. The true temperature was found to have a uniform value over the sphere, independent of pressure and varied between 2600 to 3300°K. The current-density was therefore also supposed to have a uniform value over the sphere. (The current was varied from 0.25 to 6.0 amp.). Plotting the log of the current against the reciprocal temperature, straight lines were found parallel to the curve of thermionic emission for tungsten. For a given current, as the cathode surface was increased, the temperature dropped according to the emission law. As the temperature gradient along the wire was photographically measured, the loss of energy of the cathode by conduction, radiation and electron emission could be calculated. (This work was done at the University of Basle and will be published in full in the Helvetica Physica Acta, February or March, 1928.

28. The relation between arc stream dimensions and light intensity. W. B. NOTTINGHAM, Bartol Research Foundation.—The three regions of electric arc discharge are (1) the positively charged cathode space, (2) the negatively charged anode space, (3) the arc stream with zero space charge. If the average electrical field along the direction of the arc axis is assumed to be uniform, as indicated by experiment, the average number of electrons per unit volume would be proportional to the average current density crossing a surface perpendicular to the arc's axis. Light given off the arc stream due to single impacts of electrons on neutral atoms should be $l_1 = ai$, and due to double impacts $l_2 = bi^2$. (l = measured light per unit volume; i = measured average current density; *a* and *b* constants). If the slope of the curve "log l" versus "log i" is 1.0 or 2.0, light production by single or double impacts respectively would be indicated.

RESULTS OBTAINED

Metal	Atmosphere	Impacts	Remarks
Cadmium	Argon	Double	Current 1.0 and 2.0 amp.
Cadmium	Argon	Combination	Current 4 amp.
Copper	Air	Combination	Green lines, 8 amp. 3000 amp./cm.^{2} = Current density at cathode
Copper	Air	Single	Blue lines, 8 amp.
Tungsten	Air	Single	Blue lines
Carbon	Air	Indeterminate	4216 cyanogen bands

29. **Effect of an interfering tone upon the hearing of a normal and a deafened ear.** JOHN GUTTMAN, New York Post Graduate Medical School and L. B. HAM, Washington Square College, New York University.—Two audible frequency oscilators were connected to a common telephone receiver so that one or two tones could be introduced into the ear. Energy of a given frequency from the first oscillator was increased to threshold intensity. Then an interfering tone of 50 transmission units (T. U.) above threshold for the person examined was introduced by the second oscillator which suppressed the first tone so that its intensity had to be increased for new threshold. Magnitude of the suppression was measured in T. U. also, and plotted against frequencies of the first oscillator. Preliminary experiments show that a given relative increase of energy produces in a deafened ear a greater hearing sensation than in a normal ear in the presence of an interfering tone whose multiple energy value above threshold is the same for every person. Artificial deafening with oils produced similar results. Indications are that, for the same degree of deafness, the effect noted depends upon the type of deafness. Resultant curves are shown.

30. **Experiments on audition by bone conduction.** C. E. DEAN, Johns Hopkins University—Bone conduction is a term used by otologists to designate audition due to vibration of the skull. Special telephone receivers to produce this vibration and other equipment from the Bell Telephone Laboratories were used. By a second person listening with a stethoscope for minimum sensation, a standard amplitude of skull vibration may be established. In this way the bone conduction produced by ordinary telephone receivers was found to be negligible except for cases of considerable deafness. Beats between two bone conduction stimuli are heard, and between ordinary and bone conduction stimuli if both reach one ear. The difference in effect at the near and far sides of the head, of a bone conduction stimulus applied on one side was measured from 362 to 2048 cycles for two cases in which the auditory nerve had been cut on one side, and was found to be small, averaging 4 T. U., or an amplitude ratio of $10^{-0.2} = 0.6$. For this reason noise in the opposite ear should be used in all examinations of bone conduction sensitivity. It is also important that calibrations and tests be made in a silent place. An explanation was found of the frequent cases in which all bone conduction sensations seem in one ear.

31. **The vibrations of tuning-forks.** ELMER A. HARRINGTON, Bureau of Standards.—A study of the energy dissipated by frictional and viscous forces in tuning-forks. Two electrically-driven tuning-forks were used: (1) an ordinary fork, (2) a fork made by clamping two steel bars, with a rectangular block between them, in a vise so that practically no energy was expended in moving the stand. The following properties were investigated: (1) the logarithmic decrement, and the effect on the logarithmic decrement of damping due to vanes at the ends of the prongs; (2) the relation between the current driving a fork and the deflections of the prongs produced, both for steady and resonant deflections; (3) the equivalent length of a rigid straight bar turning through the same angle as the tangent at the end of the prongs; (4) the energy due to emission of sound, and the energy dissipated by internal friction. It was found that: (1) the change in the logarithmic decrement was roughly proportional to the area; (2) the deflections of the prongs were proportional to the square of the current; (3) a straight bar 73% of the length of the prong is approximately the equivalent length; (4) about 3.5% of the total energy is converted into sound, while nearly all of the remainder is expended in overcoming internal friction.

32. Internal friction in metals. R. H. Canfield, Johns Hopkins University.—A tubular specimen of metal is used as the elastic control of a heavy metal pendulum which is set into forced vibrations by electro-magnetic forces. The mode of vibration is either torsional or transverse, so that the internal friction is determined for two types of stress; the principle being analogous to Searles' method of determining elastic constants. Observations are made on the maximum amplitude (peak of the resonance curve) from which the friction constants are easily deduced. Logarithmic decrement observations can be made, and agree with the results of the other method. The phase of the vibration relative to the impressed forces can be determined and leads to Kimball's conclusion that the dissipative stresses are non-viscous. Preliminary results show two definite discontinuities in the relation between dissipated energy and stress amplitude, of which one depends on the mechanical history of the specimen, and the other is independent of it.

33. Friction and frictional torque in gyroscopic motion. R. C. Colwell, West Virginia University.—When a rotating top is hung upon two inclined rods the friction at the points of suspension will start and stop the precession in such a way that the top will walk down the rods. The equations are developed for this motion. In a suitably mounted top the frictional torque will cause the top to rotate rapidly about its point of support. The precession of the top may then be made to act with or against the motion due to friction, so that this top will automatically reverse its direction of spin.

34. Motion of the ball on a bowling alley. L. W. Taylor, Oberlin College.—This is an experimental study of the motion of the ball on a bowling alley. A recording device registers to hundredths of a second the times of passage of the ball through successive half-meter intervals. Initial velocity is rendered reproducible by launching the ball with a catapult, in place of doing it by hand. Systematic deviations from the behavior prescribed by the simple theory are found, which indicate that the coefficient of friction is a function of the velocity. The results of the experiment suggest a general form for this function.

35. The effect of heat treatment of bismuth in the Hall effect. Palmer H. Craig, Premier Laboratory Company.—Investigation of the initial heat treatment of bismuth plates used in the Hall Effect shows that cast plates prepared by very rapid cooling exhibit abnormalities which do not occur in plates prepared by annealing. The high values of the Hall coefficient previously reported in bismuth at low magnetic field strengths were confirmed in plates very rapidly cooled, but the shape of the Hall coefficient-field strength curve was found to be much more regular for slowly cooled, cast bismuth plates, as reported by C. W. Heaps. Similar results were obtained using alternating current, and graphs obtained from experiments on rectification of alternating current by the Hall Effect indicate a possible empirical formula for such cases.

36. Thermoluminescence excited by high voltage cathode rays. Frances G. Wick and Edna Carter, Vassar College. —Specimens of powdered calcite, fluorite and magnesium sulphate containing a small amount of manganese, exposed to the powerful stream of cathode rays outside of the metallic window of the Coolidge cathode ray tube showed brilliant thermoluminescence when heated to a relatively low temperature. The exposures were made in the General Electric laboratory at Schenectady with the generous co-operation of Dr. W. D. Coolidge and the assistance of Dr. Moore. The specimens were immediately put into liquid air and kept at this low temperature until the observations could be made at Vassar College. Photometric observations of maximum brightness and rate of decay of thermoluminescence were made with variation in (1) time of exposure, (2) temperature of exposure, (3) voltage on the cathode ray tube during exposure, (4) temperature of observation. The effect of cathode rays is similar to that of exposure to x-rays but there are some differences. Cathode rays produce a more intense thermoluminescence which appears at a lower temperature and the effect is more permanent than that due to x-rays. Saturation is produced in 10 seconds by cathode rays in specimens which it takes one hour to saturate by exposure to x-rays under the conditions previously described by Wick and Slattery.

37. Evidence obtained by x-ray analysis of films of iron in magnetic fields as to the ultimate nature of magnetism. T. D. YENSEN, Westinghouse El. and Mfg. Co., East Pittsburgh.—The results of K. T. Compton and Trousdale, (1915) and of A. H. Compton and Rognley (1918–1920) showed that there is no change in the crystal structure of single crystals of magnetite and hemetite when subjected to strong magnetic fields. In the present investigation films of electrolytic iron were analyzed by x-rays to determine whether there is any change in the random orientation of the minute crystals (of the order of 150A) found in these films when subjected to strong magnetic fields (up to 2600 gauss). If so, the uniform circular diffraction patterns resulting from the randomly oriented crystals should be changed to show greater density along one diameter than along the other, perpendicular to it, due to the preferred orientation. The circles were analyzed microphotometrically and the results indicate no change in the orientation. The average of all the measurements is a ratio of the intensities along the two diameters of $1.00 \pm .08$, the variation being attributed to incidental sources arising from the developing and handling of the film. The conclusion, therefore, is that the most minute crystal aggregates in iron are not oriented in a magnetic field and lends strength to the previous conclusion in regard to the ultimate nature of magnetism, namely, that the magneton is an atomic property.

38. An apparatus for the measurement of radiation intensity over a wide range of wavelengths (0.02–3A.). OTTO GLASSER and V. B. SEITZ, Cleveland Clinic Foundation.—The instrument consists of, (1) a condenser attached to an ionization chamber, and (2) an improved type of string electrometer with static charger. The procedure is as follows: The condenser unit is electrically connected with the electrometer unit and the whole system charged to a known potential. The condenser unit is then removed and placed together with the ionization chamber in the field of radiation to be measured. After exposure for a specified time it is again returned to the electrometer and the loss of charge read. In order to prevent any radiation from affecting the charge in the condenser unit other than that at the ionization chamber, a solid dielectric completely surrounds the charged part of the system thus dispensing with lead. In order to obtain protection at the point where electrical connection is made between the two units, a mechanically operated cover of dielectric is incorporated in the form of a switch. Ionization chambers of a material with an effective atomic number equivalent to that of atmospheric air are used and range in size from 1/50 c.c. up. Radiation intensities are measured in R units for the range of wave-length from 0.02 to 3A. This complete range is covered with but one change in the ionization chamber.

39. Intensity of reflected x-rays and the distribution of electrons in crystals. G. E. M. JAUNCEY, and W. D. CLAUS, Washington University.—Williams (Phil. Mag., 2, 657 (1926)) and Jauncey (Phys. Rev., **29**, 757 (1927)) have suggested that the intensity of x-rays reflected by a crystal is less than that on the classical theory, due to the modified scattering taking place at the expense of regular reflection. Havighurst (Phys. Rev., **31**, 16 (1928)) takes issue with Williams and Jauncey. The present paper is a reply to Havighurst. By trial a reasonable Bohr model of the chlorine ion has been found which gives F values, calculated in accordance with Jauncey's theory, at all angles in good agreement with the experimental values. When a Fourier analysis is applied to the theoretical F values an electron distribution (or U) curve is obtained which is similar to that obtained from experimental F values. The areas under the theoretical and experimental U curves are 16.64 and 16.74 electrons respectively for a grating space of 3.1A. Yet our theoretical U curve gives no particular information about the model from which it is derived. This is because the Fourier analysis is invalid since the number of diffracting centers does not remain constant as the angle of reflection is varied.

40. Quantum mechanics of the rotational distortion of multiplets in molecular spectra. J. H. VAN VLECK and E. L. HILL, University of Minnesota.—A formula is derived with the new quantum mechanics for the rotational distortion of the multiplets in molecular spectra which are due to different orientations of the axis of the electrons' internal spin. This problem was formulated and treated by Kemble with the old quantum theory (Phys. Rev. **30**, 387, (1927)). Our solution is obtained as a determinant which yields an algebraic equation for the energy W of the same order as the multiplicity. For the doublet case this gives the simple formula

$$W=[(j+\tfrac{1}{2})^2-\sigma_k^2-\tfrac{1}{2}\pm((j+\tfrac{1}{2})^2+[A^2I^2\sigma_k^2-2AI\sigma_k^2])^{1/2}]h^2/8\pi^2I$$

where j, σ_k, I, have their usual significance and $A\sigma_k h^2/4\pi^2$ is the doublet interval in the absence of rotation. Hund's cases (a) and (b) correspond respectively to $I/A=0$ and $A=0$. The adiabatic correlation of energy levels between (a) and (b) in the above formula is precisely that predicted by Hund and Kemble, including the anomalous behaviour of the component $j=\sigma_k-\frac{1}{2}$ in "regular" multiplets ($A>0$). Work is in progress on the derivation of intensity and Zeeman effect formulae applicable, like the above energy equation, throughout the range from case (a) to case (b).

41. The second order Zeeman effect in the new quantum mechanics. E. L. Hill and J. H. Van Vleck, University of Minnesota.—The formula for the Zeeman effect in atomic spectra has usually been calculated in the new mechanics only to linear terms in the magnetic field, except for the doublet case where Heisenberg and Jordan have shown that Voigt's formula is valid. Landé (Zeits. f. Phys. **30**, p. 329, 1924) has calculated in the old theory the term in H^2 for any multiplicity and we have done likewise in the new mechanics. The resulting equation is:

$$W=W_0+\Omega hgm+(\Omega^2h^2/16)[F(j)/(W_j-W_{j-1})+F(j+1)/(W_j-W_{j+1})]+\cdots$$

where $F(j)=[(s+k+1)^2-j^2][j^2-(s-k)^2][j^2-m^2]/j^2(j-\frac{1}{2})(j+\frac{1}{2})$ and where $\Omega=He/4\pi\mu c$; and W_j is the energy for a state of inner quantum number j for $H=0$. Besides the above term in H^2 due to the interaction of the anomalous spin magnetic moment with the field, there is another term in H^2 which is related to the diamagnetic effect (proportional to R^2). The formula for this term has also been obtained.

42. Theory of the magnetic nature of gravity and Newton's laws. Cornelio L. Sagui, Castelnuovo dei Sabbioni, Arezzo, Italy.—As in a gravitational field the magnetic quanta of two electromagnetic fields spacially superposed, with one lagging behind the other, react elastically upon each other in such a way that those advancing meet those returning. The latter would be pushed farther away and the former would recede, and different magnetic densities would result. An electron would result as an assembly of a large number of elementary electromagnetic fields (energy-wave) with a gravitational atmosphere (gravity-wave). The repelling forces are explained and radiation connected with the oscillation of electrons between attractive and repelling forces. Again high-frequency spectra would be due to oscillating helium atoms and hydrogen molecules within the atom. A magnetic wave would be an atomic asymmetry. A star may possess a movement, due to an asymmetry of its gravitational field, towards its less gravitational density. The equilibrium would be reached after a sufficient crowding up of magnetic quanta by velocity on the side of less density. The Newtonian laws are investigated from this viewpoint by considering the magnetic depression which I have supposed to be formed between two bodies in order to explain attraction.

43. Doublet separation of Balmer lines and the molecule of hydrogen in relation to the electromagnetic quantum theory. Cornelio L. Sagui, Castelnuova dei Sabbioni, Arrezzo, Italy.—Doublet separation of Balmer lines of hydrogen is calculated from the point of view of the electromagnetic quantum theory and good agreement found. From the view point of the same theory the continous spectrum was considered as formed by oscillations of electromagnetic quanta within an electron and reasons give as to its intensity variation as a function of the atomic number of the anticathode material and of the second power of the voltage applied. The formation of hydrogen molecules was also investigated. Two atoms of hydrogen would unite by penetrating one another to a certain extent in agreement with the general equilibrium of the new system formed. It is shown how combination lines may be thus formed and how the Lyman ultra-violet spectrum may be formed. The infra-red spectrum was also studied, and it is supposed that many of its lines are due to a general shrinkage of the energy levels of the atom since the attractive forces of the molecule are larger than those of a single atom.