PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE NEW YORK MEETING, DECEMBER 27, 28, 29 AND 31, 1928

The Thirtieth Annual Meeting (the 155th regular meeting) of the American Physical Society was held in New York City, Thursday, Friday, Saturday, and Monday, December 27, 28, 29 and 31, 1928. The presiding officers were Professor Karl T. Compton, President of the Society, and Professor Henry G. Gale, Vice-President. The average attendance was about 350.

The annual joint session with Section B was held on Friday afternoon at the American Museum of Natural History. The presiding officer was Professor P. W. Bridgman, Vice-President of Section B. The program consisted of an address by Dr. W. S. Adams of the Mount Wilson Observatory on "A Large Telescope and its Possibilities" and an address by Dr. W. J. Humphreys of the U. S. Weather Bureau on "Samples of Outdoor Physics."

The address of the Retiring Vice-President of Section B., Professor Arthur H. Compton, was delivered as the Sigma Xi address on Friday evening. Preceding the address there was a joint dinner of the Sigma Xi Society and the American Physical Society attended by 387 persons.

On Monday there was a joint session of the American Physical Society and the American Mathematical Society consisting of a Symposium on Quantum Mechanics, with an attendance of about 400. The principal addresses were by Professors J. C. Slater, J. H. Van Vleck, H. Weyl, and N. Wiener. In addition there were a number of short ten minute papers.

Annual Business Meeting. The regular annual business meeting of the American Physical Society was held on Saturday morning, December 29, at eleven o'clock. A canvass of the ballots for officers resulted in elections for the year 1929 as follows:

President:	Henry G. Gale
Vice-President:	W. F. G. Swann
Secretary:	W. L. Severinghaus
Treasurer:	George B. Pegram

Managing Editor of the Physical Review, Three-year term:
John T. Tate

Members of the Council, Four-year term:
Herbert E. Ives Alfred L. Loomis

Members of the Board of Editors of the Physical Review, Three-year term:
Edward U. Condon C. J. Davisson F. K. Richtmyer

The Secretary reported that during the year there had been 307 elections to membership. The deaths of 15 members had been reported during the year, 27 had resigned and 19 had been dropped. The membership of the Society on December 29, 1928 was as follows: Members, 1637; Fellows, 520; Honorary Members, 6; Total Membership, 2163. The numbers are approximate because they include elections and transfers at the November and December meetings. In the year there had been a net increase of 191 members, a net increase of 55 fellows and a decrease of 1 honorary member.

On motion the Society passed a resolution expressing its thanks to the retiring Secretary for his services during the past six years.

Meeting of the Council. At its meeting held on December 27, 1928 the Council adopted a minute expressing regret at the death of Professor Alfred Dodge Cole and recognition of his services as Secretary from 1913 to 1918.

The following resolutions were adopted:

1. That the Society authorize the publication of supplements to the Physical Review, these to contain resumés, discussions of topics of unusual interest and, in a broad sense, material that will give valuable aid to productive work in physics and yet that cannot appropriately be published in the Physical Review.

2. That the editor of these supplements be the Editor of the Physical Review and that there be an advisory editorial board to be appointed by the President upon the recommendation of the Editor.

3. That the Society assume the financial responsibility for the issuance of 300 pages in 1929 and for more pages if funds other than those of the Society can be secured for the purpose.

4. That the subscription to these supplements be separate from that of the Physical Review and be not included in the membership fee at present.

Professor Leonard B. Loeb was appointed Local Secretary for the Pacific Coast Section for 1929.

Four persons were elected to Fellowship, six persons were transferred from Membership to Fellowship, and fifty-two were elected to Membership. *Elected to Fellowship:* Alexander Goetz, Charles A. Kraus, Charles Sheard and Hermann Weyl. *Transferred from Membership to Fellowship:* H. E. Farnsworth, Ertle L. Harrington, Alfred L. Loomis, Morton Masius, W. J. Pietenpol and Oscar K. Rice. *Elected to Membership:* Gabrielle Asset, P. M. S. Blackett, Julian M. Blair, Emily H. Boggs, J. Lloyd Bohn, Ralph K. Bonell, E. Milton Boone, Francis H. Bowen, Louis F. Brown, Willoughby M. Cady, A. Dixon Callihan, G. Harvey Cameron, V. L. Chrisler, Robert B. Corey, C. L. Cottrell, W. Robert Couch, Richard B. Dow, Theodore Dunham, Jr., W. E. Gordon, Robert J. Havighurst, Harold Heins, Dorothy Heyworth, J. P. Jacobson, Merton W. Jones, Marie Kernaghan, L. Merle Kirkpatrick, Louis Malter, H. Artis Miley, Harry R. Mimno, Leo Nedelsky, D. E. Olshevsky, Harry F. Olson, Lars Onsager, Clarence J. Overbeck, R. V. Parsons, Dixon B. Penick, George E. Read, J. K. Roberts, Arthur L. Samuel, Louise A. Schwabe, Harold H. Scott, Gayle Shirey, Maynard P. Shoemaker, Howard P. Stabler, Wesley Stein, Doris Thomas, Richard Tousey, M. A. Tuve, Newton Underwood, Dorothy W. Weeks, Everett C. Westerfield, E. Russell Wightman.

The regular program of the American Physical Society consisted of 70 papers, Numbers 1, 10, 40, 42, 45, 52 and 70 being read by title. The abstracts of these papers are given in the following pages. An AUTHOR INDEX will be found at the end.

HAROLD W. WEBB, *Secretary*

ABSTRACTS

1. The surface tension of mercury in the presence of gases under varying pressures. S. G. COOK, Washington University. (Introduced by G. E. M. Jauncey.)—Quincke's method with Worthington's correction (Pogg. Ann. **139,** 1 and Phil. Mag. (5), **20,** 51 (1885)) was used. Contrary to the accepted values the maximum surface tension of mercury, (515 ± 7 dynes/cm at 31°C) is reached when only mercury vapor is present. A surface freshly created in a gas at 760 mm has a high initial tension approaching that when the surface is created in mercury vapor. The tension falls as the gas is adsorbed until an equilibrium value for a given pressure is attained. As the pressure is reduced the equilibrium value rises to a maximum which depends upon the nature of the gas. For instance, this maximum tension for mercury-hydrogen occurs at the critical pressure of 2.8 mm. If the pressure is lowered to stiction the tension remains unchanged so long as the mercury is not agitated beyond a certain amount. This maximum value for mercury-hydrogen is 442 dynes/cm which is less than the mercury-mercury vapor value of 515 dynes/cm. If the mercury- hydrogen is violently agitated when the pressure has been reduced to stiction the tension approaches 515 dynes/cm, the mercury-mercury vapor tension.

2. Internal friction in metals. R. H. CANFIELD, Naval Research Laboratory.—Further experiments using the author's method (Phys. Rev. **32,** 3, (1928)) have been made on copper and iron to determine the effect of grain-size, cold work, and other physical factors, on the coefficient of internal friction and other features of the dissipation curve.

3. Photographic observations of ballistic phenomena. L. THOMPSON AND N. RIFFOLT, Dahlgren, Va.—The subject records were obtained in a photographic study of the development of secondary explosion and the propagation of gases subsequent to ejection from large caliber guns; of the motion of a projectile during the penetration of armor; of bursting projectile in flight, by single exposure method; velocity data by trace on stationary film; measurement of long time intervals using an oscillographic modification of a high speed motion picture camera and series of electrically controlled high frequency indicators; application to the determination of velocity and time of fall, burst ranging data, and to the study of operations requiring precise evaluation of periods of considerable duration.

4. The effect of temperature treatment on the establishment of a stable condition of the electrodes in a polarization cell. E. E. ZIMMERMAN, Cornell University.—If measurements of the value of polarization capacity of a cell having freshly polished plain platinum or gold electrodes are made soon after the electrodes are inserted, it is found that successive measurements may give widely different values of capacity, especially in the case with platinum electrodes. It has been found that by a process of temperature treatment of the cell, in which the temperature is increased through a range from 0°C to 90 or 95° and then decreased through the same range, with probably one or two repetitions of the procedure, the electrodes are brought to a condition corresponding to minimum capacity. During the process of treatment, the polarization capacity decreases from 10 to 40 percent and the polarization resistance increases by a similar amount. Curves are given showing the manner in which the polarization capacity and resistance change during process of treatment. This method of reducing the electrodes to a stable condition is more effective and requires much less time than the method of leaving the electrodes shorted and in the solution for several hours.

5. A new theory of the rectifying action of the aluminum cell. W. B. PIETENPOL AND A. P. FRIESEN, University of Colorado.—The oxide layer-gas film theory has been largely accepted

for the valve action of the aluminum cell. (Guthe; Gunther-Schulze; Fitch; Meserve.) Previous investigators differ as to the relative importance of the oxide layer and the gas film formed on the aluminum anode in explaining the electrical characteristics of the cell. Much experimental evidence has convinced the authors that the oxide-gas film theory is not satisfactory and a modified theory is proposed. Aluminum when exposed to air has a thin oxide layer on its surface. In contact with an electrolyte like sodium bicarbonate a gelatinous hydrate is formed. The behavior of the cell is attributed to a double layer, aluminum oxide and aluminum hydroxide. The hydroxide layer acts as a semi-permeable membrane to certain ions. The accumulation of negative ions in this layer when aluminum is the anode accounts for the high resistance and the counter electromotive force observed. To this double layer likewise is attributed the capacity of the cell. The thickness of the gelatinous hydroxide layer depends upon the rate at which aluminum oxide is formed and the rate at which aluminum hydroxide goes into solution. With time of applied d.c. voltage ultimately an equilibrium condition is reached. On the present theory the oxide layer decreases in thickness with time of open circuit. The current-time relationship found by Meserve (Phys. Rev. **30**, 215, (1927)) is shown to be limited.

6. Equilibria in systems with surface phases. N. RASHEVSKY, Westinghouse El. & Mfg. Co., East Pittsburgh, Pa.—It is shown by thermodynamical considerations, that in a system which contains a monomolecular surface-phase at the boundary surface, and in which the surface energy is comparable to the volume energy, the free energy of the system depends not only on the total masses of the components and the volume, but also on the area of the boundary surface. For a given mass and volume of the system, there is a definite value of this area, for which the free energy has a minimum, and which corresponds to the stable equilibrium of the system. For this value of the area the capillary pressure vanishes, and thus a free liquid system, not subject to gravity, may acquire a non-spherical shape. The case is observed on myelinic formations. Furthermore, the modifications of the phase-rule, due to not neglecting the surface energy, are investigated.

7. Orientation of crystals in magnetic fields. DIMITRY E. OLSHEVSKY, University of Pittsburgh. (Introduced by A. G. Worthing.)—The statistical orientation of small crystals exposed to strong magnetic fields has been studied theoretically and experimentally. The problem of orientation of a single crystal suspended in a viscous liquid is treated first, including the influence of the Brownian movement. The statistical problem of orientation for a microcrystalline suspension is then studied on the basis of (a) elementary laws developed for a single crystalline particle, and (b) thermodynamical considerations. Lastly, the problem of a growing particle is treated and the probability function of orientation for a crystalline deposit at the bottom of a container is deduced. Both the three dimensional probability function and its orthogonal projection (observed from a distant point) are found. Quantitative experimental work has been carried out particularly with basic sulphate of iron and ammonium with field intensities of 13500 gausses. Distribution curves of orientation were obtained from 160 individual crystals. Two cases of orientation are found corresponding to the hexagonal bases of the prismatic crystals (1) approximately parallel to plane of deposit (2) approximately perpendicular to it. In the first case the distribution function has six major and six minor maxima, the former corresponding to first order crystallographic axes. The existence of discrete orientations for the elementary magnets is suggested. In the second case the distribution function has two maxima in agreement with theory.

8. Some electromechanical properties of Rochelle Salt crystals. W. G. CADY, Wesleyan University.—Up to the present time the values of the piezo-electric strain-constants δ of Rochelle salt have been known, but not those of the moduli ϵ. The writer has now computed the latter from Pockels' values of the strain-constants ($\Delta_{14}=10^{-5}$, $\delta_{25}=-165\times10^{-8}$, $\delta_{36}=35\times10^{-8}$) together with the elastic constants as recently determined by Mandell (Proc. Roy. Soc. A. **116**, 623, (1927)). The resulting values are $\epsilon_{14}=1.64\times10^{6}$, $\epsilon_{25}=-53{,}300$, $\epsilon_{36}=43{,}400$. From the δ's and ϵ's the extent to which the dielectric constant k is modified by the presence of piezo-electricity in the case of Rochelle salt has been computed, completely explaining the very large value of k found by Valasek (Phys. Rev. **19**, 478, (1922)). On the experimental

side, the natural vibration frequencies of many Rochelle salt plates variously oriented with respect to the crystal axes were measured. Fair agreement was found with the frequencies computed from Mandell's elastic constants. When plates having their edges parallel to the crystallographic axes are placed in an alternating electric field of suitable frequency, resonant vibrations are set up which are not of compressional type, but due to stationary systems of shear, or transverse, waves (waves of distortion).

9. Modulation of light waves by high frequency radio waves. A. BRAMLEY, Fellow, Bartol Research Foundation of the Franklin Institute.—The light from an iron arc was passed through a parallel plate Kerr cell containing water; the Kerr cell formed part of a high frequency generator which oscillated at from 3 to 10 meters wave-length depending on the capacity. The light, after passing through the cell was photographed with a quartz spectrograph. It was found that certain of the lines were displaced toward the red by .06A when the high frequency oscillator was operating. In the region examined in detail from 2480 to 2500A with a microphotometer, two lines showed the change in wave-length, the wave-length of the other 15 in this region being unchanged. The frequency shift was found to be independent of the amount of the oscillatory current in the circuit, and also independent of the temperature of the water in the range from 20° to 60°C which was investigated.

10. The recombination spectra of the halogens. H. C. UREY AND JOHN R. BATES, The Johns Hopkins University.—The emission spectra of flames of hydrogen and chlorine and of hydrogen and oxygen containing chlorine, bromine and iodine have been observed with the expectation of securing the continuous recombination spectrum when the following reactions take place: (a) $H+X\rightarrow HX$ or $H+X'\rightarrow HX$ and (b) $X+X'\rightarrow X_2$. The hydrogen chlorine flame emits a continuous spectrum extending to about 3200A with no evidence of structure. The flame containing H_2, O_2 and halogens emit the water bands, the continuous spectra and a faint near ultra-violet banded spectrum whose spacings varied with the halogen present. This band spectrum is believed to be due to some molecule of halogen and oxygen. The limits of the continuous spectrum for chlorine, bromine and iodine change to longer wave-lengths in the order given. The relative positions of the violet limits of these spectra can be qualitatively explained by the Franck-Condon theory applied to the reaction (b) above assuming that the temperatures of the flames are the same. These limits are such that they are emitted by two colliding atoms one in the $^2P_{3/2}$ and the other in the $^2P_{1/2}$ state having the sum of the relative kinetic energy and the energy of excitation of the one atom equal to about 14000 wave-numbers. Enough collisions of this class may be expected in the flames to account for the energy radiated. The possibility that the continuous spectrum is due wholly or in part to the reaction (a) cannot be excluded.

11. Directional distribution of the relative velocity of the decomposition products in the optical dissociation of sodium iodide. ALLAN C. G. MITCHELL, Bartol Research Foundation of the Franklin Institute.—Sodium iodide may be dissociated by ultra-violet light into an excited sodium and a normal iodine atom, the energy necessary corresponding to a wave-length of λ2450. When a wave-length shorter than λ2450 is used the excess energy goes into relative kinetic energy of the two atoms as they fly apart and the excited sodium atom emits *D*-lines with a corresponding Doppler broadening. The following experiment was designed to show whether the two atoms have any tendency to fly apart in the direction of the electric vector of the exciting light. A beam of light from a powerful Cd (λ2399–2144) or Zn(λ2139–2026) spark, respectively, was directed into a quartz tube containing NaI vapor. A photometer arrangement containing a sodium absorption cell served to measure the percentage absorption and hence the Doppler broadening of the *D*-lines. By making observations perpendicular and parallel to the beam of exciting light, the relative kinetic energy of the two atoms, and hence their tendency to fly apart in a given direction was measured. The percentage absorption of sodium light observed in either direction was the same. Hence, it was concluded that the atoms fly apart in either direction with equal probability.

12. The emission of positive ions from tungsten at high temperatures. LLOYD P. SMITH, Cornell University.—It has been found that a tungsten filament, after being flashed at a tem-

perature above 3000°K and operated at 2500°K for ten hours in order to remove impurities such as alkali metals, emits positive ions. The ion current is steady and is related to the temperature of the filament by the relation $-i_+ = AT^2e^{-b/T}$. It's magnitude at 2500°K is about 6.6×10^{-8} amperes per square cm of emitting surface. The mass of the ions could not be determined by using the principle of the Hull magnetron with a collecting cylinder 3.2 cm in diameter and an axial magnetic field of 5000 gauss, under a difference of potential of 20 volts between the filament and cylinder. This shows that the mass of the ion is greater than that of a potassium ion. Theoretical considerations indicate that the ions are produced in the tungsten and may be tungsten ions. The ion current at a given temperature remains unchanged when an inactive gas such as argon is admitted to the tube provided its density does not become great enough to appreciably cool the filament.

13. Arcs with small cathode current density. J. SLEPIAN AND E. J. HAVERSTICK, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.—A theory of the cathode of an arc based on the drawing of electrons from a thermionically inactive electrode by very intense electric fields has been proposed. This field is maintained by space charge of positive ions next to the cathode, and it may be shown that this requires a current density of more than 1000 amps/cm² even at low gas pressures. Experiments have been carried out demonstrating the existence of arcs with current densities of less than 100 amps/cm² so that the above theory seems untenable in the case of these arcs.

14. Striking potential of aluminum arc. S. HERBERT ANDERSON AND WILLIAM BLEAKNEY, University of Washington.—In a report made at the Los Angeles meeting, May 1927, it was pointed out that Simeon's theory of the striking potential of metallic arcs (Phil. Mag. **46**, 816, (1923)) was not substantiated. Further investigation with aluminum electrodes in atmospheres of hydrogen, nitrogen, oxygen and air indicates that: (1) a gaseous atmosphere is necessary for the striking of the arc; (2) the striking potential depends upon the nature of the surrounding gas and its pressure, as well as the nature of the electrodes.

15. Probe and radiation measurements in the normal copper arc. W. B. NOTTINGHAM, Bartol Research Foundation.—The Langmuir probe has been used to measure the electron temperature, the space potential, and the positive ion concentration in the stream of the copper arc. With an increase in the arc current from 2.5 to 6.0 amp., the electron temperature decreased from 19,000°K (2.45 volts) to 15,500°K (2.0 volts). The electrons gain energy from the field and make elastic collisions until they have sufficient energy to excite the atoms. Thus the average velocity is probably controlled by the electron transition in the copper atom from the metastable "D" level to the 2^2P level involving energies of 2.14 and 2.4 volts. For arc currents from 2.5 to 6.0 amp., the positive ion concentration increases according to the equation $n_+ = a\epsilon^{bI}$, where I = arc current and a and b are constants. The intensity of the resonance radiation λ3274 and λ3248 emanating from the arc stream half way between the electrodes is related to the current by $l = c\epsilon^{2bI}$ where l = light per unit volume. These equations give $l = (c/a^2)n_+^2$. Since the electron and the positive ion concentrations are equal in the arc stream, this relationship shows that the major part of this radiation is due to some cumulative action.

16. The time lags of spark gaps in air at various pressures. J. W. BEAMS AND J. C. STREET. University of Virginia.—Using a method described by one of us (Beams, Jour. Franklin Institute: in press) the time between the application of the over-voltage and the spark discharge, that is, the so called "time lag" of the spark in air at various pressures has been measured. This time lag was found not to be a definite magnitude but to vary with the number and distribution of the ions in the gap at the time of application of the voltage. When ions were blown into the gap or generated there by radioactive material the lags were shortened. On the other hand, when the air was dry and free from ions, the lags were very much lengthened. If the pressure is raised or the voltage applied to the gap lowered, the lags were increased. The fields used always exceeded 50,000 volts per cm at some point in the gap and were applied by as steep wave fronts as could be obtained. Under certain conditions in moist air at atmospheric pressure the lags could be made as short as 10^{-8} sec.

17. The distribution of ionic mobilities in moist air. JOHN ZELENY, Yale University.—The preliminary work previously reported (Phys. Rev. **31,** 1114, (1928)) has been completed for air having a water content between 1.5 mg and 7.6 mg per liter. A modified procedure permits an evaluation of the effects of diffusion and mutual repulsion of the ions. When corrected the results still show a band of distribution of mobilities which for the positive ions extends about 40 percent and for the negative ions about 30 percent of the lowest value. The corrected mobilities for the centers of the bands, at atmospheric pressure and at 20°C, for the negative ions and the positive ions respectively are $2.00 \pm .02$ cm/sec. · volt/cm and $1.22 \pm .02$cm/sec. · volt/cm.

18. Shot effect of secondary electrons. LUCY J. HAYNER AND A. W. HULL, General Electric Company.—The shot-effect of secondary electrons from plates of triode tubes was measured with a tune-circuit amplifier at 10^6 cycles, introducing calibrating voltages into the tuned input circuit. Calculations of the electronic charge from shot-effects of temperature-limited primary currents, to check the method, agreed within 1 percent with Millikan's value. Measurements were made on five tubes having different secondary emissivities. The average number of secondaries per primary electron, ω, ranged from 1 to 4.5. In every case the shot-effects of both grid and plate currents were measured and found greater than those of equal primary currents. This was expected since there are random fluctuations of ω superposed on the fluctuations of the primary current. For large ω, shot-effects several times larger than those of equal primary currents were observed, due to the fluctuations of ω. Applying Campbell's general expressions for shot-effects of secondary emission, it is concluded from the observed differences between the plate and grid shot-effects that secondary emission is simultaneous with primary impact within 10^{-5} sec. Since results of Hull and Williams indicate at least partial independence of these two events at 10^6 cycles, this investigation will be extended to higher frequencies.

19. Maximum excursion of the photoelectric long wave limit of the alkali metals. HERBERT E. IVES AND A. R. OLPIN, Bell Telephone Laboratories, Inc.—Earlier experiments have shown that the long wave limit of photoelectric action in the case of thin films of the alkali metals varies with the thickness of the film. A maximum value is attained greater than that for the metal in bulk, which for the majority of the alkali metals lies in the infra-red. The wave-length of the maximum excursion of the long wave-limit has been studied for Na, K, Rb and Cs. *In each case it is found to coincide with the first line of the principal series, i.e. the resonance potential.* It is suggested that photoelectric emission is caused when sufficient energy is given to the atom, to produce its first stage of excitation. The identity of photoelectric and thermionic work functions suggests that atomic excitation is the initial process in thermionic emission as well.

20. A photo-e.m.f. in single crystals of selenium. R. M. HOLMES AND N. L. WALBRIDGE, University of Vermont.—The photo-e.m.f. reported (Phys. Rev. **31,** 1126, (1928)) for acicular crystals is now found in greater magnitude with thin lamellar single crystals. A translucent platinum film is sputtered on each of the two parallel faces of the crystal. The films are connected to a galvanometer. When the radiation from a tungsten lamp, using a water cell, passes through one film, electrons flow from selenium to platinum at the illuminated contact. By simultaneous illumination of both sides or by the introduction into the galvanometer circuit of an opposing p.d. this photo-current may be reduced to zero. The relation between this balancing p.d. and light intensity and the relation between photo-current and light intensity have been investigated. The balancing p.d. increases rapidly with illumination and finally reaches a nearly constant value sometimes as high as 130 millivolts for 0.4 lumen/cm^2. The photo-current continues to increase with illumination, becoming as high as 5.5 microamperes for 4 lumens/cm^2. Preliminary investigation with an equal energy spectrum shows a maximum with green and a slight reversal with red light. A decrease in the photoelectric work function by altered image attractions may explain the photo-e.m.f. and current. The effect is not thermoelectric.

21. Fatigue in the cathodo-luminescence of zirconia. D. T. WILBER, Cornell University.—The luminescence of zirconia, produced by the discharge from a cold cathode was found to reach a maximum and decrease sharply while the vacuum, voltage and current in the tube increased together. (Phys. Rev., **17**, 713, (1921)). By using a hot cathode and varying the vacuum, voltage and current independently, it is found that the maximum does not depend on vacuum but upon the power delivered on the zirconia and the consequent heating as measured by a thermo-couple. The previously observed maximum may also be associated with the decrease in thermal conductivity of air at low pressures. All bright luminescence results in a temporary decrease in luminescent power due to heating and a permanent fatigue due to reduction and blackening of the oxide. Standing in air restores the luminescence lost by deoxidation. A brief luminescence of extreme brilliancy is obtained from a thin coating of zirconia on a copper rod which is cooled by liquid air, when the zirconia is bombarded with 30 m.a. at over 10 kv. This intense luminescence is scarcely less brilliant than the incandescence which follows it at once.

22. Persistence of λ2537 in mercury at low pressures. HELEN A. MESSENGER AND HAROLD W. WEBB, Columbia University.—The persistence of λ2537 was measured for mercury vapor pressures corresponding to the temperature range 78° to −19°C. The radiation was excited by electron impact and detected by a nickel photoelectric plate in a modified Lenard tube. A quartz window prevented metastable atoms from reaching the plate. The alternating potential method previously described (Phys. Rev. **21**, 479, (1923)) was used to measure the persistence. The persistence expressed as the time constant of a simple exponential decay varied from 4×10^{-5} sec. at 78° to 10^{-7} sec. at −19°C. In the temperature range between 78° and 17° the time constant varied as the first power of the pressure and not as the square of the pressure as predicted by the simple theory of diffusion of radiation. The values of the time constant were, however, so small that it still seems necessary to explain the persistence as due to a series of absorptions and reemissions, with possibly a wave-length change at each step. The life of λ1849 was found to be less than 3×10^{-9} seconds. Two other radiation processes were observed, one having a life of 2×10^{-6} seconds, excited at 7.1 volts, and the other a life of about 8×10^{-5} seconds, excited between 5 and 6 volts.

23. Sound radiation from a system of vibrating circular diaphragms. IRVING WOLFF AND LOUIS MALTER, Radio Corp. of America.—Using the expression for the velocity potential due to a point source radiating into a semi-infinite medium Lord Rayleigh has determined the sound radiation from a vibrating circular diaphragm in an infinite wall. Following the same method, the radiation due to any shaped diaphragm or combinations of diaphragms can be determined. Curves are given for circular diaphragms showing the distribution of pressure over the surface bounding the semi-infinite medium. These curves enable the determination of the radiation from any combination of vibrating circular diaphragms placed in the surface. Calculations have been carried out for a number of special cases. At low frequencies the diaphragms react upon each other to increase the efficiency of radiation. This effect vanishes at high frequencies. The mutual aid of the diaphragms decreases very rapidly as the distance between the diaphragms is decreased. In certain cases the combination may result in decreased efficiency over particular frequency ranges. These results are all explainable on the basis of phase differences between the motion of a diaphragm and the pressure over the surface of another diaphragm due to the motion of the first.

24. Sound propagation. D. G. BOURGIN, Department of Mathematics, University of Illinois.—A theory of the propagation of sound has been developed based on the balancing of internal and kinetic energies by collisions of the first and second kinds. Radiation effects are included without change in the formulas but it appears that, except for high temperatures or low densities their rôle is negligible. The asymptotic expansions at high frequencies contain only parameters involved in the long wave-length formulas. The extension of the theory to gas mixtures marks, it is believed, the first attempt to treat sound kinetics in mixtures. The low frequency velocity is given by the quotient of a cubic by a bi-quadratic and the absorption term by the ratio of a bi-quadratic to a septic polynomial in the concentrations. The formu-

las simplify when it may be assumed that, approximately, the effect of foreign molecules in promoting transfers is the same as that of molecules of the same gas (cf. a preliminary abstract in Nature). Only if, besides this, the gases have the same number of degrees of freedom and comparable molecular weights does the theory support Abello's interesting empirical suggestion of linearity of dependence of the difference in absorption coefficients on concentration.

25. Conditions for securing ideal acoustics in auditoriums. F. R. WATSON, University of Illinois.—A study of recent investigations in auditorium acoustics indicates (Acoustics of Auditoriums, Science, March 30, 1928. Ideal Auditorium Acoustics, Journ. Am. Inst. Architects, July 1, 1928.) that ideal acoustics can be obtained by two procedures. First, to surround the speaker or musician with suitably arranged reflecting surfaces so that he can "hear himself" and then adjust his performance to secure the best generation of sound; and second, to adjust the auditorium so as to approximate the reverberation conditions of an outdoor theater, which is generally regarded as "perfect" for hearing. Reflected sounds reaching the auditors within 0.05 second after the direct sound are beneficial in reenforcing words, (Petzold, Elementare Raum Akustik.) but sounds coming later than 0.05 second produce a blurring and should be absorbed at the reflecting surface. It can be shown that reflected sound is not as important in securing loudness as heretofore supposed. Experimental evidence supports the preceding theory and points the way for securing ideal acoustics.

26. Comets and terrestrial magnetic storms. H. B. MARIS AND E. O. HULBURT, Naval Research Laboratory.—Practically all observed details of terrestrial magnetic storms have recently been shown to be explainable by the assumption that the solar disturbance is a half-hour ultra-violet flash, such as would come from a spot at 30000°K and 1/10000 of the solar disk in size. Such a flash would be expected to cause changes in comets much as it does in our own atmosphere, and we find that this is so. For, in nearly every instance the date on which a comet was observed to undergo an unusual change, such as breaking up of the nucleus, loss of tail, sudden increase in brightness, etc., was found to follow within a week the date on which a strong magnetic storm occurred on the earth, provided the necessary condition was fulfilled that the earth and the comet were approximately on the same side of the sun. When the comet and the earth were on opposite sides of the sun, changes in the comet were found to occur between periods of terrestrial magnetic storms separated by a solar rotation. Further, the action of the ultra-violet light of the quiet (undisturbed) sun on the nucleus is shown to account for some hitherto unexplained characteristics of the tail.

27. Weather forecasting by the intensity of radio signals. R. C. COLWELL, West Virginia University.—Observations made at Morgantown, West Virginia upon the signal intensity of station KDKA at Pittsburgh, Pa. have shown that the intensity of the signal after sunset is very variable. The variations are shown graphically upon the paper strips of a Shaw Recorder. Curves taken at various times over a period of two years indicate that increasing intensity after nightfall foreshadows cloudiness or rain for the following day; while decreasing intensity is a sign of clearing weather the next day. The results obtained from the fading curves are compared with the usual prognostications for several weeks of the past autumn.

28. The sun's radial magnetic gradient and atmosphere. ROSS GUNN, Naval Research Laboratory.—*Theory of the rapid radial magnetic gradient of the sun based on diamagnetic effect of ions in the reversing layer.* A theory of the sun's radial magnetic gradient has been worked out which explains quantitatively the phenomena in terms of the diamagnetic effect produced by ions spiralling about the impressed magnetic field. The free paths, temperature, ionization and magnetic field are precisely those most effective in producing a large diamagnetic effect. This diamagnetism explains adequately the extraordinarily large observed gradient and an extrapolation of the effect into the lower layers where the diamagnetic effect drops to low values indicates that the polar field strength at the surface of the sun may be several times the present accepted value. *Ionic densities have been obtained as a function of the altitude above the photosphere.* The ionic densities derived from the diamagnetic relations agree with densities inferred from other unrelated sources. The effective atomic mean weight of the particles in the sun's atmosphere is found to be approximately 3.3.

29. Resistance of bismuth in alternating magnetic fields. WILLIAM W. MACALPINE, Columbia University.—An oscillator was constructed with a 50 watt tube producing fields up to 50 gauss r.m.s. at 10^6 cycles in a coil 3/4″ diameter by 2″ long to modulate a constant field. Bismuth wire was wound bifilarly on a bakelite tube placed inside the solenoid and both immersed in liquid air. A single turn of copper wire around the tube served to measure the field strength and phase. Direct current was passed through the bismuth wire, and being held constant by a radio frequency choke, an alternating voltage appeared across its terminals proportional to and in phase with its resistance. To measure this voltage in phase and magnitude a double potentiometer was constructed. The change in resistance of the bismuth wire was found to be in phase with the field and equal in magnitude to that which was calculated from d.c. measurements of resistance against field strength. The overall precision was about 5 percent. Similar work had been done at 50,000 cycles and room temperature when the effect was also found to be normal. Fields up to 700 gauss r.m.s. between dust core poles were obtained at the latter frequency.

30. The specific resistance of beryllium. EVAN J. LEWIS, Cornell University.—A rod of metal obtained from the Beryllium Company of America was used to determine the specific resistance of Beryllium from the temperature of liquid air to 700°C. The experiment was performed by the "fall of potential" method. At first a decided lowering of the resistance was observed while the temperature remained constant or nearly so. After a prolonged heat treatment, however, the resistance of the speciman reached a final, steady state and results were reproduced in successive trials. The value found was about 6.8 microhm-centimeters at 20°C.

31. Double-valued characteristics of a resistance-coupled feed-back amplifying circuit. PRESTON B. CARWILE, Lehigh University.—A Hartley resistance-coupled feed-back amplifying circuit may be connected in such a way that under ideal conditions the feed-back control does not affect the non-feed-back amplification factor. The total amplification is then a simple function of two independent variables. When the feed-back action goes beyond a certain critical value two non-reversible discontinuities appear in the characteristic curve between output and input voltage. Between these points of discontinuity the characteristic has two branches, representing two possible values of output voltage for each single input value. A simple explanation accounts for the two discontinuities, their non-reversibility, and the double valued characteristic.

32. High amplification by making use of grid currents. PETER J. MULDER AND JOSEPH RAZEK, University of Pennsylvania.—The mutual conductance of a vacuum tube was found apparently to change on the insertion of a high resistance into the grid circuit. With a well insulated grid, the apparent change varied in a definite manner with the value of the grid resistance inserted. Assuming $E_g=E_c-Ri_g=E_c-Rki_p$; $\partial i_p/\partial E_c=G^1=G/(1+RkG)$ where G is the mutual conductance, R is the external grid resistance, k is the ratio of the grid current to the plate current, and E_c is the biasing voltage. For a 312A tube, with negative grid potentials of 2.5 volts or more, k is negative and constant. When operating in this range, and using a suitable value of R, the apparent value of G can be made very large. For amplification of photoelectric or other small currents, we obtain $\partial i_p/\partial i_x=GR/[(1+JR_1)(1+R/r)+RkG$ where i_x is the photoelectric current, r is the grid-to-ground resistance, J is the plate conductance, and R_1 is the external plate resistance. Using a photoelectric cell connected to the grid of a 312A tube, and giving to this grid a negative bias through a suitable resistance, we have obtained an amplification of 16 million. The photoelectric current was measured on a sensitive galvanometer (2×10^{-11} amp/mm) and the corresponding tube plate current change was measured on a milliammeter.

33. Photoelectric spectro-photometer. JOSEPH RAZEK AND PETER J. MULDER. University of Pennsylvania.—A photoelectric spectro-photometer consisting of an optical system, a photoelectric cell, and vacuum tube amplifier has been built. The amplifier comprised two vacuum tubes placed into the arms of a bridge. The sensitivity of this circuit was found to be

$\partial I_G/\partial E_g = G/[2+R_G(J+1/R_1)]$ where J and G are respectively, the plate, and the mutual conductance of the tubes, R_1 is the external plate resistance, and R_G is the galvanometer resistance. It was subsequently found that the same circuit has already been described by Wynn-Williams (Proc. Cam. Phil. Soc. **23**, 810, (1927)) who gives a similar sensitivity expression. We have obtained a sensitivity of 500,000 mm/volt with good stability. The addition of grid resistors of proper magnitude will increase the sensitivity. The computed and measured values of the amplification agree to 1 percent, which is the accuracy to which the quantities involved were measured. The light to be examined is passed through a spectrometer into the photoelectric cell. The cell is connected to one grid in the bridge circuit. The deflection of the galvanometer is a function of the light intensity. Spectral curves of light from an arc and of light diffusely reflected from opaque objects were obtained. A portable self-recording instrument embodying these ideas is in course of construction. It is believed that this device will prove simpler than others recently suggested for the same purpose.

34. Perturbations in band spectra. JENNY E. ROSENTHAL AND F. A. JENKINS, New York University.—Curves for the deviations of the lines at the perturbations in the states $n'=12$ and $n''=11$ of the violet CN system have been completed. They show additional examples of the resonance form previously reported. (Phys. Rev. **31**, 539 (1928)). The wave mechanics treatment of perturbations given by Kronig (Zeits. f. Physik **50**, 347(1928)) interprets them as due to the coincidence of terms of equal j in two different electronic states. The level $n=11$ in the lower ^2S state of the violet CN bands lies close to that of $n=4$ in the ^2P initial state of the red bands. An investigation of the structure of the (4, 2) band of the latter system (from a plate kindly furnished by Roots and Mulliken) shows a perturbation similar to the above in the $^2P_{3/2}\rightarrow{}^2S$ sub-band. As expected, its maximum occurs at the same rotational quantum number ($j=13$) as that for the corresponding perturbation in the ^2S state. Other features in agreement with the theory are (1) the deviation of the terms are in the opposite sense from those in the ^2S perturbation, (2) only one of the components (symmetric or anti-symmetric) of the σ-doublets is affected. The $^2P_{1/2}$ levels of $n=4$ are also perturbed at a higher value of j.

35. Detection of the Isotopes of lead by means of their oxide band spectra. SIDNEY BLOOMENTHAL (Introduced by R. S. Mulliken) University of Chicago.—The band spectra from an ordinary lead arc and from one containing lead of atomic weight 206 (uranium lead) have been photographed in the second order of a 21-ft. Rowland grating. A similar comparison has been made by Grebe and Konen (Phys. Zeit. **22**, 546(1921)) who found that the band lines from uranium lead near 4250A were sharper than those of ordinary lead, and displaced 0.055A towards shorter wave-lengths. The differences noted here agree with those predicted by the theory of the isotope effect in band spectra with PbO as the emitter if ordinary lead contains as principal istopes atomic weights 208, 206, 207 with the relative abundance in this order. For instance each strong line near the head of the λ5678.5 band obtained from Pb206 corresponds to the long wave component of a group of three equally spaced lines in the spectrum of ordinary lead the weak central member (Pb207) of which is separated from the two outer components (Pb208 and Pb206) by 0.125A. These results agree with Aston's positive-ray analysis of ordinary lead.

36. Formation of MH molecules; effects of H atom on M atom. ROBERT S. MULLIKEN, University of Chicago.—Observed electronic states of diatomic hydride molecules (CH, NH, OH, MgH, CaH, ZnH, CdH, HgH, etc.) are derivable from unexcited H plus familiar low-energy states of M atoms (Hund, Hulthén, Mecke, Mulliken). Observed states and especially observed $\Delta\nu$ intervals in ^2P or ^3P states of such MH molecules indicate that the effects of the H on the M atom are confined essentially to the following; (1) the couplings (if any) between l_τ vectors of M atom outer electrons to give a resultant l are completely broken down by the field of the H nucleus; the M atom orbits are otherwise scarcely changed, except for slight shielding or similar effects produced by the H electron and nucleus; the usual l_τ selection rules are, however, abolished; (2) the uncoupled vectors l_τ are separately space-quantized with reference to the electric axis, giving component quantum numbers σ_{l_τ}; (3) the electron of the H atom ($\sigma_{l_\tau}=0$) takes its place with the M electrons, sometimes becoming equivalent to one

of them giving a new closed shell (of two electrons); (4) the original couplings of s_r vectors are often broken down; always, the spin of the H electron alters the original multiplicity by one unit.

37. Computation of properties of certain excited states of H_2. E. C. KEMBLE AND C. ZENER, Harvard University.—A first order perturbation theory computation of the potential energy curves for the two-quantum P-type states of interacting pairs of H atoms (Cf. E. C. Kemble, Phys. Rev. **31**, 1131, (1928)) shows that two of these states have the potential energy minima requisite for molecular formation. One is a singlet state to be identified with the upper energy level of the Werner bands while the other is a triplet state which may be identified with the 2^3P state reported by Richardson (Proc. Roy. Soc. A, **114**, 643, (1927)). The agreement of the computed curves and the empirical data is fair. The theoretical confirmation of the existence of a 2^3P state shows that London's valence theory needs modification when applied to the excited states of symmetric diatomic molecules where the wave functions are multiply degenerate at infinite internuclear distances. A similar calculation for the remaining (S-type) two-quantum states of the H_2 molecule is in progress.

38. The spectra of trebly ionized vanadium, V IV and quadruply ionized chromium, Cr V. H. E. WHITE, Cornell University.—The neutral atoms of vanadium and chromium contain five valence electrons, $3d^3\ 4s^2$, and six valence electrons $3d^5\ 4s$, respectively. The removal of three electrons $3d\ 4s^2$ from vanadium and four electrons $3d^3\ 4s$ from chromium yields two isoelectronic systems, V IV and Cr V, the lowest energy levels of which are represented by the two remaining electrons $3d^2$. The spectra from these two systems should resemble very closely the spectra of neutral calcium, singly ionized scandium and doubly ionized titanium. Extrapolations from the already known data of Ca I, Sc II, and Ti III, to V IV and Cr V have led to the identification of some thirty energy levels in both triply ionized vanadium and quadruply ionized chromium. The strongest lines in these spectra arise from combinations between ^3P, $^3D'$, ^3F, ^1P, $^1D'$, ^1F ($3d4p$) and ^3D, ^1D ($3d4s$), and ^1S, $^3P'$, ^1D, $^3F'$, ^1G $(3d)^2$. The latter configuration gives the lowest levels in the spectrum. The Moseley diagram and the irregular doublet law served admirably in determining the approximate positions of the various singlet and triplet levels as well as the approximate location in the spectrum of the radiated frequencies. The ionization potentials, that is the voltage necessary to remove one $3d$ electron from the normal state $^3F_2$ $(3d)^2$ of V IV and Cr V, to the normal state $^2D_2$ $(3d)$ of the once more ionized atoms are determined at about 48.2 volts and 72.4 volts respectively.

39. The hyper-fine structure of singly ionized praseodymium. R. C. GIBBS AND H. E. WHITE, Cornell University.—Recently King at the Mt. Wilson Observatory in photographing the furnace, the arc, and the spark spectra of the rare earth group of elements found that a great many of the praseodymium spark lines, Pr II, show what may be called hyper-fine structure. Using the large solar spectrograph on Mt. Wilson, dispersion 1.5A per centimeter, one of the authors photographed some of the more prominent hyper-fine groups within the region 3900–5000 Angstroms. All of the completely resolved hyper-fine structures reveal six components. The frequency intervals between the hyper-fine structure for any one set of six lines follow very closely the Landé interval rule and the relative intensities of the lines in each group decrease with the interval. Some of these groups of lines show decreasing intervals and intensities toward longer wave-lengths while others are similarly degraded toward shorter wave-lengths. For example, one group at about λ4756 degrades toward the violet with outside components separated by 0.33A, while another group at about λ4747 degrades toward the red with outer components separated by 0.22A. A theoretical interpretation requires the introduction of quantum conditions in addition to those necessary for ordinary line spectra. At present it is suggested that the new quantum conditions may be associated with either a spinning nucleus or with a $4f$ electron. Before attempting to interpret these observations further, Zeeman patterns of these hyper-fine structures will be studied.

40. An exception of Pauli's g-sum rule. J. B. GREEN, Ohio State University, and R. A. LORING, Northwestern University.—According to Pauli's g-sum rule, the sum of the splitting-

factors of all terms of the same inner quantum number of any configuration of electrons, is the same as the sum gotten from the use of the Landé g-formula, even though the single value for the different terms are not those calculated from the formula. This rule has been found valid in most spectra investigated, well within the limits of experimental error. In the lowest configuration of Sb, s^2p^3, Hund's theory gives $^4S_2$, $^2D_{23}$, $^2P_{12}$, as the possible levels. Of these, $^2P_1$, is the only one with inner quantum number $\frac{1}{2}$, and should, therefore, according to the above rule, have the theoretical g-value, namely. The line selected to test this is the combination $^2P_1{}^2P_2$, 3029.824. The line gave a Zeeman pattern, $\overline{0.268}$ 1.019 $\overline{1.544}$, as a mean of three sets of plates taken with the Paschen-Runge mounting at the Jefferson Physical Laboratory. The plates were measured in the second and third orders, dispersions of 0.97 and 0.65A/ mm respectively and checked by microphotometer measurements. The g-values determined from the measurements are 0.740 and 1.276, while the value 1.285 was found for one of the terms from independent measurements on another line. The theoretical value for $^2P_1$ is 0.667. This leaves a discrepancy of over 11 percent to be accounted for. The experimental error was certainly under 3 percent.

41. The use of series inductance in vacuum spark spectra. ALICE M. VIEWEG, C. W. GARTLEIN AND R. C. GIBBS, Cornell University.—In attempting to extend the identification of lines in the Cd I sequence as partially reported by us for Sb IV and Te V at the Pomona meeting last June, it became necessary to have another criterion, in addition to the ordinary methods of identification, in order to distinguish the lines emitted by an atom in its various stages of ionization. Some lines that satisfied many criteria had been already reported as belonging to other stages of ionization. Somewhat as in the case of ordinary sparks in air inductance in series with a vacuum spark, utilized to some extent by Fowler, has served to strengthen lines arising from lower states of ionization and to weaken lines coming from atoms that are highly ionized. By making several exposures on the same plate, it has been possible in some cases to sort out, from the relative quality of the lines, radiation coming from five different stages of ionization. While some detail is lost by reproduction and enlargement many of these differences are readily recognized in a lantern slide projection. Thus it nas been found possible by these added criteria to identify lines belonging to the various multiplets with much greater certainty.

42. Regularity in frequency shifts of scattered light. W. F. MEGGERS AND R. M. LANGER National Research Fellow, Bureau of Standards.—Published data on combination scattering seem to show a capriciousness as to which lines of the source are capable of exciting the modified lines, and as to which modified lines a particular line of the source will excite. There are also much greater variations in frequency shift than the precision of measurement estimated. These irregularities are not real. For example, in benzol, in the spectral region used (3000–6600A) all the stronger lines namely 3126, 3132, 3341, 3650, 3654, 3663, 4047, and 4358 give rise to all the stronger shifted lines (i.e., shifts of 606, 848, 992, 1178, 1584, 3059 wave numbers). In some cases the shifted line falls on an Hg line and is not observed. There are about 50 lines observed in this region. In CCl_4 and $CHCl_3$ there are even more. Shorter wave-lengths are not useful because of absorptional chemical action. The relative intensity and character of different modified lines due to a given exciting line are about the same no matter which exciting line is taken. The relative intensity of a given frequency shift usually increases slowly as the exciting frequency increases. More accurate measurements of frequency shifts (using 21-ft. grating) show them to be independent of the exciting line within one wave number. This work will be published in the Bureau of Standards Journal of Research.

43. Mercury spectrum by high voltage electrodeless discharge. OTTO STUHLMAN, JR. AND M. W. TRAWICK, University of North Carolina.—Spectra of the electrodeless discharge through a capillary and of the ring discharge in a 12 cm spherical bulb were compared with the spectrum from a quartz mercury vapour lamp. Spectrograms of the ring and capillary discharge were made at 25°C and 5 microns pressure; frequency of damped oscillations 1.5×10^8; capacity .0016 mf; sparking voltage 18×10^3; intensity controlled by spark gap. The spectrum of the discharge through a capillary is identical with that of the luminous ring discharge in the bulb.

Spark and arc lines are about equal in number. No continuous spectra were observed under above conditions. In $1s-mp_1$ frequencies up to $m=17$ were classified. Twelve faint lines beyond this frequency are as yet unclassified.

44. Excitation of sodium by ionized mercury. HAROLD W. WEBB AND S. C. WANG, Columbia University.—Rayleigh has shown that metallic vapors are excited by ionized vapors distilled from arcs of other vapors. (Proc. Roy. Soc. A **112,** 14, (1926)). We have studied the excitation of sodium by mercury vapor distilling from an arc, mixing the vapors at a great distance from the main arc to avoid direct excitation by electrons. By an auxiliary electrode directly excited 2^3P mercury atoms were introduced into the stream of ionized mercury vapor, in order to differentiate between the effects due to excited atoms and those due to ions. The excitation by ions may be explained as due in part to the ionization of the sodium but also in large part to the production of excited mercury atoms by the recombination of mercury ions and the subsequent excitation of the sodium. There is, however, strong evidence that the process involves a three-body impact between a mercury ion, a normal sodium atom and an electron. This is suggested by the nature of the sodium spectrum and by the marked enhancement of the mercury lines originating at the 3^3S and 3^1S levels produced by the introduction of sodium vapor into the ionized mercury. There was no indication of direct electron excitation in this apparatus, although Rayleigh's results indicate that this type of excitation may have been important in his apparatus.

45. The Weiss, Planck and Rydberg constants in the theory of the electromagnetic quantum. CORNELIO L. SAGUI, Castelnuovo, Dei Sabbioni, Arezzo, Italy.—To a neutral proton an electron is added. Its electromagnetic undulatory energy would flow into the proton as a circular current directed downward, of which the work on a unitary pole would be $2r\times1.6\times10^{-20}$. The energy corresponding to this work would be distributed among the 60 levels of the proton; therefore $\mu=2r\times1.6\times10^{-20}/60=1.7\times10^{-21}$, Gauss·Cm is its value appearing at the surface level of the proton as a magnetic moment, the Weiss constant. A radiation must be referred now to $\frac{1}{2}\mu^{1/3}$ since μ is the volumetric energy distributed on both sides of a level, and an oscillating electron would have only one degree of freedom along one dimension only of the euclidean space. It was found that the voltage $V=r\mu^{1/3}$ for one oscillation only. It was also found that $e(r\mu^{1/3})=h=1.6\times10^{-20}\times3.14(1.85\times10^{-21})^{1/3}=6.18\times10^{-22}$, the Planck constant. Since the proton is supposed to be made up of 1830 electrons distributed among 60 levels, each electron in each level contributes the energy h and the whole energy of a proton would then be $60\times1830\ h=109800h$, where 109800 is the Rydberg constant in waves/cm. The results check each other fairly well.

46. Radiation and the electron. R. D. KLEEMAN, Schenectady, New York.—The author in his investigations on the zero of internal energy and entropy was led to deduce thermodynamically that the electron possesses the following properties:—1. It may possess internal energy apart from kinetic energy. 2. The whole, or a part, of its internal energy may be converted into electromagnetic radiation, apart from emitting radiation on undergoing acceleration. 3. It may absorb radiation in indefinite amounts and convert in part into internal energy. 4. If in motion, the absorption of temperature radiation tends to decrease its kinetic energy and increase its internal energy, in a degree depending on its internal energy. 5. The electric force acting upon it when in a field depends on its internal energy. An alternate proof of these properties may be obtained by making use, besides, of some of the fundamental notions in kinetic theory and electromagnetic radiation. By means of the foregoing properties and the principles of conservation of momentum and kinetic energy, and making use of the fact that radiation takes place in quanta, the various phenomena involving the interaction of radiation and the electron may readily be explained.

47. Proposed interpretation of the fundamental quantum law. BENJAMIN LIEBOWITZ, 415 Fort Washington Ave., New York City.—If we regard $V=h\nu/e$ as an empirical relation between *voltage* and frequency *without reference to quanta*, suggestive interpretations present themselves. (1) The idea of a frequency proportional to a difference of potential, or energy,

or frequency follows immediately. (2) The fact that the voltage is propagated without change implies the concept of "wave-voltage" and suggests a close analogy to waves on wires. (3) From this view-point a light wave may be regarded roughly as consisting of a "core" of approximately longitudinal electric components surrounded by substantially transverse electric and magnetic fields analogous to the forces in and around a current-carrying filament. An expression for the maximum longitudinal force is derived: $E_s = 2\pi h\nu^2/ec$. Assuming this force to act on a free electron, values are obtained for the wave-length and amplitude of the resulting scattered radiation by means of both ordinary and relativity mechanics. The shifts exceed Compton's value 0.0243A by 5 percent at 1A and 37 percent at 0.2A. As developed thus far the theory gives only the *maximum* shift and indicates that the modified line should have a sharp long wave-length limit analogous to the maximum velocity limit of photoelectrons. The $(1-\cos\theta)$ law for a single electron follows as a simple Doppler effect.

48. A wave mechanism of quantum phenomena. R. V. L. HARTLEY, Bell Telephone Laboratories, Inc.—An analysis of the motions of a coupled mechanical system which differs from those ordinarily treated in that the coupling is a function of the magnitudes of the motions has led to the prediction of the appearance under certain conditions of subsynchronous motions in response to a simple single frequency driving force. The appearance of these additional frequencies has been verified by experiment. It is apparent that here is a process expressible in terms of ordinary materials and ordinary mathematics which allows quantum distributions of energy to arise, through simple mechanical restraints, from a continuous supply of vibrant energy. The analogy to the Raman effect is obvious. A consideration of the interrelations of matter and radiation has shown that the required conditions for the appearance of this effect can be satisfied by an atomic model based on a universal spacial distribution of charge of one sign. This charge obeys the laws of an elastic solid, and hence the relation between electric "pressure" and volume which serves as a coupling between longitudinal and transverse waves is non-linear. With this concept in mind a mechanical model of the universe may be imagined which will operate in remarkable accord with many observed phenomena.

49. Sigma-type doubling in the asymmetrical top. S. C. WANG, National Research Fellow, University of Wisconsin.—An elaboration and a more complete analysis of Witmer's work on the asymmetrical top (Proc. Nat. Acad. **13**, 60 (1927)) treated as a perturbation of the symmetrical one show that the complete Hamiltonian is diagonal in j and independent of m. Since there are $2j+1$ values of n for given j, the problem is equivalent to the reduction of a quadratic form in $2j+1$ variables to its principal axes. Without actually solving the characteristic determinant, we find the terms divisible into symmetric and antisymmetric groups just as in the sigma-type doubling in diatomic molecules treated by Kronig (Zeits. Physik. **50**, 347 (1928)), Hill, VanVleck and Mulliken (Phys. Rev. **32**, 250, 327 (1928)). Our doublet separation is, in Witmer's notation $\Delta\nu = [hcb^n(j+n)!]/[2^{3n}\pi^2(j-n)!^2]$ where $c = A^{-1} - (B^{-1}+C^{-1})/2$ and $b = (B^{-1}-C^{-1})/2c$. The formula obtained for the energy values agrees with Witmer's except for the inclusion of the doubling phenomenon. The experimental detection of this doubling, which is proportional to some power of b, would furnish a measure of molecular dissymmetry.

50. The classical theory of the Raman effect. E. H. KENNARD, Cornell University.—The Raman effect was predicted by Kramers and Heisenberg via the correspondence principle, but their treatment, being general, is very abstract. It may be of interest to describe a simple concrete example of the effect in classical theory. Consider the scattering of light by an electron in one atom of a polar diatomic molecule. For purposes of visualization a treatment by successive approximations is convenient. The force $eE \sin 2\pi\nu t$ due to the incident electric field of amplitude E would produce, in the absence of the other atom, a displacement $x = \gamma_\nu eE \sin 2\pi\nu t$ (e = electronic charge, γ_ν = a constant). This will alter the differential or polarizing force F_m on the electron due to the other atom by $\delta F_m = x\partial F_m/\partial x$, in which, F_m being dependent chiefly upon the distance s between the atoms, and the interatomic vibration of frequency ν_m being not quite harmonic, we can write $\partial F_m/\partial x = \sum_{r=1}^{\infty} a_r \sin 2\pi r\nu_m t$. Thus δF_m produces an additional displacement of the electron equal to $\delta x = \gamma_r \delta F_m = \gamma_\nu eE \sin 2\pi\nu t \sum_{r=1}^{\infty} \gamma_r a_r \sin 2\pi r\nu_m t$

$=\frac{1}{2}\gamma_\nu eE\sum\gamma_r a_r[\cos 2\pi(\nu-r\nu_m)t-\cos 2\pi(\nu+r\nu_m)t]$. There is no other term in the displacement of the first order in E. The term x causes the Tyndall scattering; the term, δx, scatters light whose frequencies are different from the incident frequency and are obviously related to the infra-red vibrational frequencies $r\nu_m$ in the manner characteristic of the Raman effect.

51. Collisions and coalescence of light quanta. A. L. HUGHES AND G. E. M. JAUNCEY, Washington University.—In view of several discussions (e.g. de Broglie, Witmer, and Rosenfeld) in which the possibility of collisions between light quanta, whether in a hohlraum or not, is contemplated, it is desirable to investigate what types of collision satisfy simultaneously (1) the conservation of energy, (2) the conservation of momentum, and (3) a microscopic reversibility in which both the forward and reverse processes are equally natural. It is found that the coalescence, on collision, of two quanta, whatever be the angle between their paths, cannot satisfy both conservation principles, nor is (3) possible unless one is prepared to postulate a spontaneous dissociation of a single quantum. Two quanta, however, can collide and give rise to two quanta with new frequencies and still satisfy all three principles. As a particular case, two quanta of the same frequency ν, in a 90° collision, give rise to one quantum of frequency 1.707ν, travelling forward along the line bisecting the 90° angle and a second quantum of frequency 0.293ν, travelling in the opposite direction. Although two quanta cannot coalesce, yet a collision of three quanta can give rise to two quanta with new frequencies and still satisfy (1), (2) and (3).

52. Quantum resonance and chemical reaction rate. R. M. LANGER, National Research Fellow, Bureau of Standards.—The theory of resonance in quantum mechanics leads to a suggestion as to the mechanism of chemical reaction which, applied to homogeneous unimolecular reactions, gives a simple, physically plausible picture. It is shown that only in the case of complex molecules is a unimolecular decomposition to be expected. The point is that if there is an equality of energy levels in several chemical bonds, resonance causes a circulation of energy among them and it is difficult to add energy to one above the resonance level without first "loading" the others. This can be done only through many collisions. Moreover, as soon as the several resonant bonds together have more than the dissociation energy for the weakest one, decomposition is possible without collision, but the mean time before decomposition will depend on the energy. The high temperature coefficient found experimentally fits in naturally, but the current motion of "activation," loses or rather entirely changes its significance. Those cases where this theory shows unimolecular reaction can occur turn out to be just the cases where the difficulty of maintaining the "rate of activation" disappears. The variation of specific reaction rate with pressure and the change of temperature coefficient for different members of a series (e.g. dimethyl and diethyl ether) can be interpreted.

53. The hydrogen molecular ion as a wave-mechanical perturbation of the helium ion. P. M. MORSE AND E. C. G. STUECKELBERG, Princeton University.—Unsöld, Heitler and London and others have studied the electronic levels in a diatomic molecule by considering the perturbations caused by the approach of two separated atoms. In the following calculation the molecular electronic levels are obtained by determining the perturbation caused by splitting the nucleus of a simple atom. In particular, the hydrogen molecular ion has been obtained from the helium ion and the electronic energy as a function of the nuclear separation gives a curve which checks with that calculated rigorously for the ground state by Burrau within the limits of validity of the method. The curves for the excited states, which Burrau could not obtain by his method, show clearly the "promotion of the electron" as predicted by Hund and Mullikan. That is, the state $n=2$, $l=1$, $m=0$ for the "united atom," goes to the state $n=1$, $l=0$, $m=0$ for the separate atoms. This method is also used in the study of the neutral hydrogen molecule.

54. A problem of Brownian motion. G. E. UHLENBECK AND S. GOUDSMIT, University of Michigan.—Gerlach investigated the rotation Brownian motion of a small mirror suspended on a fine wire (Naturwiss. **15**, 15 (1927)). It follows from the theorem of equipartition that the average square deviation of the mirror will depend on the temperature alone of the

surrounding gas. Gerlach verified this for a large range of pressures (1 to 10^{-6} atm.). The analogy which we found that existed between this problem and the well-known treatment of the shot effect by Schottky, enabled us to give a more detailed theory of this phenomenon. If the displacement, registered during a time, long compared with the characteristic period of the mirror, is developed into a Fourier series, we found the square amplitude of each Fourier component to be a function of the pressure and molecular weight of the surrounding gas as well as of its temperature. The sum of those squares, however, is a function of the temperature alone. This explains why the curves registered by Gerlach at different pressures, though all giving the same mean square deviation, are quite different in appearance.

55. Reflection of soft x-rays. Jos. E. Henderson, Yale University, and Elizabeth R. Laird, Mount Holyoke College.—The reflecting power of glass for soft x-rays at glancing angles up to 20° has been studied. General radiations from a nickel target excited by the stopping of electrons, whose velocity ranged from 100 to 4000 volts, was used. Total reflection, sharply defined, such as exists in the hard x-ray region is found not to exist in this region. The curves for all voltages exhibit a continuous decrease in reflecting power with increasing glancing angle as was reported earlier (Proc. Nat. Acad. Sci., Oct., 1928). The unexpected crossing of the curves described there has been investigated with greater precision and the effect definitely found to exist. The lower voltage radiation is less reflected at small angles (under about 4°) than the higher voltage radiation. At larger angles the lower voltage radiation is more reflected than the higher voltage radiation. A theory is proposed explaining the continuous decrease in reflecting power with increasing glancing angle and the crossing of the curves.

56. Dispersion of soft x-rays in glass and platinum. Elmer Dershem, University of Chicago.—The refractive indices of a sample of glass, density 2.50 gm/cc, composition unknown but evidently containing Al_2O_3, were determined by the total reflection method for wave-lengths from 4.2 to 9.15A. Plotting $1-\mu=\delta$ against λ reveals lowered values of δ at the K absorption limits of silicon and aluminum. The maximum critical glancing angle observed was 1°20′ at 9.15A. The corresponding value of δ being 2.7×10^{-4}. These measures were observed to be affected by surface conditions. Preliminary measurements in the M region of platinum previously reported, (Phys. Rev. **31**, 305 (1928)), have been repeated in more detail and the resulting dispersion curve shows three marked minima in values of δ, one at a wave-length corresponding to a mean of the wave-lengths of the M_I and M_{II} limits, another at the M_{III} limit and the third at a mean of the M_{IV} and M_V limits. The region of anomalous dispersion extends over a considerable frequency range on either side of an absorption limit. Hence the minima due to limits having small frequency separations are not easily resolved. The major part of this work was done at the University of California.

57. The crystal structure of tri-calcium aluminate. Wheeler P. Davey and F. A. Steele, Pennsylvania State College.—Tri-calcium aluminate has cubic symmetry. The density and the diffraction pattern of the powder show that the unit of structure contains $9CaO.3Al_2O_3$. The theory of space groups permits about 1500 cubic structures containing 9A, 6B, and 18C. The packing radii of the ions involved make all but 40 of these structures impossible unless we grant a linear compression of at least 10 percent beyond what is found in other compounds. Of these 40, 37 show calculated values of intensities widely different from those found by experiment. The remaining three structures are very similar to each other. The best fit gave Ca at 8*c* and 1*a*, Al at 3*a* and 3*b*, and O at 6*d* and 12*f* (Wyckoff nomenclature). None of the three structures show any evidence of units of CaO, AlO_3, or Al_2O_3. The oxygen ions are symmetrically shared by both Ca and Al. It is proposed to call this type of compound "mixed ionic." The side of the unit cube is 7.624A.

58. Satellites of certain x-ray lines. F. K. Richtmyer, Cornell University.—It has been long known that accompanying many x-ray lines, usually on their short wave-length side, are found fainter lines which do not fit into the usual x-ray energy level diagrams and which, until we have an acceptable theory of their origin may be called "satellites." Because of their probable bearing upon the problem of the origin of spectra, it is desirable to secure, if possible,

more precise data as to wave-length, excitation potentials and relative intensities of these satellites. Such a study has been initiated and the present paper is a preliminary report concerning the wave-lengths of certain of these lines. Measurements of the satellites of $L\alpha_1$, $L\beta_1$, $L\beta_2$ and $L\gamma_1$ for the elements Rb(37) to Sn(50) have been made from plates taken by the author and R. D. Richtmyer in Professor Siegbahn's Laboratory. $L\alpha_1$ has five satellites (possibly seven): $L\beta_1$ has three; $L\beta_2$ has three (possibly five); and $L\gamma_1$ has two. The results confirm the empirical law, previously proposed by the author for the satellites of $K\alpha$ (Phil. Mag. **6,** 64 (1928)), that the square root of the frequency difference between a satellite and its parent line is a linear function of atomic number. (The author acknowledges assistance from the Heckscher Research Council of Cornell University.)

59. Fine structure of scattered x-rays. DANA MITCHELL AND BERGEN DAVIS, Columbia University.—Examination of $MoK\alpha$ rays scattered from aluminum at approximately 90° has been made by the method used with graphite and reported at the last April meeting of this society (Phys. Rev. **31,** 1119; **32,** 331 (1928)). Four lines attributable to $MoK\alpha$ have been found in the following positions: $MoK\alpha_1$ unmodified, $MoK\alpha_2$ unmodified, one between $MoK\alpha_1$ and $MoK\alpha_2$ and one on the long wave-length side of $MoK\alpha_2$. These two shifted lines correspond to about 2.3 and 5.6 X.U. from $MoK\alpha_1$. If the loss of energy of these scattered Mo quanta is correctly described by $Ve=h\nu-h\nu'$ the energy levels of aluminum can be determined from the convenient form $\Delta\lambda=\lambda^2/(\lambda s-\lambda)$ where $\Delta\lambda$ is the wave-length shift. These give two of the absorption limits of aluminum as 57 ± 6 and 136 ± 6 equivalent volts. At the date of writing the aluminum K shift is 69 X.U. Preliminary data using Be gives an anti Stokes L and Stokes K.

60. Gamma and cosmic rays. J. A. GRAY AND A. J. O'LEARY, Queen's University.—Experiments with gamma-rays have led to the following conclusions: (1) Accurate values of the variation of intensity of cosmic rays with height are not obtained by assuming that they travel in straight lines without scattering and have an absorption coefficient independent of depth. This method of calculation leads to too high a value for the intensity near the surface of the atmosphere. (2) Wave-lengths, obtained by assuming that Dirac's formula connecting scattering coefficients with frequency is correct, are too long. (3) The soft or local rays observed in cosmic-ray experiments are not produced by the hard rays. There is some evidence that part of the hard radiation is of terrestrial origin also. It is difficult to make the correction due to the local rays in balloon and other experiments. The use of the results of such experiments without this correction leads to too high a value for the total intensity of cosmic rays.

61. The significance of measurements of ionization in closed vessels in relation to cosmic radiation. W. F. G. SWANN, Bartol Research Foundation of The Franklin Institute.—A cosmic ray of absorption coefficient 0.1 per meter of water could produce, by the complete utilization of its energy, about 5.5×10^6 ions. If we assume that, on the average, the rays produce 1.4 ions per cc per second at sea level only one cosmic ray could be absorbed in 4000 seconds in a vessel of 1 liter capacity. Most of the ionization which this ray is capable of initiating through its secondary radiation is of course produced outside of the actual air in the vessel, and the ionization produced in the vessel comes mainly from secondary radiation initiated by the absorption of primary rays in the vessel wall. The development of these considerations leads to the following conclusions in relation to variation of residual ionization with pressure. If N is the ionization which would be produced at standard pressure in the volume of the vessel by the cosmic radiation but with the walls absent, the increase per atmosphere in the neighborhood of one atmosphere is equal to the ionization at one atmosphere, and is greater than N while the increase per atmosphere at sufficiently high pressures attains a constant value which is equal to the ionization produced in the volume of the vessel at the higher pressure by the cosmic rays and their secondary radiations absorbed in that volume alone at one atmosphere.

62. The "anomalous dispersion" of electron waves by nickel. C. J. DAVISSON AND L. H. GERMER, Bell Telephone Laboratories, Inc.— Our experiments on the reflection of electrons (Proc. Nat. Acad. **14,** 619 (1928)) indicate strongly that electron waves are refracted on passing into a metal. The dispersion curve for nickel which we constructed from the data of these

experiments shows elaborate and surprising features. In particular, near $\lambda = 1.3$A this dispersion curve has a discontinuity suggestive of optical anomalous dispersions. Further evidence of this phenomenon has been found in a re-examination of the data of our earlier experiments on diffraction beams of the Laue type (Phys. Rev. **30**, 705 (1927)). Only one of these beams occurs near the anomalous region about 1.3A. This beam is first detected at $\lambda = 1.37$A; it increases in intensity to $\lambda = 1.33$A; then becomes very weak through the anomalous region; and finally grows rapidly stronger again, reaching its maximum intensity at $\lambda = 1.19$A. With further decrease in wave-length this beam steadily decreases in intensity in the manner characteristic of other beams of the Laue type, finally vanishing at $\lambda = 1.07$A. The condition for an intensity maximum is that λ/μ have the value $(2d \cos\theta)/n$. It looks as if, with μ changing rapidly with λ, there are two values of λ (1.19A and 1.33A) for which this relation is satisfied, and the beam really occurs twice.

63. The reflection of hydrogen atoms from crystals. THOMAS H. JOHNSON, The Bartol Research Foundation of the Franklin Institute.—The experiments published under this same title in the Journal of the Franklin Institute, Sept. 1928, have been continued with the following new results. Quantitative measurements of the intensities of the specularly reflected hydrogen atom beams from a cleaved surface of a hot crystal of rock-salt have been made with the results given in the table.

Angle from grazing	5°	10°	15°	30°	45°	60°
Intensity of reflected beam: intensity of incident beam	.01	.0097	.0096	.0087	.0041	.0021

Although no specular reflection was found from KCl under the conditions of the earlier work, such beams have now been found and they vary in intensity with the angle about as the beams reflected from rock salt but they are at least ten times weaker than the latter. To test the possibility that the probability of specular reflection depends critically upon the velocity of the atom, the specularly reflected beam at 20° from grazing from one rock-salt crystal was again reflected at the same angle from a second crystal. Since no specular beam appeared from the second crystal during an exposure of more than ten times that required to obtain an observable record from the first crystal it is concluded that the velocity selection in the specular beam cannot be very pronounced.

64. Angular scattering of electrons in gases. GAYLORD P. HARNWELL, Princeton University.—A slightly modified form of the apparatus described in an earlier paper (Proc. Nat. Acad. **14**, 564 (1928)) has been used to repeat and extend the results reported there. The negative results that had been obtained for the scattering of fast electrons through large angles have been confirmed. Evidence of the scattering of electrons, whose energies are in the region from 50 to 150 volts, through small angles has been obtained. It has been found that the angular region, through which electrons that have lost no energy are scattered, is very limited. In very few cases does this region extend more than ten degrees on either side of the original beam. As the energy of the primary electrons increases this region tends to become still narrower. The evidence also indicates that for electrons with an energy of 100 volts very few of those which have suffered an inelastic impact remain in the original beam. However, they are only deflected through angles of a few degrees. As the energy of the primary beam increases these electrons also tend to be deflected through smaller angles.

65. The Compton effect produced by standing electromagnetic waves according to wave mechanics. MILDRED ALLEN, Bartol Research Foundation.—If x-rays, in the sense of classical electromagnetic theory, pass out from a point and are reflected by two crystals so as to form two oppositely directed beams of electromagnetic waves, the net result will be a system of stationary electromagnetic waves. The results to be predicted by the wave mechanics for the Compton effect in this case are not immediately obvious, particularly in view of the absence of a resultant electromagnetic momentum for the standing waves. On submitting the matter to calculation, it turns out that, to a first approximation, the solutions for the vector and scalar potentials resulting from the $\psi\bar{\psi}$ distribution divide themselves into two parts, corresponding to the two

oppositely directed electromagnetic waves; and it results from this that where the interpretation of the wave mechanics solution is made in terms of probabilities of Compton transitions, the result is the same as though each of the oppositely directed waves acted independently of the other. The paper concludes by sketching the relation between the general theory of the Compton effect and Schroedinger's original theory made in terms of the reflection of the electromagnetic waves, according to the Bragg law, from gratings generated by the $\psi\bar{\psi}$ distributions.

66. Lattice energetics of thermal vibrations in solids. R. H. CANFIELD, Naval Research Laboratory.—Assuming that the energy of a space-lattice may be expressed, as by Mie, Grüneisen and others, in terms of the "average distance" of an atom from its neighbors, a formula is derived for the upper limit of amplitude of thermal vibration, and hence for the width between branches of the energy curve at room temperature. This largest amplitude, ρ equals $C_vK/9\alpha\bar{r}^2$, where C_v equals specific heat per atom, k is compressibility, α is the coefficient of linear expansion, and $\bar{r}$ is the cube root of the volume per atom. If the slope of the energy curve where it intersects the room temperature axis is much larger at the intersection where $r<\bar{r}$ than it is where $r>\bar{r}$, then ρ as given above may be taken as the true half-width of the energy curve. It is shown that the calculated half-widths of the curves for fourteen cubic metals account for their falling into body- or face-centered lattices; that the calculated frequencies agree with the demands of the quantum theory of specific heats; and that a possible rule for the melting point may be that it occurs when the accoustic wave-lengths become as small as twice the distance between atoms.

67. The temperature coefficients of resistance of low melting point metals in the solid and liquid states. W. B. PIETENPOL AND H. A. MILEY, University of Colorado.—The authors have given a preliminary description (Phys. Rev., **30**, 697 (1927)) of a unique method of measuring the resistance-temperature coefficients of low melting point metals through the solid and liquid states. The difficulties in the way of making such measurements have been largely eliminated by employing oxide films as containers for the molten metals. In the present article the resistivity-temperature curves are shown for the metals (Pb, Sn, Zn, Bi), and the temperature coefficients of resistance are given for 10° intervals throughout the range 20°C to above 550°C. The resistance-temperature coefficients of zinc above the melting point are found to be positive instead of negative as reported by E. F. Northrup and V. A. Suydam (Jour. Frank. Inst., **175**, 153 (1913)). The coefficients of these metals are all positive except those for bismuth in the regions 160°–180°C and 225°–275°C. The negative coefficients may be explained in the first case as due to a transformation in the crystalline metal, and in the second case they are due to the decrease in the resistivity of the bismuth as it approaches the melting point and passes from the solid to the liquid state.

68. Improved methods of exciting Raman spectra of scattered radiation. R. W. WOOD, Johns Hopkins University.—The mercury arc suffers from the disadvantage that no single line can be used for excitation even by the use of filters (4358 is triple, and 4046 cannot be separated from 4077). On this account the spectrum lines cannot be identified, until all λ's are measured and the frequency differences calculated. The author has employed a spiral helium tube surrounding a tube of black glass (colored by nickel oxide) which is very transparent to the strong helium line 3888. Within this tube is the tube containing the liquid, or the tube of black glass may have a window of clear glass fused to its end, and be employed for holding the liquid. In this way one obtains a Raman spectrum by strictly monochromatic excitation. A wave-length scale graduated for infra-red frequencies (i.e. in μ's) can be prepared and placed in coincidence with an enlargement of the spectrum. In this way the infra-red absorption bands can be determined without any wave-length measurement or calculations.

69. A rational proposal for the control of a hurricane. WM. S. FRANKLIN, Mass. Inst. of Technology.—The great Florida-Porto-Rico hurricane of mid-September was preceded by a widely extended state of instability of the atmosphere with warm moist air near the ground and colder air above, and if this state of instability could have been "touched off" at several places in the neighborhood of the Florida coast the local energy of this unstable state might have been

frittered away in several mild storms so that there would have been no energy left to feed the great storm when it reached the Florida region. It is thus conceivably possible to control a hurricane. The question is however; is it humanly feasible to "touch off" an unstable atmospheric state and start a storm? No one knows the answer to this question, and although I am inclined to think it is not feasible, I believe that a corps of observers should be assigned to the Porto Rico and Florida region to make continuous studies of the vertical distribution of temperature, humidity, and wind velocity in the atmosphere so as to capture data for a pre-hurricane state. Then from these data one could calculate, by the method of L. F. Richardson, how much of an upward impulse would need to be given to a specified volume of air in order to "touch off" a storm. If this needed amount of impulse should be only moderately large it might then be worth while to build an air-impulse gun to try the "touching off" of a storm, and then make an attempt to fritter away the energy of any atmospheric state that might arise and threaten to form a severe hurricane.

70. Heat transmission of air space by hot plate method. L. F. MILLER, University of Minnesota.—The hot and cold plate apparatus, with guard ring, taking foot square layers of insulating material, was used. The double layers each side of the hot plate, consist of two sheets each 6.55 mm thick, of a firm rag felt insulation between which uniform layers of air space of increasing thickness may be introduced by stacking small pieces of cork at eight or ten different points. Designating the heat transmission as, h_s for the two felt sheets in immediate contact with no air space, h_a for the various thicknesses of air layer, and H for the felt sheets and air layer combined, then from the relation $1/H=1/h_s+1/h_a$, the value for the different air layers h_a can be calculated, since H and h_s are measured in the apparatus. As the thickness of air space increases (convection presumably building up) h_a decreases along a curve which flattens out and has a minimum for an air layer about 20 mm thick. If we calculate a coefficient of thermal conductivity for each of these air layers and plot these values, the curve runs into a value of 5.68×10^{-5} calories per sec per cm^3 per deg C, as thickness of air layer approaches zero where convection vanishes. This checks with the accepted value of the coefficient of thermal conductivity of air.

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