JANUARY 1, 1930 PHYSICAL REVIEW VOLUME 35

PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

Minutes of the Chicago Meeting, November 29 and 30, 1929

The 159th regular meeting of the American Physical Society was held in Chicago, Illinois at the Ryerson Physical Laboratory of the University of Chicago on Friday and Saturday, November 29 and 30, 1929. The presiding officers were Professor Henry G. Gale, President of the Society, and Dr. W. F. G. Swann, Vice-President.

On Friday evening the Physical Society had a dinner at the Quadrangle Club. There were about one hundred members present. The after dinner speakers were Dr. W. F. G. Swann, Dr. Dayton C. Miller and Professor A. J. Dempster.

At the regular meeting of the Council held on Friday, November 29th, 1929, one was elected to fellowship, one was transferred from membership to fellowship, and one hundred and fifty-two were elected to membership. *Elected to Fellowship:* John B. Whitehead. *Transferred from Membership to Fellowship:* William V. Houston. *Elected to Membership:* T. E. Allibone, Emerson D. Bailey, William Baldwin Jr., E. G. Bangratz, LeRoy L. Barnes, Milton Bergstein, Arthur Bernhart, Donald K. Berkey, Luther M. Bingaman, Francis Birch, Heaton P. Blakeslee, Charles D. Bock, Gilbert F. Boeker, Isabel Boggs, Thomas H. Briggs Jr., Leslie E. Brooking, William F. Brown Jr., O. H. Caldwell, C. Wesley Carnahan, A. B. Carr, Randle V. Cartwright, Margaret L. Clark, Philip Constantinides, Trevor R. Cuykendall, Beryl H. Dickinson, James F. Duncan, J. R. Dunning, M. A. Easley, Sister Mary Edwina, Alexander Efron, Charles D. Ellis, John H. Findlay, Arthur W. Fleming, Hazel M. Fletcher, Arthur E. Focke, J. Franck, Austin R. Frey, Harold Q. Fuller, James W. Givens Jr., A. T. Goble, Martin Grabau, Newton M. Gray, John P. Hagen, August Hagenbach, Sigmund Hammer, O. Philip Hart, Charles D. Hartman, Alexander Harvey, Clifford E. Harvey, Edgar R. Hauser, Thomas Hazen, C. M. Hebbert, Jesse C. Hendricks, Willard H. Hickok, A. F. Horlacher, D. S. Hughes, Lewis H. Humason, Malcolm C. Hylan, H. F. Kaiser, Roy J. Kennedy, W. Jay Kennedy, James R. Kershaw, George E. Kimball, Harold L. Knowles, Matsui Kumiyasu, A. M. Kuethe, Olive M. Lammert, Charles C. Lauritsen, Glenn Q. Lefler, Lewis Larrick, Urner Liddel, Tate Lindsey, Erwin F. Lowry, Janet M. MacInnes, Homer E. Malmstrom, Louis Marick, D. E. Marshall, Tanaka Masamichi, F. A. Maxfield, Ronald L. McFarlan, R. T. McGoldrick, Edwin M. McMillan, Harold Mestre, Earl R. Miller, John S. Millis, Carol G. Montgomery, Howard R. Moore, Neal D. Newby, J. L. Nickerson, Foster C. Nix, Will V. Norris, Helen B. Notestein, Leonard M. Onsgard, Herbert N. Otis, F. L. Partlo, John V. Pennington, William M. Pierce, Milton S. Plesset, Richard G. Poindexter, Wilson M. Powell Jr., Simeon A. Ratner, John J. Rheins, Charles E. Rich, Donald E. Richardson, H. P. Robertson, Walter W. Roehr, Harry Rolnick, Donald C. Rose, Jenny Rosenthal, Philip W. Rounds, Edward W. Samson, A. Sandow, S. P. Sashoff, Edwin G. Schneider, Harold F. Schwede, Raymond W. Sears, Shirleigh Silverman, William W. Sleator, F. Raymond Smith, John F. Smith, Letha A. Smith, David L. Soltau, Wayne T. Sproull, John R. Stehn, Louis Strait, Kuno Takuji, Tutomu Taraka, John B. Taylor, James S. Thompson, John A. Tiedeman, John S. Tobin, John W. Todd, A. H. Toepfer, Charles B. Vance, Robert J. Van de Graaff, Frank L. Verweibe, Alice M. Vieweg, Donald S. Villars, Worth Wade, Henry Walther, William H. Watson, Wayne Webb, Max Wehrli, Thomas W. B. Welsh, W.W. Wetzel, Mary A. Wheeler, John L. Wilson, E. O. Wollan, Ralph W. G. Wyckoff, Imaoka Yoshio, Suga Yosuke, and Rolland M. Zabel.

The regular scientific session consisted of forty-two papers, five of which—Nos. 1, 16, 17, 21, 38—were read by title. The abstracts of these papers are given on the following pages. An AUTHOR INDEX will be found at the end.

W. L. Severinghaus, *Secretary*

ABSTRACTS

1. Thermal expansion of "Carboloy." Peter Hidnert, *Bureau of Standards.* Measurements have been made on the linear thermal expansion of two samples of "Carboloy" (a new tool material) purchased several months ago from Carboloy Company, Inc., 350 Madison Ave., New York City. An interferometer was used in the determinations at various temperatures between 20° and 400°C. The following results were obtained.

		Average Coefficients of Expansion per Degree Centigrade				
Sample	Heating	20 to 60°C	20 to 100°C	20 to 200°C	20 to 300°C	20 to 400°C
		$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$	$\times 10^{-6}$
1374 I	First	5.2	5.3	5.5	5.6	5.9
	Second	5.1	5.2	5.6	5.7	6.0
1375 I	First	5.0	5.2	5.5	5.8	6.0
	Second	4.9	5.2	5.5	5.8	6.0

The coefficients of expansion of "Carboloy" are larger than the corresponding coefficients of tungsten. For the range from 20° to 400°C, the average coefficient of expansion of the two samples of "Carboloy" is approximately 30 percent greater than the coefficient of expansion of tungsten.

2. Young's modulus determined with small stresses. Darol K. Froman, *University of Chicago.* (*Introduced by A. J. Dempster.*)—An interferometer method, similar to that used by E. G. Grüneisen (Ann. d. Physik **22,** 801, (1907)), was used to determine the extensions of metallic rods under small stresses. The applied stresses ranged in value from less than 1 kg/cm^2 to the smallest usually used in commercial testing, about 300 kg/cm^2. For the substances examined, Young's Modulus was found to increase very rapidly as the stress increased from zero, to reach a maximum at a comparatively small stress, and then to decrease almost exponentially to the ordinary value. The maximum elasticity was found to be from 10 to 30 percent higher than that at large stresses. The annealing of the rods is probably connected with this divergence from Hooke's Law with small stresses, as slight differences were found on reannealing some of the rods.

3. The construction of a master clock with light controlled contacts. J. V. HOFFACKER, *Purdue University.* (*Introduced by K. Lark-Horovitz.*)—Mercury contacts for controlling circuits periodically by means of pendulums, because of their unreliability and their effect on the period of the pendulum, have been replaced by photoelectric cells influenced by beams of light interrupted periodically by the swinging pendulums. But since selenium cells are equally sensitive to light when operating with direct or alternating current they can be used with a specially constructed relay employing alternating current from lighting mains as the only source necessary. Low resistance selenium cells transformer coupled and high resistance cells as grid leaks in triodes have been used successfully. The relayed current rectified by a dry rectifier is used to keep the pendulum itself going so that no clockwork is necessary to operate repeater clocks.

4. The Nernst heat theorem. HERBERT J. BRENNEN, *Northwestern University.* The Gibbs-Helmholtz equation requires that the limit of $(\partial U/\partial T)=0$, as T approaches zero. Nernst makes the further assumption that the limit of $(\partial A/\partial T)=0$, as T approaches zero. On putting: $U=U_0-bT^2-2cT^3-$etc., integrating the Gibbs-Helmholtz equation and using Nernst's assumption, one finds: $A=U_0+bT^2+cT^3+$etc. Whence, $Q=A-U=2bT^2+3cT^3$ $+$etc.; where A, Q, U and T have their usual significance. Hence, for small values of T, as a first approximation: $(\partial \log Q/\partial \log T)$ is equal to two, which is double that demanded by the Carnot heat theorem. In order to account for this discrepancy, it is suggested that: (1) since U is a function of the volume as well as the temperature, both U and T be regarded as independent variables and A, a dependent variable; (2) the Gibbs-Helmholtz equation be generalised to: $A-U=T(\partial A/\partial T)+KU(\partial A/\partial U)$ where K is a constant. This equation be comes identical with that of Gibbs and Helmholtz when $U=0$ or when A is independent of U.

5. Porous plug measurements with air. J. R. ROEBUCK, *University of Wisconsin.*—In an earlier article (Proc. Amer. Acad. **60,** 537, (1925)) I described apparatus and methods used for measuring the Joule-Thomson coefficient over 25 to 280°C and 1 to 215 atm. The present work extends the data down to −150°C. The measurements give isenthalpic curves in a pressure-temperature field. The derivative $(dT/dp)_h=\mu=$Joule-Thomson coefficient has been plotted as a function of p and T over the whole field. The original curves were used to spread C_p at 1 atm. over the 215 atm. range. With the aid of data on (pv) for air taken from the literature, the free-expansion (Joule) coefficient $(dT/dp)_u=\eta$ has been calculated over −100° to +200°C and 1 to 100 atm. These again give the elastic coefficient $1/v(dv/dp)_t=\gamma$ and $(du/dv)_t=\lambda$ over this field. λ can be used to calculate the correction to the constant volume air temperature scale, which is being done. This completes the work with air, and the apparatus is being rebuilt into a closed system to measure pure gases of which the first is to be helium.

6. The function of the base metal in oxide coated filaments. E. F. LOWRY, *Westinghouse Elec. &Mfg. Co., East Pittsburgh.*—Measurements on a number of UX-281 Radiotrons with oxide coated platinum-iridium filaments and others having oxide coated "Konel" filaments show that the base or core metal plays an important part in the behavior of such filaments. Konel, an alloy of nickel, cobalt, iron and titanium, has a much higher thermal emissivity than platinum and therefore, when operated at 4 watts per cm^2, reaches a temperature about 150°C lower than that reached by oxide coated platinum with the same energy input. Nevertheless, oxide coated Konel filaments give slightly higher emissions than oxide coated platinum filaments under like conditions of input energy. This anomalous behavior requires a modification of the present theory of oxide emission. This requirement is met by assuming that the source of the electron emission is a layer of metallic barium in contact with the base metal and that the electrons diffuse through the pores in the oxide coating which is a rather good non-conductor. This hypothesis serves as a satisfactory basis of explanation for the varied and somewhat confusing phenomena of oxide emission.

7. Photoelectric behavior of solid and liquid mercury. DUANE ROLLER, *University of Oklahoma.*—With monochromatic light, the photoelectric threshold for solid mercury, freshly distilled in vacuum, was found at 2750 ± 25A for all temperatures between −190°C and the melting point. The threshold for liquid mercury at room temperature was at 2735 ± 10A, confirming the value established earlier by Kazda and by Hales. The emission for monochromatic light was independent of the temperature between −190° and −40°C. There was no indication of a change in the crystal structure of mercury in this region of temperatures. The emission for the solid phase was always somewhat higher than that for the liquid at room temperature, possibly due in part to a change in the optical absorptivity of the mercury surface with change in phase. A study of the optical absorptivity of solid mercury is in progress. Between −39° and 0°C the emission was about 75 percent of that at room temperature but showed hysteresis with successive warming and cooling of the mercury. Thus a further study of liquid mercury between melting and room temperatures is needed. Most of this work was done at the California Institute of Technology.

8. Spatial distribution of photoelectrons. S. SZCZENIOWSKI, (*International Education Board Fellow*) *University of Chicago.*—The perturbation of a hydrogen-like atom by a plane polarized electromagnetic wave is considered on the basis of Dirac's equations, and perturbed wave-functions are obtained. These functions lead by a method similar to that used by Sommerfeld in his "Wellenmechanisches Ergänzungsband," to a formula for the spatial distribution of the photoelectrons, but differing from his in the first approximation, by a factor equal to 5/9. This factor follows from a consideration of the normalization factors for the spherical harmonics, which were not introduced by Sommerfeld. A second approximation has also been obtained showing the influence of electron spin. This formula differs from that obtained by Carrelli (Zeits. f. Physik **56,** 694, (1929)) in that the spin and some other terms not considered by Carrelli appear.

9. Electron velocities in an electrodeless discharge. CHARLES J. BRASEFIELD, *University of Michigan.*—A high frequency discharge in hydrogen was obtained by applying high frequency voltages to the movable external electrodes of a cylindrical discharge tube. By observing the change in the ratio of the densities of certain singlet and triplet lines of the secondary spectrum (see Phys. Rev. **34,** 437 (1929)), the mean electronic velocity in the discharge was studied as a function of (1) the frequency of oscillation, (2) voltage between electrodes, (3) distance between electrodes and (4) gas pressure. Observations were made at frequencies of oscillation corresponding to the wave-lengths 15, 25, 50, 100 and 200 meters. For example, at 0.03 mm pressure with 1400 volts applied to the electrodes, the electronic velocity increases from 23.7 volts at 25 meters to 25.8 volts at 200 meters. At 25 meters and 0.03 mm pressure, the electron velocity increases from 20.8 volts to 23.7 volts as the voltage between electrodes is increased from 500 volts to 1400 volts. Finally, at 25 meters with 1000 volts between electrodes, the electron velocity increases from 22.7 volts to 24.7 volts as the pressure is reduced from 0.06 mm to 0.01 mm. It appears that conditions in the electrodeless discharge should be quite similar to those in the positive column of an ordinary Geissler tube discharge. This probably explains why such small changes in electronic velocity were observed.

10. Motion of electrons in carbon monoxide. H. B. WAHLIN, *University of Wisconsin.*—In a paper which appeared in an earlier issue of the Physical Review [**21,** 517 (1923)] it was shown that the mobility of electrons in CO obey the equation $U=A/[B+V]^{1/2}$ with a high degree of accuracy. Shortly after the appearance of this paper K. T. Compton showed that the equation for the mobility should be of the form $U=A/[1+(1+BV^2)^{1/2}]^{1/2}$. Application of this equation to the data presented earlier shows that for low fields the Compton equation holds within the limits of experimental error. At values of X/P above 0.4 volts/cm/mm pressure a systematic deviation from this equation appears due probably to a decrease in the electronic free path with increasing electron velocity. The electron free path in thermal equilibrium with the gas and at a pressure of 1 mm is found to be 0.069 cm.

11. Slow caesium ions in hydrogen and helium. J. S. THOMPSON, *University of Chicago, (Introduced by A. J. Dempster.)*—The motion of positive caesium ions in hydrogen and helium has been examined for ion velocities ranging from 3 to 600 volts. Three different experimental arrangements were used in which the ions traversed a known gas path and in which any weakening of the bundle could be observed. No absorption of 10 to 600 volt ions was observed for gas pressures up to 0.030 mm of Hg. At the highest pressure the ions make 20 collisions without deflections from their original directions. Below 10 volts and for pressures above 0.010 mm a definite weakening of the bundle sets in and increases rapidly with the pressure. In all cases studied the ions were retarded, and the velocity distribution produced has been measured. The final velocities show an approximate probability distribution about a mean retardation. This distribution becomes more nearly that of the error curve for smaller velocities and higher pressures. The large absorption of the caesium ions observed by Ramsauer is accounted for on the basis of this retardation. Lithium ions in helium show considerable scattering which decreases as the velocity is increased and rises rapidly as the velocity is reduced below 50 volts.

12. Ionization efficiency of electrons in potassium vapor. J. KUNZ AND A. HUMMEL, *University of Illinois.*—Using a direct method in which a beam of electrons is projected into a field-free chamber, the number (N) of positive ions formed per electron per centimeter path per unit pressure has been measured and plotted against the energy of the primary electron. Scattering of the primary beam was prevented by means of a magnetic field of 350 to 400 gauss parallel to the beam. A small transverse electric field was employed to drive the positive ions to the collecting plate. Two other plates served to make this field uniform in the region from which the ions were collected. For potassium vapor N was found to have three maxima occurring at 40, 81, and 122 volts accelerating potential. The second and third maxima are respectively 18 percent and 11 percent greater than the first. N is approximately 20 times the value of N for argon. The curve for argon has a maximum value for N of 0.108 appearing at 88 volts which compares with the maximum 0.113, at approximately 125 volts, observed by Compton and Van Voorhis.

13. A study of the ions produced in mercury vapor by electron impact. WALKER BLEAKNEY, *University of Minnesota.*—In a recent paper (Phys. Rev. **34**, 157 (1929)) a method was proposed for analyzing the primary results of ionization by electron impact. The method has been applied to a quantitative study of the five mercury ions Hg^{+}, Hg^{2+}, Hg^{3+}, Hg^{4+} and Hg^{5+}. The results show that the fraction of the current carried by the Hg^{+} ion falls rapidly from 100 percent at electron velocities between 10.4 and 30 volts to about 70 percent at 100 volts, and then approaches a nearly constant value of about 60 percent for increasing electron speeds. At 300 volts the fractions of the total positive ion current carried by the five ions, in order, are 59, 26, 11, 3.5, and 0.5 percent respectively. The results have been reduced to number of ions per electron per cm path per mm pressure at 0°C as a function of the electron velocity. These data show a distinct maximum of magnitude about 21 for the Hg^{+} ion in the neighborhood of 50 volts while the value at 300 volts has dropped to half as much. Maxima also appear for Hg^{2+} and Hg^{3+} at 115 and 210 volts respectively.

14. Absorption of lithium ions in mercury vapor. I. W. COX, *University of Chicago. (Introduced by A. J. Dempster.)*—The absorption of 25 to 300 volt lithium ions in passing through mercury vapor at various pressures up to 48×10^{-4} mm was observed by two different methods. In the first method the ions described a semicircular path in a magnetic field and the decrease as the pressure was increased was observed. In the second method the ions, after this magnetic analysis, described a straight path to a collecting chamber and the decrease in the number entering the circular aperture of the collecting chamber was observed as the pressure was increased. A consistent difference was found in the absorption coefficients given by the two methods. It was also altered by a change in the aperture of the collecting chamber in method 2. This indicates that the collisions with the mercury atoms are not elastic, but that a large fraction of the deflections are through small angles. Ionic diameters deduced from the absorption depend on the apertures of the apparatus used. The ions collected are not slowed up appreciably, and there is a dependence of the absorption observed with any particular aperture on the velocity of the ions.

15. The reflection of lithium ions from metal surfaces. R. B. Sawyer, *University of Chicago.* (*Introduced by A. J. Dempster.*)—Experiments have been performed on the reflection of lithium ions from reflectors of platinum foil and of nickel crystals deposited on tungsten foil (Rupp, Ann. d. Physik [5], **1,** 801 (1929)). Movable ground joints in the tube were entirely eliminated. Readings were taken with both cold and hot reflectors. Spodumene was used as a source of ions and reflection was studied in the meridian plane only. Superposed on a diffuse scattering of ions were two reflected beams. One was reflected nearly specularly, as found by Read (Phys. Rev. **31,** 155 (1928)) and Gurney (Phys. Rev. **32,** 467 (1928)), the angle of maximum reflection, however, being independent of accelerating potential. The other beam appeared only at voltages above 200 or 250 and was composed of ions most of which had retained 80 percent or more of their original energy. This beam was found between the incident beam and the normal to the surface, at angles independent of the accelerating potential up to 700 volts. This independence of angle on voltage forbids diffraction interpretations. A tentative explanation consists in supposing specular reflection from the (110) planes of the nickel cyrstals, but the agreement is not entirely satisfactory.

16. Secondary emission of nickel under positive ion bombardment in the positive column in neon. W. Uyterhoeven and M. C. Harrington, *Princeton University.*—An attempt is made to measure the secondary emission under positive ion bombardment of metal collectors in the positive column under conditions as near as possible to those in the cathode fall. A combination of a fixed collector and a movable one opposite the first, was used. The movable one was given a negative potential and the ion current to it compensated; then the potential of the fixed electrode was varied and the corresponding change in current to each measured. The results obtained so far show that for an accelerating potential of about -150v, the secondary emission can reach 50 p.c. of the total current collected on a negatively charged electrode. (Proc. Nat. Ac. Sc. **15,** 32 (1929)). The electron mean free path seems to depend markedly on the degree of ionization of the gas, the measured values being less than the gas kinetic values (e.g. 50 p.c.). A large fraction of the electron emission from the metal is apparently due to the impact of metastable atoms on the collector. (Oliphant, Proc. Roy. Soc. **A124,** 228 (1929)), but for higher accelerating potentials of the positive ions their effect becomes more and more important (Penning, Physica, **8,** 13 (1928)).

17. Zeeman effect in λ5211 MgH band. G. M. Almy, F. H. Crawford and E. L. Hill, (*National Research Fellow*), *Harvard University.*—The Zeeman effect for molecules lying between Hund's cases (a) and (b) has been treated theoretically by the quantum mechanics, and the results applied to the MgH band at λ5211. For states near case (a) the theory predicts the usual splitting into $(2J+1)$ magnetic substates. When the magnetic separations are comparable with the doublet separations (very high fields or small doublet intervals) a Paschen-Back effect sets in corresponding to uncoupling of the electronic spin and the rest of the molecule with a degeneration of the term system into that of a symmetrical top superposed on that due to practically free spin. In a $^2\Sigma$ state (neglecting rho-type doubling) this degeneration is sensibly complete at all fields. The theory is verified quantitatively in the λ5211 MgH band. In the earlier lines the size of the fine structure patterns agrees numerically with calculations. In the higher lines the Paschen-Back effect causes a filling in of the normal doublet interval with an unresolved band in addition to the appearance of outer wings which move out and become fainter with field. Pattern widths, separation of components, and line displacements, where observable, have been measured from plates taken at fields between 5000 and 28000 gauss. No detailed intensity calculations have been made.

18. A magneto-optic method of chemical analysis. Fred Allison and Edgar J. Murphy, *Alabama Polytechnic Institute.*—This is a refinement of a method previously reported by one of us (Allison, Phys. Rev. **30,** 66 (1927) and **31,** 313(A) (1928)). Each chemical compound produces a minimum of light at a point characteristic of the compound. The surprising result has been found that this characteristic minimum does not disappear until the concentration has been reduced to less than one part in 10^{10}. The method thus affords a very sensitive and rapid means of chemical analysis. A large number of such analyses has been made. The presence of compounds, instead of elements, is detected. Each inorganic compound is characterized by either a single minimum or two or more close minima. The number of these minima, with few exceptions, is the same as the number of known isotopes of the metallic element of the compound. The investigations have been confined to a number of organic liquids and an extensive series of nitrates, chlorides, sulphates and hydroxides in solution. The positions of the minima are some inverse function of the chemical equivalent of the metallic element of the inorganic compounds. The effect is no doubt a time effect, but a complete interpretation must await further investigations, which are in progress.

19. **The absorption spectrum characteristic of vitamin A.** JAY W. WOODROW AND H. L. CUNNINGHAM, *Iowa State College.*—The absorption spectra of substances containing vitamin A were obtained in the region from 290 to 350 mμ by means of a sensitive photoelectric spectrophotometer. Fresh cod-liver oil and spinach juice gave prominent absorption bands with maxima at 310 and 326 mμ with minor bands at 320, 330 and 337 mμ. When the oils were extracted with ether, the bands were shifted toward the shorter wave-lengths by 3 mμ but their relative intensities remained the same. These bands were obtained with cod-liver oil, spinach juice, egg yolk and butter, all of which are known to be rich in vitamin A. Peanut oil which is rich in vitamin D but contains no vitamin A, gave the characteristic vitamin D bands at 270, 280 and 290 mμ but gave no indication of the bands in the neighborhood of 326 mμ. Bubbling air through the cod-liver oil at a temperature of 90°C for an hour or exposing it to the ultra-violet light from a quartz mercury arc for 20 min., either of which will destroy most of the vitamin A, caused the disappearance of the absorption bands at 310, 320, 326 and 330 mμ.

20. **A new absorption band of atmospheric oxygen and the vibrational frequency of the normal molecule.** HAROLD D. BABCOCK, *Mount Wilson Observatory.*—Four possible absorption bands in the "atmospheric" system of oxygen have been sought with air paths of 40 to 70 kilometers, (0, 1), (2, 1), (2, 2), (1, 1). The last has been discovered; the others are not yet established. The intensity of (1, 1) is roughly 1/2500 that of (0, 0). Over 30 lines are identified and 26 are accurately measured. Wave-number differences are taken from these to corresponding lines in (0, 0), (1, 0), (2, 0) and (3, 0). Eliminating the rotational effect and using the known spacing of the vibrational levels in excited O_2, these combinations give 1556.31 ± 0.05 cm^{-1} as the most probable value of the vibrational frequency of the normal molecule having 1 unit of vibrational energy. Results from P branches are more concordant than from R branches, which show a slight linear dependence on the upper vibrational state. The new value is compared with the Raman displacement, and its usefulness is discussed in other relations such as, calculation of isotopic displacement and of heat of dissociation. The data also help to establish a test for the consistency of solar standards of wave-length.

21. **On the active nitrogen glow.** RICHARD RUEDY, *Toronto.*—With strong afterglows in N_2 the 3 prominent bands can be seen for several seconds; such a persistence is longer than the time necessary for the recombination of N atoms (the formation of H_2 being taken as a basis of comparison) and considerably longer than the life of metastable systems. However, the potential energy curve for the initial state of the afterglow bands shows that, although emission of light takes place when during their oscillations the atoms have reached their greatest elongation, dissociation is likely to occur at the inner turning point, particularly for the smaller heats of dissociation which have found favor since it was shown that no Xe lines could be obtained in the afterglow, (Trans. R. Soc. Can. **22,** 303 (1928)). This dissociation process provides for the afterglow the necessary number of atoms, and eventually for metastable atoms. The real excitation potential of level A seems to be below 7 volts. In a 1 to 2 l bulb an initial intensity of the glow, corresponding to about one candle, can be obtained at a few mm Hg, and a total intensity of a few candles. This corresponds to 10^{17} emission processes initially, or to 10^{14} radiating molecules per cm^3 (10^{-3} mm Hg), an insufficient amount for ordinary absorption measurements.

22. The excitation of certain nitrogen bands by positive ion impact. H. D. SMYTH AND E. G. F. ARNOTT, *Princeton University*.—In the sources of light usually used for the study of band spectra excitation is chiefly by electron impact. It is now generally agreed that an electron impact does not alter the rotational nor vibrational momentum of a molecule. However, it might be expected that in excitation by positive ion impact both the vibrational and rotational momentum might be altered. We have, therefore, undertaken the study of the intensities of band spectra excited in nitrogen by the impact of mercury ions. Mercury canal rays pass through the cathode of a discharge tube into an atmosphere of nitrogen. The feeble light excited is found to consist almost exclusively of the negative nitrogen bands. In the two bands (λ4278 and λ3914) which have been photographed with a small grating, the lines corresponding to the lowest rotational states are definitely weaker than in comparison photographs taken with an electrodeless discharge. In fact the first two lines of the R-branch and the first line (perhaps the first two) of the P-branch are entirely missing. Theoretically one might expect one more line of the P-branch than of the R-branch to be missing. The investigation is still in a very preliminary stage.

23. The spectrum of singly ionized indium. R. J. LANG, *University of Alberta* AND R. A. SAWYER, *University of Michigan*.—The indium spectrum has been excited in a hollow cathode discharge in helium, using the same technic as in the authors' previous work with gallium. The spectrum has been photographed throughout the entire photographic region. The first spark spectrum is a two electron spectrum with singlet and triplet terms of which the chief combinations have been identified. Enough higher terms have been found to permit the calculation of approximate term values. The deepest term, $(5s^2)^1S$, is placed at 152350 cm^{-1} corresponding to an ionization potential of 18.81 volts.

24. Intensity measurements in neon spectrum. H. N. SWENSON, *University of Illinois*.—The Ornstein method of photographic photography has been applied to a study of the neon discharge. Special emphasis was placed upon elimination of errors in the optical system and in the development of plates. Density screens were prepared by sputtering platinum films of various densities on quartz plates. This screen was placed in an optical system similar to that of Ornstein and vibrated electrically to eliminate possible errors due to non-uniformity. Development was carried out at constant temperature and with forced circulation of developer around the plate. Intensity ratios were obtained for 19 lines in the region from 5800A to 6700A. The discharge was excited by a 10,000 volt transformer, the pressure being 2 mm. The intensity ratios for multiplets which are transitions from the same upper level, are not in agreement with the values of Dorgelo or those predicted by the Ornstein-Burger intensity rules, but show marked agreement with values recently published by Ende using electron impact excitation.

25. Intensity relations in some of the stronger multiplets of chromium I and chromium II. CEDRIC E. HESTHAL, *Ohio State University*.—The relative intensities of thirteen multiplets in the spectrum of chromium I and of five multiplets in the spectrum of chromium II have been determined by photographic photometry. The method used was that described by G. R. Harrison in the Journal of the Optical Society (**17**, 389 (1928); **18**, 287 (1929)). Numerous violations of the intensity formulas which have been derived by H. N. Russell, R. de L. Kronig and others are found. In some multiplets all the lines appear anomalous while in other multiplets only a fraction of the lines are abnormal. In general, the violations are more numerous than those observed by Harrison in titanium and fewer than those observed in iron and nickel by Ornstein, showing that perturbations increase with atomic number among the elements of the iron group. The intensities of multiplets forming two triads have also been determined and the equivalent excitation temperatures for these calculated. For one of these triads the method fails showing that this triad does not obey the formulas of R. de L. Kronig while for the other, temperatures between 2800°K and 4800°K were observed for different exposures. Data have been obtained to show that the equivalent excitation temperature is not the same for multiplets having final states in different regions of the atom.

26. Relations between hyperfine structure separations. S. GOUDSMIT AND R. F. BACHER, *University of Michigan.*—The quantum mechanics conception of a spinning electron in an s-state makes it probable that its interaction energy with a nuclear moment i is simply proportional to the average of is cos $(i \cdot s)$. In some cases where the hyperfine structure is mainly caused by an s-electron one can evaluate this cosine. This gives relations between the hyperfine structures of different levels which agree well with observations on Tl II (McLennan).

The large hyperfine structures in Tl II are due to the presence of the deeply penetrating single $6s$-electron, those of Tl I are much smaller ($6s^2$). In Tl III only the normal state $6s$ will show a very large hyperfine structure which must be about 8 cm^{-1}. In more complicated cases one can only tell that the interaction energy will be proportional to ij cos $(i \cdot j)$ which causes the interval rule to be valid for hyperfine structure.

27. Relativity transformation of an oscillation into a traveling wave, and de Broglie's postulate in terms of velocity angle. VLADIMIR KARAPETOFF, *Cornell University.*—The author has previously described a method of representation of space-time relationships in restricted relativity, by means of oblique coordinates (J.O.S.A. and R.S.I. **13**, 155 (1926)). The theory has been applied to the following problem: Two observers, S and S', are moving at a relative velocity q. The S' observer has in his system a set of pointers oscillating in synchronism and in phase with one another. It is required to describe the motion as seen by the observer S. By drawing two sine waves in the Lorentzian plane, it is shown graphically that for the S observer the pointers do not swing in synchronism, but form a traveling wave whose velocity of propagation, u, is connected with q by the familiar relationship $uq = c^2$, where c is the velocity of light.

Introducing the so-called velocity angle, α, determined by the relationship sin $\alpha = q/c$, various other properties of the traveling wave, as seen by S, have been deduced, such as the apparent frequency at a point in space, the apparent amplitude and its velocity of propagation, the Fitzgerald contraction of the oscillating system, the slowing down of the frequency of oscillation, the group velocity of "super-light" waves, and de Broglie's quantum principle. The article appeared in the Journal of the Optical Society of America for November, 1929.

28. The significance of the Michelson-Morley-Miller experiments in relation to the restricted theory of relativity. W. F. G. SWANN, *Bartol Research Foundation.*—While aether drift experiments originally suggested the line of thought which leads to the formulation of the restricted theory of relativity, it would seem that the fundamental significance of that theory does not depend primarily upon these experiments. The most logical origin of the transformation of the restricted theory is to be found as a special case of the general theory, and the purpose of the present paper is to show how, with this in view, the fundamental working content of the restricted theory, the invariance of laws under the Lorentzian transformation, is something which has no fundamental relation to the question of whether the aether drift experiments do or do not give a positive result.

29. Electron distribution in magnesium oxide. ERNEST O. WOLLAN, *University of Chicago.* (*Introduced by A. H. Compton.*)—The intensity of x-rays reflected from powdered crystals of magnesium oxide were measured for all lines out to $\theta = 45°$. The values of the structure factor, F, were calculated and plotted against sin θ. Using the values of F from this curve as coefficients in the Fourier Series given by Compton ("X-Rays and Electrons") the radial electron distribution for the atoms of magnesium and oxygen was determined. The electron distribution curves for these atoms are very similar to the curves by Havighurst (Phys. Rev. **29**, 1 (1927)) for NaCl and NaF. However, the data indicate that the number of electrons associated with magnesium and oxygen is more nearly that of the neutral atoms than that of the ions, whereas Havighurst concludes that the lattice points are occupied by ions. A recalculation of some of Havighurst's data brings results which are in closer agreement with those of the author.

30. The efficiency of x-ray fluorescence. A. H. COMPTON, *University of Chicago.*—A review of the published data describing the intensity of fluorescent x-rays shows that the various observers agree that the number of quanta of fluorescent x-rays emitted by a radiator is considerably less than the number of quanta which it absorbs from the primary beam. The values of the efficiency of fluorescence that appear in the literature are for the most part, however, found not to be quantitatively reliable. New experiments give values of the "fluorescence yield," or ratio of the number of fluorescent K quanta to the number of photoelectrons ejected from the K shell, of 0.68 for a molybdenum radiator, 0.56 for bromine, 0.54 for selenium, and 0.37 for nickel. The values seem to be independent of the wave-length of the exciting rays. These measurements agree within experimental error with Auger's values of the fluorescence yield, based on his count of the frequency of occurrence of the compound photoelectric effect, and thus indicate that it is this effect which makes the fluorescence yield less than unity. Knowledge of the fluorescence yield gives an expression for calculating the relative intensity of two x-ray beams of different wave-length, in terms of the ionization currents obtained, and other factors.

31. Efficiency of production of continuous spectrum x-rays. WARREN W. NICHOLAS, *Bureau of Standards.*—There is a large discrepancy between the efficiency estimated by Kulenkampff (Handbuch der Physik vol. 23), who found $k=8\pm 2\times 10^{-10}$ in the formula, *efficiency* $=kZV$, where Z is the atomic number of the anticathode material and V is the potential across the tube in volts and the more recent experimental determination by Rump, who found k to be about 15×10^{-10}. This discrepancy makes desirable a closer consideration of some of the secondary processes (reflection of cathode rays from anticathode, etc.) occurring in both gas filled and hot cathode x-ray tubes, as well as a further examination of corrections for absorption (including absorption in the anticathode) and for asymmetric spatial distribution of x-ray energy. A correction of Rump's data on this basis leads to a value of k about 10×10^{-10}. Some estimates of actual x-ray energy, both continuous and characteristic, obtained outside a tube are obtained incidentally.

32. Absolute measurement of certain x-ray wave lengths. J. M. CORK, *University of Michigan.*—An x-ray vacuum spectrograph employing a plane glass grating 30,000 lines per inch and having a distance between grating and photographic plate of one meter has been used to obtain the absolute wave-length value of the L-series emission lines for elements molybdenum (42) to antimony (51). In addition many other lines are present due to extraneous sources in the x-ray tube. These wave lengths have been previously accurately measured by many observers employing the crystal method. A comparison of the two sets of values is made bearing on the question regarding the Avogadro number and electronic charge. The results obtained for the wave-lengths of the two molybdenum lines $L\alpha$ and $L\beta_1$, are respectively 5.3943 and 5.1658 A.U., indicating for e the value 4.821×10^{-10} e.s.u.

33. The index of refraction and absorption coefficient of gold for the Kα line of carbon. ELMER DERSHEM, *University of Chicago.*—An experimental curve showing the intensity of reflected radiation plotted against glancing angle of incidence was obtained for a sputtered gold surface and the $K\alpha$ line of carbon ($\lambda=44.6$A) by the use of methods and apparatus previously described (Phys. Rev. **34,** 1015 (1929)). The absorption coefficient (μ) of gold leaf for this wave-length was measured and a value of the extinction coefficient (κ) determined from the relation $\kappa=\mu\lambda/4\pi$. The experimental value being $\kappa=0.0086$. A computation by the use of the Drude-Lorentz dispersion formula gives $1-n=\delta=0.009$ for the case of gold and this wave-length. These values of κ and δ were substituted in a modified form of the Fresnel reflection equations and a theoretical curve relating reflected intensity and glancing angle was thus obtained. To secure perfect agreement with the experimental curve either κ or δ or both must have smaller values. Hence curves are also computed with various pairs of arbitrarily assigned values of κ and δ which show the effect of changes in the values of these constants upon the theoretical curve.

34. Diffraction of x-rays in liquids and the effect of temperature. E. W. SKINNER, *University of Iowa.*—Fourteen liquids have been examined for x-ray scattering both at room temperature and close to their boiling points. Results for principal maxima are as follows: 1. Change in intensity. a. Heptyllic acid, cyclohexane, benzene, octane, lauryl alcohol, and 2–7 dimethyloctane show a decrease in intensity with increase in temperature. b. Mesitylene, di-n-propyl carbinol, tertiary butyl alcohol, 4 hydroxy 1–3 dimethylbenzene, 2 hydroxy 1–3 dimethylbenzene, 2–2–4 trimethylpentane, phenol, and napthalene show an increase in intensity with increase in temperature. 2. An increase in molecular dimensions at higher temperatures was found, and, in general, the change is in agreement with the expected change in density due to expansion. 3. Change in peak width. The large peak common to all liquids thus far examined in this laboratory, appears to be wider at higher temperatures in all cases which is in agreement with existing theories of temperature effect in crystal scattering. All results are shown to be in agreement with the theory of the cybotactic condition except that an additional effect is needed to account for (1b).

35. Polarization of x-rays from thin aluminium anti-cathodes. BALEBAIL DASANNACHARYA, *University of Chicago.* (*Introduced by A. H. Compton.*)—An electron-beam 5 mm in diameter falls on thin aluminum foils of thickness varying from 6–250.10^{-5} cm, mounted on a cylindrical frame-work attached to a glass tap and regulated from outside. A graphite plate on an ionization spectrometer served to measure the polarization. The voltages varied from 27–56 KV. For a given voltage, polarization increases slowly at first with diminution of thickness but rises exponentially for thicknesses smaller than 2.5.10^{-4} cm. For different voltages the form of the curves remains the same, but the value of the polarization slightly diminishes with increase of voltage. The maximum polarization obtained was 47.5 percent. It looks likely that for a thickness of about 5.10^{-6} cm the polarization would be complete.

36. A relation between the Compton effect and the diffraction by electrons. JAKOB KUNZ, *University of Illinois.*—In the Compton effect a quantum of radiation of momentum $h\nu/c$ is transformed into the momentum of an electron mv and into a weaker quantum of radiation of momentum $h\nu'/c$. If we assume that the reversed process also is possible and that an electron strikes a quantum head on, then we obtain: $mv=h\nu/c=h/\lambda$, or $\lambda=h/mv$, which is the relation given by wave mechanics for the diffraction of electrons.

37. Paschen-Back effect of hyperfine structure. S. GOUDSMIT AND R. F. BACHER, *University of Michigan.*—By replacing the quantum vectors (s, l, j) and the magnetic moments (sg_s, lg_l, jg_j), of the ordinary multiplet theory by those of the hyperfine structure theory $(i, j, f; ig_i, jg_j, fg_f)$, it is possible to adapt the work of Heisenberg, Jordan and Darwin on Zeeman effect and intensities in any field strength, to the study of the Zeeman effect of hyperfine structure. The thallium line $(6p\,^2P_{1/2}-7s\,^2S_{1/2})\lambda 3776$ is an example of incomplete Paschen-Back effect which can be treated quantitatively with the above method. The calculated splitting up of this line in a field of 43350 gauss is in cm^{-1}. −3.00, −2.52, (−1.43), −(1.20), (+1.28), (+1.36), +2.45, +3.08. Measurements by Professor E. Back and Dr. J. Wulff at Tuebingen give −3.02, −2.54, (−1.42), (−1.22), (+1.35 strong), +2.43, +3.10. Without hyperfine structure the Zeeman effect would have been (±1.36), ±2.71.

38. Rectifier characteristics and detection diagrams. RICHARD RUEDY, *Toronto.*—The average current I_m obtained per cycle when, in addition to the constant voltage E, the potential $E_0 \sin \omega t$ is applied to a rectifier possessing the characteristic curve $I=f(E)$, has been calculated and compared with experiment for different $f(E)$. The curve $I=c\epsilon \exp [E/e_c]$ giving at open circuit a voltage independent of E applies to all types of vacuum tubes when the A.C. voltage does not exceed a few tenths of a volt, or 0.5 volts in the case of oxide-coated emitters. The curve $I=I/E$ gives $I_m=I/(E^2-E_0{}^2)^{1/2}$, and applies to certain types of glow and arc discharges in which an a.c. e.m.f. is superimposed upon d.c. Parabolic curves, for which the increase in I is independent of E, represent the actual current I_m better than the theoretical curves $I=CE^{3/2}$.

39. A new equation of state. HERBERT J. BRENNEN, *Northwestern University.*—Dieterici (Ann. d. Physik **66**, 826 (1898)) put forward the equation of state: $P(V-b)=RT \exp(-A/RT)$ where P, V and T are the pressure, volume and temperature, respectively, and A, b and R are parameters. However, limit (PV/T), as V becomes infinite, is equal to R and has the same value for one mole of all substances. Hence, we may replace RT by a new variable E and

Dieterici's equation becomes a two parameter equation. Since, a straight line intersects this equation in three real finite points at temperatures below the critical temperature, mathematical theory demands, in general, three parameters which makes Dieterici's equation, in general, mathematically absurd. Accordingly, I propose the new equation: $P(V-b)=RT$ exp $[-A(V-b)/RTV^n]$ which, for large values of V becomes identical with the equation (Proc. Nat. Acad. Sci. **15,** 11–18, Jan. (1929)) already proposed by me, and where n is the third or missing parameter. This new equation predicts that the Law of Corresponding States is true only for substances having the same values of the critical ratio, RT_c/P_cV_c.

40. On the origin of the line absorption spectra of the rare earths. OTTO LAPORTE, *University of Michigan.*—In the rare earth group of elements the configuration $4f^n$, $4f^{n-1}5d$, $4f^{n-1}6s$ will compete in the formation of the lowest terms. For neutral atoms or ions of low order, terms with $5d$ and $6s$ electrons will be most stable; for higher ionizations, terms due to $4f$ will be lowest, as is easily seen by comparing the slopes of the Moseley curves of the three configurations in question. Consequently, there will be intermediate stages of ionization, where the Moseley lines of the $4f^n$ and $4f^{n-1}5d$ terms cross, and spark spectra, for which the frequency of the allowed transition $4f^n-4f^{n-1}5d$ lies in the visible or at least at much longer wave-lengths than is usual for ions of (say) third or fourth order. The sharp absorption lines exhibited by rare earths in the liquid or crystal state are believed to be due to this transition. The fact that the absorption lines of gadolinium, recently measured by Freed and Spedding (Phys. Rev. **34,** 945, (1929)) lie farther towards the violet than those of any other rare earth may be understood in analogy to the group-theoretical ionization potentials as obtained by Peierls (Zeits. f. Physik **55,** 738, (1929)).

41. Further experiments on the disintegrative synthesis of oxygen of atomic weight 17 from nitrogen of atomic weight 14. WILLIAM D. HARKINS, *University of Chicago,* AND ARTHUR E. SCHUH, *Bell Telephone Laboratory.*—By the method of Harkins and Ryan (J. Am. Chem. Soc. **45,** 2095 (1923)) approximately 34,000 photographs of alpha ray tracks from thorium C and C' were taken as they appeared in a modified Wilson-Shimizu apparatus. Two disintegrative syntheses were given by 270,000 tracks of 8.6 cm and 145,000 tracks of 4.9 cm range in air. The gas used was nitrogen. It may be assumed that the alpha-particle attaches itself to the nitrogen nucleus, thus forming the nucleus of an atom of fluorine, which in less than a millionth of a second emits a fast hydrogen particle (proton) thus giving an oxygen nucleus of mass 17. By the use of the same general procedure Blackett (Proc. Roy. Soc. **A107,** 349 (1925)) obtained eight, and Harkins and Shadduck (Proc. Nat. Acad. Sci. **12,** 707 (1926)) obtained two such disintegrative syntheses. In this work 38 "collisions" of the alpha-particle were found in which the alpha-particle is deflected by more than 90°, while in the work of Harkins and Shadduck about 30 such collisions were found. If it is assumed that only such approximately direct impacts give a probability of a disintegrative-synthesis, then the possibility that the nitrogen thus transformed has an atomic weight of 15 seems negligible. A special search was made for the much more numerous short range hydrogen particles assumed by some workers to be emitted, but none of these were found. Thus far in this laboratory about 8 disintegrative syntheses per million long range alpha-particles, have been observed. Thus about eight protons per million long range alpha-particles were obtained in nitrogen, while Rutherford and Chadwick observed two with aluminum. However their scintillation method is not exactly comparable.

42. An isotope of nitrogen, atomic weight 15. S. M. NAUDÉ, *University of Chicago.* (*Introduced by Elmer Dershem.*)—(The abstract of this paper appeared as a Letter to the Editor, (Phys. Rev. **34,** 1498 (1929)). The following slight corrections should, however, be made in the calculated value of the wave-lengths of the isotope heads: Q_1 heads: 2155.263($N^{14}O^{17}$), 2155.753($N^{15}O^{16}$), 2156.744($N^{14}O^{18}$). P_1 heads: 2156.498($N^{14}O^{17}$), 2156.978($N^{15}O^{16}$), 2157.949 ($N^{15}O^{18}$). For the (0, 0) band the calculated shifts of the P_1 head are for $N^{14}O^{17}$, $N^{14}O^{18}$ and $N^{15}O^{16}$, -2.595 cm^{-1}, -4.952 cm^{-1} and -3.375 cm^{-1} respectively. This corresponds to the wave-lengths 2269.536A, 2269.659A and 2269.577A.

The third from the last paragraph of the letter should read as follows: "The effect on the (0, 0) band is very difficult to observe owing to its smallness. The wave-lengths of the displaced heads found are 2269.60($N^{15}O^{16}$) and 2269.70($N^{14}O^{18}$) which correspond within experimental error with the calculated shift. The displaced head due to the $N^{14}O^{17}$ molecule could not be observed."

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