Proceedings of The New England Section of the American Physical Society

(MINUTES OF THE MIDDLETOWN MEETING, OCTOBER 14, 1933)

THE third regular meeting of the New England Section was held in Middletown, Connecticut on Saturday, October 14. The Presiding Officers for the morning sessions were Professor E. C. Kemble, Chairman of the Section, and Professor S. R. Williams. The Presiding Officer for the Business Meeting and the afternoon session was Professor E. C. Kemble.

About 80 were present at the Section's morning meeting and about 130 at the afternoon session.

The morning sessions were devoted to the reading of contributed papers, the abstracts of which appear below.

A business meeting of the Section was held at noon. The Secretary-Treasurer reported that 131 members had joined and paid their dues to date and that the Section had a cash balance of $279.29.

The election of officers for the Section for the calendar year 1934 then took place. The officers elected were:

PROFESSOR W. G. CADY, *Chairman*
PROFESSOR LOUISE MCDOWELL, *Vice-Chairman*
PROFESSOR P. M. MORSE, *Secretary-Treasurer*
PROFESSORS BLACK AND SAUNDERS, *Members of the Program Committee*

Invitations were kindly extended by both Brown University and Williams College for the Section to hold its October, 1934, Meeting at their institutions. The decision about this meeting will be taken under advisement by the Program Committee.

It was moved that the Program Committee take steps to change the date of this year's winter meeting from February to March, 1934, to avoid conflict with the Christmas Meeting of the A.A.A.S.

A vote of thanks was extended to the members of the Physics Department at Wesleyan for their efforts which had made the meeting such a success.

The Section had its lunch at the '92 Theater. President McConaughy of Wesleyan University was present and gave a speech of welcome to the Section.

The afternoon session was devoted to invited papers. Professor W. G. Cady of Wesleyan talked on *A Survey of Piezoelectricity*. Professor V. E. Eaton of Wesleyan gave a talk about some new experiments for the elementary physics laboratory. These experiments were on display in the laboratory and were inspected by the Section after the papers had been concluded.

Dr. Karl K. Darrow of the Bell Telephone Laboratories gave a very interesting talk on *Elementary Particles*.

The program of the Section consisted of 19 papers, the abstracts of which are given below. An author index will be found at the end.

PHILIP M. MORSE, *Secretary-Treasurer*

ABSTRACTS

1. Velocity of High Frequency Sound in Tubes. GARDNER A. NORTON, *Cruft Laboratory, Harvard University.* (*Introduced by E. C. Kemble.*)—A study of the velocity of high frequency sound in air in tubes has been undertaken in the effort to check the Kirchhoff-Helmholtz formula, which gives the decrease in sound velocity from the free space value as a function of tube diameter and frequency. A magnetostriction oscillator is used both as the source and detector of the sound wave system, in the resonance method similar to that of G. W. Pierce, who first used quartz crystals as high frequency sources. The results verify the Kirchhoff-Helmholtz relation at high frequencies, for all diameters and frequencies used, to 1 part in 1000 or better. Any departure from the simple or ideal conditions of the experiment, however, leads to results which are not in agreement with the above law. The reduction in velocity in a very thin-walled tube is observable, though of small magnitude. The average free-space velocity as derived from the complete set of tube observations agrees to within 1 part in 4000 with the free-space value recently obtained in these Laboratories by Dr. Grabau who also was using magnetostriction. Further, a careful investigation has been made of frequency change of the source, near-source velocity value, and the avoidance of both air circulation and sound diffraction effects, in order to keep the experimental conditions which are postulated in the development of the theoretical formula.

2. The Absorption and Reflection of Gold Between 380A and 1400A. I. LIBEN AND H. M. O'BRYAN, *Massachusetts Institute of Technology.*—With a one-meter vacuum spectrograph and a "hot spark" between carboloy electrodes, the reflection from gold mirrors at various angles of incidence, and transmission of thin gold films have been determined. Sputtered gold mirrors gave more reproducible reflecting powers than evaporated surfaces. At normal incidence 12 percent of 1000A is reflected with a gradual decrease to less than 1 percent of 400A. The absorbing films were evaporated on celluloid films about 10^{-6} cm thick. The gold films appeared green by transmitted light and from their absorption in the region of 2500A to 6000A are estimated to be from 10^{-6} cm to 3×10^{-6} cm thick. The absorption coefficient is about 5×10^{5} per cm, showing that gold is almost as transparent as celluloid from 1000A to 400A. Films of silver and selenium show quite different absorption in this region. Preliminary calculation by means of Fresnel's equations from the reflection data give values of the extinction coefficient which agree in order of magnitude with those from direct absorption. The oil coated plates used were tested for reciprocity failure in the near ultraviolet and in the extreme ultraviolet gave parallel characteristic curves indicating no failure of this law over an intensity range of thirty. The magnitude of the absorption in this region accounts for three electrons per atom of gold. This includes some of the O IV, V electrons as well as the conduction electron.

3. The Reflecting Power of Aluminum and Its Alloys in Different Regions. D. H. CLEWELL AND J. WULFF, *Massachusetts Institute of Technology.*—The reflecting power of aluminum, beryllium, magnesium, silicon and silver alloys have been measured throughout the region 2000–7000A at normal incidence by photographic intensity studies and by photoelectric measurements. The polished alloys have been compared with films of the same metals in reflecting power. Electron diffraction and chemical studies permitted a control of physical and chemical composition of the films. Here component metals were evaporated at the same time from different filaments at the proper temperature and separately. From the above data, the most efficient reflectors for the region of 2000 to 7000A have been determined; Al–Si 2000–3000A, Al–Ag 3000–6000A. An 85 percent Al, 10 percent Ag, 5 percent Si alloy film has approximately the same reflecting power (80–85 percent) from 2300A–5800A.

4. A Vacuum-Tube Voltmeter with Logarithmic Response. FREDERICK V. HUNT, *Harvard University.*—A new vacuum-tube voltmeter which has a response proportional to the logarithm of the input voltage is described. The operation of the device is based upon the distortion of the plate-current wave form occurring in a tube of the "variable-mu" type, and upon the use of a diode rectifier to select only that portion of the wave which has been "compressed" by the curvature of the tube characteristic. The elementary circuit may be cascaded for extension of the range of input voltage over which the response is logarithmic. The speed of response of the device to changes in signal intensity is practically unlimited, and the frequency fidelity is only slightly inferior to that of a comparable impedance-coupled amplifier designed for the same frequency band. Commercially available tubes are used throughout.

5. Electron Attachment and Negative Ion Formation in Oxygen and Oxygen Mixtures. NORRIS BRADBURY, *National Research Fellow, Massachusetts Institute of Technology.*—A direct method is employed to determine the probability of electron capture in oxygen and oxygen mixtures. The principle of the method lies in the analysis of a mixed current stream at two points along its path by means of wire grids which permit only the ionic fraction of the current to pass when a high frequency field is applied between adjacent grid wires. A means of measuring the mobility of the electrons is also possible. The probability of attachment has been determined for oxygen, air, and mixtures of oxygen with rare gases. The probability of attachment is a marked function of the electronic energy, decreasing with increase in electronic energy. In oxygen and in all mixtures with oxygen, however, there is an *increase* in the probability of attachment occurring at approximately 1.6 volts electronic energy. This can be definitely explained as being due to the appearance of *low energy* electrons following inelastic impacts with O_2 molecules. The energy at which these inelastic impacts begin is well correlated with the first excited level of the O_2 molecule which is 1.62 volts above the ground state.

6. Cosmic-Ray Counters and Cosmic-Ray Counts. G. F. HULL, *Dartmouth University.*—A discussion of some characteristics of counting devices and a comparison of counts obtained for single tubes and for tubes combined to give directional effects.

7. Directional Effects in Electron Diffraction from Single Crystals. G. A. MORTON, *Massachusetts Institute of Technology.*—Electron diffraction photographs, in the form of oscillation diagrams near grazing incidence, were made from the cleavage surfaces of cubic crystals. The pictures show that the resolution of the diffracted spots varies with the azimuth of the crystal, being low when the incident beam is in the direction of a cube edge or diagonal and high when it is at other angles. This effect was found in sodium chloride and in sodium fluoride. Possible explanations will be discussed.

8. X-Ray Diffraction in Long Chain Liquids. B. E. WARREN, *Massachusetts Institute of Technology.*—The diffraction of x-rays in long chain liquids is calculated by the method of Zernicke and Prins and comparison made with the experimental results of G. W. Stewart. In the liquid, the long cylindrical molecules are arranged quite at random in space and orientation, except insofar as the condition for relatively dense packing necessitates that about any one long molecule, the nearest neighbors be roughly parallel. The main peak is due to a concentration of scattering matter at a distance about 8 percent larger than the lateral distance between chains. The inner peak, which is observed for the alcohols and the fatty acids, measures the distance from the heavy end group to the gap at the opposite end. For relatively long chains this distance becomes equal to the chain length.

9. Rotation-Vibration Coupling in Diatomic Molecules. C. L. PEKERIS, *Harvard Observatory and Meterological Laboratory, Massachusetts Institute of Technology. (Introduced by P. M. Morse.)*—The wave equation for the nuclear motion of a diatomic molecule with a Morse potential function and the rotational term included is solved. It is found that α_e and D_e in the equations for the coefficients of the rotational terms in Kratzer's formula, $B_v = B_e - \alpha_e(v+\frac{1}{2})$, and $D_v = D_e + \beta(v+\frac{1}{2})$, are given by

$$\alpha_e = (2x_e\omega_e/\omega_e)[3(B_e/x_e\omega_e)^{\frac{1}{2}} - (3B_e/x_e\omega_e)] \tag{1}$$

and

$$D_e = -4B_e^3/\omega_e^2. \tag{2}$$

Eq. (2) agrees with Kratzer's formula, while (1) differs from the corresponding relation in Kratzer's formula by the term in brackets. This term is fairly constant for a number of molecules and is equal to 0.7±0.1, as was found empirically by Birge. Values of α_e computed from (1) are in good agreement with observed values for many molecules.

10. A Potential Function for the Vibrations of Diatomic Molecules. MILLARD F. MANNING, *Massachusetts Institute of Technology*, and NATHAN ROSEN, *National Research Fellow, Princeton University.*—An expression of the form

$$\frac{1}{k\rho^2}\left[\frac{\beta(\beta-1)e^{-2r/\rho}}{(1-e^{-r/\rho})^2} - \frac{Ae^{-r/\rho}}{1-e^{-r/\rho}}\right]$$

has the proper general characteristics for a diatomic molecule potential function. The solution of the radial part of the Schrödinger equation for this potential is:

$$R/r = (1-z)^{\beta} z^m F,$$

where

$$z = e^{-r/\rho}, \qquad k = 8\pi^2 M_1 M_2 / h^2(M_1+M_2), \qquad m = (-k\rho^2 E)^{\frac{1}{2}}.$$

The function F is a terminated hypergeometric series. The allowed values of the energy are given by:

$$E = -\frac{1}{k\rho^2}\left[\frac{A-\beta}{2(\beta+v)} - \frac{v(v+2\beta)}{2(\beta+v)}\right]^2.$$

The dissociation energy for a given ω_0, $\omega_0 x$, and r_0 is greater than the quantity $\omega_0^2/4\omega_0 x$ given by the Morse function.

11. A New Treatment of the H_2 Molecule. H. M. JAMES AND A. S. COOLIDGE, *Harvard University.*—The basic state of the H_2 molecule has been treated by a form of the variation process characterized principally: (1) by the treatment of the molecule as a unit, rather than as an association of atoms; (2) by the recognition of the fact that the wave function for this molecule should be a function of five coordinates rather than of the four commonly used; and (3) by the introduction of variable parameters of such character that the labor of adjusting them is reduced to a minimum. The results obtained for the dissociation energy are of a new order of accuracy for such computations and should be more reliable than any yet obtained from experimental data. We find 4.46±0.02 v, as compared with the experimented 4.46±0.04 v of Davidson. Our wave function has been studied and compared with the other wave functions used for the description of the molecule; the difference is most marked in those parts of function space where the electrons are close together. The function $(H-E)\psi$ has been evaluated for several points and confirmation of the results stated above was obtained. Other possible applications of the method are discussed.

12. The Virial and Molecular Structure. J. C. SLATER, *Massachusetts Institute of Technology.*—The virial theorem can be applied to a molecule, assuming that external forces are applied to keep the nuclei fixed. The mean electronic kinetic energy is then the negative of the mean total internal energy, plus a term arising from the virial of the external force. Since the external force is derivable from the knowledge of the total internal energy as function of nuclear position, this theorem gives a means of finding kinetic and potential energy separately, for all configurations of the nuclei, as soon as the total energy is known, from experiment or theory. By using simple forms of curve for total energy, for the diatomic molecule, the kinetic and potential energy are derived and discussed. The curves give direct indication of the formation of the covalent bond, in cases where this occurs, by describing the removal of charge from the atoms to the region between the atoms, with resulting decrease of kinetic energy, increase of potential energy.

13. The Band Spectra of the Halides of Aluminum. F. H. CRAWFORD AND C. F. FFOLLIOTT, *Harvard University.*—Photographs have been taken at various dispersions of the discharge through the vapors of the trichloride, tri-bromide and tri-iodide of aluminum. (Work on the tri-fluoride is in progress.) The results are distinctly different in the three cases. With $AlCl_3$ a well-developed group of red-degraded bands extending from λ2550 to λ2900, about 75 in all, was observed. Of these the stronger were obtained by Jevons (Proc. Roy. Soc. **A106**, 174 (1924)) who was not able to find a satisfactory vibrational assignment. It now seems that two overlapping systems must be present, although until photographs at higher dispersion are available this cannot be definitely settled. With $AlBr_3$ a well-developed system of 40 red-degraded bands in the region λ3065 to λ2745 is found. These bands are *new* and presumably due to AlBr. The frequencies of the heads are given approximately by $v_h = 35{,}850.1 + 288.55v' - 9.25v^2 - 375.1v'' + 1.5v^2$. This gives $\omega_e' = 297.8$, $x_e' = 0.03$, $\omega_e'' = 376.6$ and $x_e'' = 0.004$. In the case of AlI_3, using the greatest range of pressures possible, a continuous spectrum of considerable intensity extending from the visible to λ2300 appeared. It does have here and there a faintly banded appearance but is different from the spectrum of I_2 under the same conditions. We are in the process of photographing these bands at higher dispersions and hope to report the results in the near future.

14. Emission and Absorption of Radiation. W. W. HANSEN, *National Research Fellow, Massachusetts Institute of Technology. (Introduced by J. C. Slater.)*—Solutions of the vector wave equations in polar coordinates used by Mie and Debye are discussed and their properties derived. They form an orthogonal vector set inside a sphere and any vector wave with vanishing divergence is expansible in this set. The radiation in a spherical box can be specified by the expansion coefficients of its vector potential. Following Dirac these coefficients are used as coordinates and the Einstein A and B coefficients determined by treating the interaction of an atom with the radiation field by perturbation methods. Because each of the functions used to describe the radiation corresponds to a particular type of radiation, as electric or magnetic dipole, quadrupole, etc., the dipole, quadrupole, etc., transitions of the atom are completely and naturally separated. The vector potential at a great distance from a complex of currents is expressed in a new form by using functions related to those described above. With this expression to compute the radiation from an atom with a given current distribution, Einstein A coefficients in exact agreement with those obtained by the Dirac method are found.

15. Asymmetries of Pressure Broadened Lines. HENRY MARGENAU, *Yale University.*—Experiments have disclosed peculiar asymmetries in the intensity distribution of pressure broadened lines. The present paper is devoted to their explanation. The simple case of a one-dimensional gas is considered and an expression for the line contour developed. By graphical methods we have calculated the line contours corresponding to three typical interaction curves. The conclusion is that, by taking proper account of the repulsive portions of the energy curves, the empirically found asymmetries can be reproduced.

16. The Characterization of Physically Admissible Wave Functions. E. C. KEMBLE, *Harvard University.*—Since the Hamiltonian operator H in Cartesian coordinates is not Hermitian with respect to all quadratically integrable functions, it is proposed to restrict physically admissible wave functions to a linear manifold X characterized as follows. (a) Every function $\psi(x)$ in X is single-valued and analytic at every non-singular point of the Schrödinger equations. (b) Both ψ and $x^n\psi$ (x being any Cartesian coordinate) are absolutely and quadratically integrable. (c) ψ and its derivatives of all orders with respect to Cartesian coordinates approach zero at infinity. (d) In the neighborhood of a singular domain, $r_{ij} = 0$, ψ and r_{ij} grad ψ are continuous. (e) The properties postulated for ψ are shared by $H^n\psi$. H is Hermitian with respect to X and the problem of finding solutions of Schrödinger's first equation which belong to X (eigenfunctions) is reducible to variational form. Solutions of Schrödinger's second equation, $2\pi H\psi = ih\dot{\psi}$, which belong to X at t_0 belong to X at any other time t. The scalar product of any two X-type solutions of Schrödinger's second equation is constant in time. It is not difficult to modify postulate (d) to adapt it to the Dirac theory of the hydrogen atom.

17. A Survey of Piezoelectricity. W. G. CADY, *Wesleyan.*

18. New Experiments and Apparatus for the Elementary Physics Laboratory. V. E. EATON, *Wesleyan.*

19. Elementary Particles. K. K. DARROW, *Bell Telephone Laboratories.*

AUTHOR INDEX TO ABSTRACTS OF THE MIDDLETOWN MEETING OF THE NEW ENGLAND SECTION