PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE POMONA MEETING, JUNE 15, 1928

The 152nd regular meeting of the American Physical Society was held in Pomona, California, at Pomona College, in affiliation with the Pacific Division of the American Association for the Advancement of Science. The meeting of the American Physical Society was held Friday, June 15th, the morning session being a joint session with the Astronomical Society of the Pacific. The program consisted of forty-two papers, eleven of which—Nos. 4, 25, 29, 33, 34, 36, 37, 38, 40, 41, and 42—were read by title. Abstracts of these papers are given in the following pages. An Author Index will be found at the end.

S. J. BARNETT
Acting Local Secretary for the Pacific Coast

ABSTRACTS

1. The spectrum of sulphur S II. S. B. INGRAM, California Institute of Technology.—The sulphur spectrum in the extreme ultra-violet was photographed with a vacuum spectrograph and a hot-spark source. Above 2000A a seven meter concave grating was used, the spectrum being obtained from a discharge tube in H_2S gas. By varying the conditions of excitation the spectrum of S II could be separated from the spectra of higher stages of ionization. One hundred and eighty-three lines have been classified and the following terms identified: s^2p^3, ^4S $^2(PD)$; sp^4, ^4P, ^2P; $s^2p^2 \cdot 4s$, ^4P, $^2(PD)$; $s^2p^2 \cdot 5s$, ^4P, ^2P; $s^2p^2 \cdot 4p$, $^4(SPD)$, $^2(PD, PDF)$; $s^2p^2 \cdot 3d$, ^4F, $^2(PDF)$; $s^2p^2 \cdot 4d$, $^4(PDF)$, $^2(DF, G)$. The low ^4S term has a value of 188824.5 cm^{-1} corresponding to an ionization potential of 23.3 ± 0.1 volts for the S II ion.

2. On the spectra of doubly ionized vanadium, V III, and triply ionized chromium, Cr IV. H. E. WHITE, Cornell University.—The neutral atoms of vanadium and chromium contain five valence electrons, ($3d^34s^2$), and six valence electrons, ($3d^54s$), respectively. The removal of two electrons ($4s^2$) from vanadium and three electrons ($3d^24s$) from chromium gives two iso-electronic systems, V III and Cr IV, the lowest energy levels of which are given by the remaining valence electrons $3d^3$. From the relations known as the irregular doublet law applied to multiplets, and a Moseley Diagram for multiple levels, along with the arc and spark spectrum of scandium and titanium respectively, doublet and quartet terms of the three electron configurations $3d^3$, $3d^24s$, and $3d^24p$ have been determined for V III, and Cr IV. From Sc I and Ti II a linear extrapolation of the radiated lines arising from the electron transition $3d^24p$ to $3d^24s$ was sufficient to locate the corresponding lines for V III around 2300A, and for Cr IV around 1800A. The terms thus determined for $3d^24p$ combine with the lowest energy levels in the spectrum, $3d^3$, giving very strong lines in the region, 1100A for V III, and 600A for Cr IV. With this determination of the lowest energy level of $3d^3$ the ionization potentials for V III and Cr IV are computed at 30 volts and 52 volts respectively.

3. Doublets and quartets of doubly ionized silver, Ag III. R. C. GIBBS AND H. E. WHITE, Cornell University.—For a sequence of iso-electronic systems starting with any element in the periodic table, if the energy levels representing any of the possible electron configurations be

plotted on a Moseley type of diagram, the lines connecting corresponding terms of each successive element will be very nearly straight lines. Furthermore it is found that the radiated frequencies resulting from those electron transitions involving no change in total quantum number (which in some cases involve at least a hundred radiated lines) are displaced to higher and higher frequencies by very nearly a constant value. Applying these relations to the known arc spectrum of rhodium, Rh I, and the first spark spectrum of palladium, Pd II, some of the doublet and quartet terms arising from the electron configurations $4d^9$, $4d^85s$, and $4d^85p$ of the second spark spectrum of silver have been determined. The transitions from $4d^85p$ into $4d^9(^2D_{2,3})$ makes it possible to determine the term value of the lowest energy level in the spectrum from which the ionization potential of Ag III is calculated to be about 34 volts. The large term separations which are characteristic of the heavier elements in the periodic table are shown by the $^2D_3-^2D_2(4d^9)$ separations, $\Delta\nu=2348$, $\Delta\nu=3538$, and $\Delta\nu=4607$ for Rh I, Pd II, and Ag III respectively.

4. Structure of praseodymium lines. ARTHUR S. KING, Mount Wilson Observatory.—The complex structure of praseodymium lines, mentioned in a former report, has been examined in more detail by means of high dispersion. Of the stronger lines from λ3100 to λ6800, nearly 400 have been listed as complex. The largest proportion is among the singly ionized lines in the blue and violet but many examples are found also in the neutral spectrum. The complexity varies from double lines to those of six components. The prevailing types are wide and narrow patterns with components of equal intensity, and wide patterns in which there is a progressive increase in resolution of components from violet to red or vice versa. The maximum interval in a six-component line of the latter type is about 0.06A, the intervals decreasing to 0.03A. Lines compared in furnace, arc and spark spectra appear to retain their structures unchanged. Recurring lines of each type in a given region indicate the presence of multiplets, and as many of these lines are of low atomic level, their similarities should aid in the analysis of the spectrum, and give additional evidence on the connection of such structure with the metastable states.

5. An optical oscillograph. SINCLAIR SMITH, Mount Wilson Observatory.—A beam of light after passing through a nicol prism, a quartz plate (perpendicular to the axis), a CS_2 cell, and a second nicol, is photographed with a rotating mirror spectrograph. The current to be studied is carried by a solenoid which surrounds the CS_2 cell. The first nicol renders the light plane polarized, the quartz plate rotates the plane of polarization according to the law $\theta=A+B/\lambda^2$, and the CS_2 cell adds to or subtracts from the rotation, depending on the current through the solenoid. The second nicol removes all wave-lengths from the beam which have suffered a rotation of $n\pi$ where n is an integer. Thus, if the light coming through the second nicol is viewed through a spectroscope, the spectrum is seen to consist of a series of bright and dark bands, the position of the dark bands depending on the current through the solenoid. If the light is photographed with a rotating mirror spectrograph while a non-uniform current is flowing through the solenoid, the fluctuations of the current are reproduced on the film. Professor Bedell has informed the author that a similar scheme was suggested by Crehore in 1894.

6. Effect of pressure and current density on the spectrum of Helium. A. C. HODGES, California Institute of Technology.—A study has been made of the intensities of the various lines of the spectrum of neutral helium, with the particular view of obtaining regularities in the variation of relative intensities with changes of current density and pressure. The method used was a modification of that developed by Ornstein at Utrecht, the modification consisting of a direct comparison of intensities of the helium lines with the same wave-lengths in the continuous spectrum from a standardized tungsten filament. A study has been made of the lines 5876, 5016, 4922, 4713, 4472, 4387, 4143, 3964, 3889, 3819, at pressures of 27, 9, and 3 mm, and currents of 65, 20, and 4 milliamperes in a capillary discharge. The results show an increase of the relative intensities of the higher members of the various series with a decrease of pressure or current density.

7. Locus of secondary image for two plane mirrors independently variable about parallel axes situated in the two respective planes. L. E. DODD. University of California at Los Angeles.—This problem is one in geometrical optics. Given two plane mirrors independently variable about parallel axes located one in each plane; required, the locus of the secondary image (in "second" mirror) of object point O. Pass a plane through O perpendicular to both mirror axes. A_0 and A are points where axes of first and second mirrors respectively cut this plane. A_0 is at left of A, both on the x axis, and O above both. Draw AO and OA_0, take A_0 as the origin, denote the distance A_0A by d, AO by r, OA_0 by D, and the angles A_0AO, AOA_0 by μ and ν. Draw a straight line through A, one through A_0, making arbitrary angles ξ and η with the x-axis, representing first and second mirrors. (Reflecting surface of the first is upward, that of second downward. Observer's position is below the x-axis. The question of cutting away of mirror planes for practical cases can be treated as a separate problem.) Draw OPO' perpendicular to M_1; $O'QO''$ perpendicular to M_2. O' is the image of O in M_1, O'' the image of O' in M_2. Required, A_0O'' $(=\rho)$ and angle AA_0O'' $(=\phi)$, coordinates of O'', in terms of the parameters d, r, D, and variables ξ, η. The solution is $\rho^2=D^2+2r\sin\alpha\,[2r\sin\alpha+2D\sin(\nu-\alpha)]$, where $\alpha=(\pi-\xi-\mu)$, $\mu=\cos^{-1}[(r^2+d^2-D^2)/2rd]$, $\nu=\cos^{-1}[(r^2-d^2+D^2)/2rD]$, and $\phi=\alpha+2\eta-\xi-\cos^{-1}[(\rho^2+r^2-d^2)/2\rho r]$.

8. An extension of the Cd I-like iso-electronic sequence to Sb IV. ALICE M. VIEWEG AND R. C. GIBBS, Cornell University.—In its neutral unexcited condition the antimony atom contains five valence electrons ($5s^2\,5p^3$). On removing three of these electrons antimony takes its place as the fourth element in the sequence of iso-electronic systems starting with cadmium; Cd I, In II, Sn III, Sb IV. By means of an almost linear extrapolation from classified lines emitted in the case of cadmium, indium and tin, in transitions from electronic configuration $5s6s$ to configuration $5s5p$, and $5s5d$ to $5s5p$, it has been possible to locate some of the corresponding lines in the spectrum of Sb IV. These lines are in the region 800–950A. We hope soon to identify more of the lines in the third spark spectrum of antimony and to extend this investigation into the spectrum of Te V.

9. The first spark spectrum of arsenic, As II. C. W. GARTLEIN, Cornell University.—The spark spectrum of arsenic was photographed below 2300A in a vacuum spectrograph using varying amounts of inductance in series with the spark. The As II lines were present in the spark even with large amounts of inductance but the lines from higher states, though present with no inductance, decreased in intensity as the amount of inductance was increased. It was also observed that the spectrum of As II was characterized by "long lines" due to glowing arsenic vapor that extended above and below the short vertical spark gap. About 75 lines have been arranged into a term scheme. All the terms of the lowest configuration, $(4p)^2$, and of the $4p5s$ configuration have been identified as well as some terms from the $4p4d$ configuration. Part of the terms due to the $4p5p$ configuration have been identified by lines in the visible spectrum due to transitions into the levels of the $4p5s$ configuration. The most prominent lines of the spectrum were identified by analogy with that of Ge I.

10. An erythema meter. ROBERT C. BURT, R. C. Burt Laboratory, Pasadena.—Erythema (sunburn) being one of the most definite and quickest observable biological reactions to ultra-violet, it is often taken as a criterion of the ultra-violet present. Besides the variable of skin, complexion, etc., little seems to be known as to the form of the time integral. An instrument is described which plots on the skin the time-intensity curve from which this integral may be determined. Observations are also taken of the growth and disappearance of erythema. It may be remarked that the erythema constant for an individual may be determined to about 10%.

11. On negative values of θ in the law of paramagnetism $K(T-\theta)=C$. LARS A. WELO. The Rockefeller Institute for Medical Research, New York.—Six iron salts of the type $[Fe_3(CH_3COO)_6(OH)_2]Cl$ obey the law $K(T-\theta)=C$ with normal values of $C=4.2$, but values of θ range from -553 to -695. Ten chromium salts of the same type give normal values of

$C=1.9$ with values of θ ranging from -89 to -116. CH_3COO may be replaced by CHOO, CH_3CH_2COO, C_6H_5COO, etc. An interpretation along classical lines is possible if we consider the organic groups as electric dipoles and adopt Debye's suggestion (*Handbuch der Radiologie*, vol. 6, p. 704) that the metallic ions have permanent electric moments as well as magnetic moments. The complex ion is then a semi-rigid structure in which the orientations of the metallic ions are electrostatically controlled by the organic groups. (For example: a triangular model, each side consisting of the chain $CH_3COO \cdot Fe \cdot CH_3COO$). In such a structure, the control which resists orientation by a magnetic field is, at every instant, equal to the control which resists disorganization by temperature agitation, and the ratio of the magnetization (or susceptibility) to its temperature coefficient should be a constant. But this is precisely the law $K(T-\theta)=C$, since in it the temperature coefficient is the quantity $-1/(T-\theta)$.

12. Measurements of thermoluminescence of glass exposed to light. R. E. NYSWANDER and B. E. COHN, University of Denver.—Glass turned violet in color due to long exposure to sunlight is thermoluminescent when heated to temperatures above 100°C. Thermoluminescence was also observed in some samples free from color, while others showed no luminescence. Effects similar to those for sunlight were also observed from glasses exposed to the carbon arc and in some cases for exposures of only a few minutes. Special glasses were made from a chemically pure zinc borate glass to which was added a trace of one of the following metals: barium, calcium, strontium, magnesium, manganese, aluminum, nickel, cobalt, chromium, silver cerium and thorium. Each of the above was exposed to sunlight and tested for thermoluminescence, the most intensely luminescent being thorium, cerium, silver, chromium cobalt and manganese. The following observations and curves were determined: growth of luminescence with time of exposure, both for sunlight and the carbon arc: effect of absorption of exciting rays due to thickness of glass: effect of concentration of solute: thermoluminescence as dependent upon temperature at excitation: total quantity of light emitted: and decay of thermoluminescence. All light measurements were quantitative and were made with a polarization photometer (Nyswander and Lind, J.O.S.A. & R.S.I., Vol. 13, No. 6, p. 551). The specimens were heated in an electric furnace.

13. Hall effect in bar of electrolytic iron. EMERSON M. PUGH, University of Pittsburgh.—The Hall effect was measured in a bar of electrolytic iron in contrast to the usual method of measuring it in thin sheets of the material. Direct measurements were taken at the same time of the magnetic induction B and of the Hall e.m.f. $-E$ The $E-B$ curve is shown to be a straight line up to $B \doteq 12{,}000$ lines/cm^2 where its slope starts to decrease. A curve of magnetizing current vs. B is seen to break away from a straight line at about the same value of B. Measurements taken at points on a "hysteresis loop" indicate that E is also proportional to B where B is due only to residual magnetism. The Hall coefficient for this bar is found to be 20 percent lower than that found by A. W. Smith for electrolytic iron.

14. Instantaneous line intensities in the alternating current arc. BRIAN O'BRIEN AND E. DICKERMAN O'BRIEN, Research Laboratories, Buffalo Tuberculosis Association, Perrysburg, N. Y.—A carbon arc containing Na and Mg salts was operated from an inverted rotary converter, to the shaft of which was attached a sector shutter so arranged that the arc could be observed continuously at any part of the alternating current wave. A contact device attached to the shaft provided for measurement of the instantaneous current through and voltage across the arc. Line intensities were determined with a small quartz spectrograph by a photographic method. Variations of intensity for the prominent lines of Na and Mg were determined throughout the alternating current cycle. Ratio of intensities of the Mg lines at 2795A, 2803A, and 2852A gave a measure of the relative ionization.

15. Gas phenomena and contact behavior in a vacuum switch. F. C. LINDVALL, California Institute of Technology.—A conditioned vacuum switch opens a circuit with a small, momentary arc. A definite rise in gas pressure within the switch is observed to follow continued switch operation. The rate at which gas is evolved is found to depend both on the value of the

interrupted current and on the circuit voltage, increasing either for increasing current or for in creasing voltage. Further, definite evidence of "getter-action" in the switch was obtained. Thus the resultant gas pressure was found to be due to that part of the evolved gas not taken up by getter-action; and a limiting equilibrium case was found in which the gas evolution and the clean-up balance each other to give a constant operating pressure for indefinitely continued switch operation. Moreover, these tests gave limiting values of gas pressure for satisfactory operation. In addition, the investigations included rupture of currents that gave excessively high contact current densities, and demonstrated that breaker operation is possible even with severe heating of the contacts. Repeated tests gave similar results for three contact metals copper, aluminum, and tungsten.

16. Measurement of arc voltage across opening switch contacts. HUGH HAMILTON, California Institute of Technology.—The measurement of arc voltage presents the unique problem of determining a small voltage of the order of 20 volts, existant for a fraction of a second which is immediately followed in the case of a circuit breaker by full line potential. The apparatus developed for this purpose consists of a high voltage kenotron in series with a 140 volt battery and an oscillograph. This circuit was connected across the switch contacts. Low voltages in the switch were thereby reproduced on an oscillogram, but high currents due to high voltages were suppressed by the saturation of the kenotron. The rated current of the oscillograph was therefore never exceeded. The results obtained with the vacuum switch establish two facts. The arc voltage proper is low and of the order of 10 to 25 volts. The arc voltage is independent of the current except for low current values. The cathode spot theory explains the performance of the switch and seemingly is in accordance with all the observed phenomena. For currents of the order of 5 amperes the arc voltage is high apparently due to the disappearance of the cathode spot. Sufficient work with these values has not yet been done to completely describe this action. Comparison of arc energy in the vacuum switch with that of the oil switch under the same circuit conditions showed that the oil switch energy is of the order of 100 times greater. The arc voltage in the oil circuit breaker is 8 to 10 times that of the vacuum switch.

17. Single crystals of metals formed in magnetic fields. A. GOETZ, California Institute of Technology.—The author has developed a method for producing single crystals of metals (Bi, Sn) in which the crystallization occurs in a strong magnetic field. If desired, half of the crystal can be grown in the field and the other half without the field. In this way, crystals are obtained which show no visible crystallographic discontinuity, but which show a marked discontinuity in electrical properties. The two halves exhibit a thermoelectric potential at their junction, and also have different changes of electrical resistance in a magnetic field.

18. A new high voltage x-ray tube. C. C. LAURITSEN AND R. D. BENNETT, California Institute of Technology.—This paper describes the construction of a tube by means of which it is hoped to extend the investigation of radiation from the now known x-ray region well into the region of gamma rays. The tube is designed for operation in connection with a 1,000 K.V.A. transformer-set capable of producing peak voltages up to 1,500,000 volts. The tube consists of glass cylinders 12×28 inches, placed end to end and thoroughly shielded inside against bombardment. The source of electrons consists at present of the rounded end of a tungsten rod 8 mm in diameter which can be retracted into the cathode sheath, thus enabling control of the field to which the point is exposed, and thereby of the electron emission The design also permits the use of a hot cathode if this should be found desirable. So far stable operation has been obtained well above half a million volts, and for short periods of time, about one million volts have been applied. The rectified current is from 5 to 25 milliamperes. Radiation can be observed by means of a fluoroscope at distances of more than a hundred feet, but so far no attempt has been made to analyse it.

19. Lagrangian functions which determine a symmetrical tensor by Schroedinger's rule, HERVEY C. HICKS, California Institute of Technology.—The choice of a Lagrangian function to be used in a variational principle may be limited by the condition that the tensor derived

from it by Schroedinger's rule shall be symmetrical. To meet this condition the function must satisfy a certain set of partial differential equations. Particular and general solutions of these equations are found in various cases—according as the function is restricted to depend (A) only on the components of a vector, (B) only on their first derivatives, or (C) on both; and according to the number of dimensions of the vector. Methods of obtaining such solutions, and of proving their independence or of finding the relations between them, are discussed.

20. Some problems in the steady motion of viscous, incompressible fluids; with particular reference to a variation principle. CLARK B. MILLIKAN, California Institute of Technology.—The question of the possible existence of steady motion in the general case of the flow of a viscous incompressible fluid, is investigated from the standpoint of a minimum or variation principle. It is shown that except for certain "exceptional cases" no Lagrangian Function exists, containing only the velocity components and their first order space derivatives, and from which the equations of motion may be deduced through the application of a variation principle. It is concluded that it is very probable that no steady state of motion exists for such a fluid, except in the "exceptional cases" defined in the paper. All the known examples of steady motion are shown to belong to this class of "exceptional cases"; and the Lagrangian Function for each of them is deduced and given explicitly. It is found that all of these Lagrangian Functions contain the same quantities and are in fact of the same general form.

21. Effect of toluene on the photoelectric behavior of mercury. DUANE ROLLER, California Institute of Technology.—When toluene vapor was introduced into an evacuated photoelectric cell containing freshly distilled liquid mercury, the sensitivity increased and the threshold shifted toward the red. The effect was immediate and its magnitude depended on the amount of vapor introduced. When vapor at 75 mm. pressure was held in the cell for one hour, the threshold shifted 100A. Upon connecting the cell to liquid air trap and pumps, the mercury surface not being disturbed in the meantime, the threshold gradually returned to the value for pure mercury. The time of return varied between 5 minutes and 46 hours, depending on the amount of vapor introduced and on the length of time it was held in the cell. The effects of xylene on both solid and liquid mercury are being investigated.

22. The direction of ejection of x-ray electrons. J. A. VAN DEN AKKER AND E. C. WATSON California Institute of Technology.—In a previous paper (Proc. Nat. Acad. 13, 659 (1927)) we have shown that the most probable direction of ejection of x-ray electrons depends to only a slight extent, if at all, upon the energy of binding of the electrons ejected. Evidence is now brought forward to show that this most probable direction of ejection is different for the electrons from the various M levels of a given atom. The same is true for electrons from the various L levels. This cannot be due solely to differences in the binding energies of these levels as these differences are small compared to the energy of the ejecting quantum (electrons ejected by the $K\alpha$ rays of molybdenum from exceedingly thin films of gold, silver, and tungsten have been studied). We conclude therefore that the direction of ejection depends upon the "shape" rather than the energy of the level from which the electron is ejected.

23. On the concentration of space charge in the vicinity of an insulating surface. BENEDICT CASSEN, California Institute of Technology.—The purpose of this investigation is the determination of the order of magnitude of the highest densities of space charge experimentally producible in the immediate vicinity of an insulating surface. Given a plane infinite emitting cathode and a plane parallel anode covered with a thin layer of insulating material of specific inductive capacity κ and thickness t, the following formula is derived for the density ρ_0 of charge, in e.s.u., at the surface of the insulating film when the anode is V volts positive with respect to the emitting surface,

$$\rho_0 = (9\times 10^4/4\pi)(\kappa VkT/ted)^2$$

where d is the distance between the emitting and insulating surfaces, e is the electronic charge in e.s.u., k is Boltzmann's constant and T is the absolute temperature. Some experimental work is described in which the maximum value of V that several insulating films could withstand before breaking down, is determined. For an ordinary aluminum oxide film this was found

to be about 27 volts. This indicates that the highest particle density of electrons obtainable in this way is of the order of 10^{12} to 10^{14} electrons per cm^3. This is very far from the degeneration concentrations so that the treatment of the problem by classical statistical considerations is justified.

24. Heats of linkage of C-H bonds from vibration spectra. JOSEPH W. ELLIS. University of California at Los Angeles.—Frequencies of bands at 3.28, 1.68, 1.145, 0.874, 0.713, 0.608, 0.532 and 0.476μ in the absorption spectrum of liquid benzene are expressible by a formula for a quantized anharmonic vibrator: $\nu^n = 3090n - 58n^2$. These yield mechanical frequencies: $\omega^n = 3090 - 116n$. These frequencies are assumed to originate in oscillations of a hydrogen atom with respect to the phenyl radical, the restoring force residing in the C-H bond. Using the method adopted by Birge and Sponer in measuring the heats of dissociation of non-polar, diatomic, gaseous molecules, the heat of linkage of a benzene C-H bond is here determined as 117,000 cal/mol. Corresponding values for hexane, cyclohexane and chloroform yield 97,000, 94,000 and 108,000 cal/mol respectively. The heat of linkage determined thermochemically for a methane C-H bond is 92,500 cal/mol. It is believed that this value checks with that determined optically for its homologue, hexane, within the limits of determination of the two values. The variations among the different compounds exceed experimental errors, and are believed to disprove the chemist's assumption of the equivalence of C-H bonds for all types of hydrocarbons. Wherever the resolving power of the spectroscope was sufficient to reveal it, the bands of hexane and cyclohexane (and other molecules not considered here) were observed double. This doubleness is here credited to an inequivalence of the four carbon valencies.

25. On the thermodynamical equilibrium of the universe. F. ZWICKY, California Institute of Technology.—The investigations on the equilibrium between radiation and matter by Stern and others, and the striking results on transformation of nuclei obtained by Millikan and Cameron make it desirable to work out the postulate of the thermodynamical equilibrium of the universe. The writer adopts the statistical method developed for chemical reactions by Ehrenfest and Trkal. Atoms, dust particles and stars are considered as molecules. For the typical reaction ν atoms $(m) \rightleftarrows$ star the equilibrium constant proves to be essentially $n_a^{\nu}/n_s = \rho^{-\epsilon/kt}$ where $E \cong fM^2/R$ is the gravitational potential energy of the star. (For the sun it is $E \cong 3.8 \times 10^{48}$ ergs, $\nu = 2 \times 10^{55}$ with $\overline{m} = 50$). This accounts readily for the abundance of the stars and the tremendously small vapor pressure of the atoms, also for the high temperature of the stars in spite of the low average temperature of the universe; for the formation of highly probable reaction products always involves excessively high kinetic energies for the individuals in the transition state. The complete picture of the equilibrium of the universe appears to involve on the one hand the transformation of matter into radiation (mainly in the stars) and the inverse process radiation $\rightarrow$ protons + electrons $\rightarrow$ higher nuclei going on throughout the spaces, conforming to Millikan's interpretation for the origin of the penetrating radiation.

26. The insulation of vibration. VERN O. KNUDSEN, University of California at Los Angeles.—The adaptation of electric circuit theory to mechanical systems is shown to offer a cogent means of investigating problems in the insulation of vibration. For example, it can be shown that any object of mass m separated by means of an elastic support or suspension from a framework (as a table or a building) which is vibrating with a frequency $\omega/2\pi$ and an amplitude a_1, is set into sympathetic vibration of amplitude $a_2 = a_1(r^2 + 1/\omega^2c^2)^{1/2}/[r^2 + (\omega m - 1/\omega c)^2]^{1/2}$, where c is the compliance (displacement per unit force) and r the resistance (mechanical ohms) of the elastic support or suspension. This equation has been verified experimentally for suspended systems having different values of m, c and r, for values of ω between 0 and 150. The factor r in most suspended systems using spiral springs or rubber bands is not significant except for high frequency vibrations. It is, however, very significant for systems where the "insulating pad" is cork or hairfelt or other materials having high internal damping. For $\omega^2 < 2/mc$ the "insulating" support or suspension gives an actual amplification of the vibration, the maximum occurring at the resonant frequency. Data are given for a typical suspended system. The usefulness of the theory is indicated by showing its application to a number of practical problems, as the prevention of vibration in apparatus and buildings.

27. An experimental method of measuring the electrostatic induction of the sun's negative charge upon the earth. FERNANDO SANFORD.—A quadrant electrometer has one diagonal pair of quadrants removed and the other pair connected together and to the metallic suspension of the needle. This system is insulated upon amber supports inside a closed metal case which is connected to the inside of a grounded wire cage and to the city water system. After being discharged to earth and allowed to stand insulated and doubly screened from outside induction the needle goes through a double oscillation every 24 hours, the range of which is more than the deflection which is produced by charging the insulated system to 150 volts. Two electrometers of different pattern and of different sensitivities give simultaneous corresponding deflections. Electric charges are measured from the earth taken as zero. An uncharged insulated body would become charged if the magnitude or the distribution of the earth's charge should change. The night side of the earth remains electronegative to the day side, hence the insulated system is positively charged at night and negatively charged by day. The potential difference of these charges is more than 150 volts.

28. The thermionic and photoelectric emission from Pt and Pd. LEE A. DUBRIDGE, National Research Fellow, California Institute of Technology.—Preliminary results of more precise measurements of the thermionic emission from outgassed platinum over a wide range of temperature confirm those previously announced that for the clean surface $b = 74{,}000°\text{K}$ and $A = 14{,}000$ amp/cm^2 deg^2, approximately. The emission currents are very small and are measured with a Compton electrometer and a series of high resistance shunts of from 7 to 20,000 megohms. The observed value of A is 230 times the theoretical value of Dushman—in disagreement with the recent theoretical work of Fowler and Nordheim. The discrepancy may be removed if the work function is assumed to decrease linearly (and only very slightly) with temperature, as suggested by Bridgman and Epstein. A decrease in the *photoelectric* work function of Pt with temperature has already been observed by the author (Phys. Rev. **29,** 451). Such a decrease also explains the linear relation between log A and b during outgassing. (See Phys. Rev. **31,** 236, 1928.) For palladium—outgassed, but probably not yet gas-*free*—the photoelectric and thermionic work functions appear to have a common value of about 5.35 volts, which value is enormously decreased by slight traces of hydrogen.

29. Superposition of x-rays. GERALD L. PEARSON AND WM. W. HANSEN. Stanford University. (Introduced by D. L. Webster.)—W. H. Watson (Proc. Roy. Soc. Edin., **45,** 48, 1925), working in the laboratory of C. G. Barkla, has performed experiments that seem to indicate that under certain conditions the effect of two x-ray beams passing through a silver film may not always be additive. The present research is a test of this point with conditions similar to Watson's, but with further refinements in accuracy of measurement. A silver film was exposed to two perpendicular x-ray beams: (A) from a tungsten-anode Coolidge tube and, (B) silver fluorescence rays excited by this same Coolidge tube. Intensity of the rays was measured as follows: (1) scattered by the silver film from beam A, (2) from B transmitted by the film, (3) combined scattered and transmitted. Intensity and quality of the primary beam was varied over a wide range by changing the voltage and by interposing aluminum filters. In all cases intensity (3) equaled intensity (1) plus intensity (2) within experimental error.

30. Recombination of ions in the chamber of an x-ray spectrometer. DAVID L. WEBSTER AND ROBERT M. YEATMAN. Stanford University.—It is usually assumed that for accurate comparisons of x-ray intensitites, the voltage applied to the ionization chamber must be sufficient to reduce the loss of ions by recombination to a fraction of the total number produced, less than the permissible error of measurement. Tests show, however, that under proper conditions the fraction lost may be independent of the total number produced, for any loss up to about 10%. With the chamber used here, this permits accurate comparisons of ionization currents with only 50 volts, instead of the 800 required to reduce the loss to 1%, and thereby minimizes errors due to battery changes. This constancy of the fraction lost, with different currents, probably indicates that the recombination is practically all columnar, as reported by other observers with alpha-rays. In the case of x-rays, columnar recombination must be recombination between ions produced by the same photoelectron. This condition must be satisfied best with faint rays, such as are used in x-ray spectrometry. With stronger rays it should break down, and *therefore these tests do not indicate anything about ordinary x-ray dosage measurement.*

31. The variation of the photoelectric effect with temperature, and a determination of the long wave-length limit for tungsten. A. H. WARNER, University of California at Los Angeles, California Institute of Technology.—The photo-current from clean tungsten has been found constant from room temperature to 1050°K with a long wave-length limit of 2720 ± 25A for this sample. The thermionic emission becomes measurable at 1050°. The photo-current begins to increase slightly here and is about 14% greater at 1160°. Beyond this point the thermionic current masks the photo-current. The target is a straight ten mil, non sag tungsten wire. The anode is a nickel cylinder, with guard cylinders on either side. The tube is of Pyrex with a graded seal to the quartz window. All leads are of tungsten. After a thorough outgassing the tube was sealed off the pumps. Magnesium was employed as a getter. The thermionic work function was used as a criterion of the cleanliness of the surface.

32. A preliminary examination of Langley's bolometric data on the solar spectrum. HAROLD D. BABCOCK. Mount Wilson Observatory.—Lack of laboratory data forced Langley to omit a discussion of the identification of the solar lines measured on his bolographs. Using modern photographic and bolometric results for laboratory spectra, his table of wave-lengths has been examined, especially in the region λ8500 to λ17000. The average deviation between Langley's solar wave-lengths and the corresponding values in the laboratory is 2 or 3A in the region now photographically accessible. Allowing some increase in this for $\lambda > 10500$A, provisional identifications are found for 43 lines in Langley's list, belonging chiefly to the lighter alkalies and alkaline earths, with a few lines of hydrogen, aluminum and metals of the iron group. From the abundance of the elements involved and the series relations of the particular lines, most of the identifications are obviously to be expected. The apparent absence of certain lines is explained. Assuming the identifications to be correct, the average uncertainty in Langley's list is about 4A for the region examined. For a few lines it is much greater. Further study of the Smithsonian results will be profitable.

33. On measurable functions of dynamical variables. BENEDICT CASSEN, California Institute of Technology.—In matrix mechanics the measurable variables of a dynamical system are represented by Hermitian matrices. If tH is the transposed matrix to H and cH is its conjugate, then if H is Hermitian, $tcH = H$. If K is another Hermitian matrix then $tc(HK) = t(cHcK) = tcKtcH = KH$ so that if HK is to be Hermitian we must have $KH = HK$. That is, if the product of two measurable variables is measurable, those variables must commute. As $tc(H+K) = tcH + tcK = H + K$, the sum of two measurable variables is a measurable variable. For a single particle, if $P_1, \cdots, P_4$ represent the momenta and $Q_1, \cdots, Q_4$ the coordinate then the most general measurable functions of these variables can be put in the form $f(P_1, \cdots, P_4) + F(Q_1, \cdots, Q_4)$ where f, F are any real functions.

34. Electric fields near the surface of tungsten wire of small diameter. C. C. LAURITSEN AND S. S. MACKEOWN, California Institute of Technology.—The thermionic current from tungsten wire of 0.00156 cm diameter was measured with electric fields as high as 2×10^6 volts per cm. From these data information regarding the electrostatic field existing outside a conductor could be obtained. The results indicate that for distances greater than 3×10^{-7} cm the magnitude of the field is given quite accurately by the image force equation, but that at distances less than this the field is smaller than that calculated from this equation. The field very close to the surface seems to depend upon the temperature of the wire, being less for higher temperatures.

35. An ultra-violet photometer. ROBERT C. BURT, R. C. Burt Laboratory, Pasadena.—An instrument is described which consists of a fused quartz photoelectric cell connected to a portable galvanometer and supplied with a series of filters of different cut-off limits. (2000A, 2540A, 3080A, 3220A, 3300A, 3350A). Due to the fact that the long wave-length limit for these cells is below the red, no correction need be made for different transmissions in the infra-red, of the filters. Also larger differences are obtained than if thermo-junctions are used. A thermopile is also described for use in calibration and for measurement of the total radiation.

36. On the widths of σ-type doublets in molecular spectra. J. H. VAN VLECK, University of Minnesota, and R. S. MULLIKEN, New York University.—These widths are calculated with quantum mechanics by one of the writers with two methods, using respectively Hund's couplings (a) and (b) as unperturbed systems. ^1P terms should exhibit a doubling varying as $j(j+1)$, and ^1D terms very weak doubling varying as a higher power of j, agreeing with Kronig's statement (Zeits. f. Physik, **46,** 820) that the effect is a perturbation of order 2σ. Including now the spin, the coupling between the components of s and l perpendicular to the figure axis induces transitions $\Delta\sigma_l=-2$, $\Delta\sigma_s=+1$ from $\sigma=\frac{1}{2}$ to $\sigma=-\frac{1}{2}$ in the angular momentum. If predominant this makes the $^2P_{1/2}$ state show a doubling varying as j, and $^2P_{3/2}$ only a higher order effect. This agrees nicely with experiment, especially in that wide multiplets (e.g. HgH), which involve relatively great coupling between l and s, show much greater doubling of $^2P_{1/2}$ than do narrow multiplets (e.g. MgH). The pronounced doubling of $^3P_0$ terms in wide triplets should be independent of j, as regardless of the rotation there are two different orientations of $s=1$ and l which give $\sigma=0$. The greater doubling of always the level with lower σ furnishes a convenient clue whether observed multiplets are regular or inverted.

37. The non-metastability of the 2s level in atomic hydrogen. V. ROJANSKY AND J. H. VAN VLECK, University of Minnesota.—The $2s$ level of H is generally considered metastable, as apparently the transition down to $1s$ violates the selection principle. However, Dirac's quantum theory of the electron shows that the $2s$ and $2p_{1/2}$ levels have exactly the same energy. Hence they form a degenerate pair, and may be scrambled together in an infinite variety of ways. In the absence of an external field any linear combination of their wave functions can be taken equally well as a proper solution of Schroedinger's equation, and only one out of an infinity of possibilities (viz., the one in which the coefficient of the $^2p_{1/2}$ part is zero) gives non-combination with $1s$. If the degeneracy is removed by a constant external electric field F, the $2s$, $^2p_{1/2}$ states are, in fact, transformed into a pair of levels whose separation is proportional to F and whose transition probabilities down to $1s$ are equal. The fact that absorption measurements of Ornstein, Zernike, and Snoek, Jr. (Zeits. f. Physik, **47,** 627) indicate $2s$ is not metastable, can thus be explained without supposing collisions of the second kind hurl atoms from $2s$ to $2p$ states. Because of the degeneracy of fine structure components with like j-values, the hydrogen spectrum should show a linear Stark effect even in weak fields, and this is calculated.

38. The ballistic method of ionization measurement with a quadrant electrometer DAVID L. WEBSTER AND ROBERT M. YEATMAN. Stanford University.—In the ballistic use of an electrometer, for ionization measurements, the chamber is exposed to rays for a predetermined time, and the reading ordinarily taken is that of the electrometer after it stops swinging. The present method, more strictly ballistic, is to read the farthest point of swing. This not only saves time, but avoids serious complications from insulation leakage. The validity of this method depends on 4 conditions: (1) linearity of the differential equation of motion; (2) its homogeneity, except for the term proportional to the ionization; (3) initial conditions, deflection and velocity zero; (4) constancy of exposure time. (4) is readily satisfied; (3) and (2) demand cancellation of natural ionization by a constant opposite current; (1) is the most questionable. The present tests, on an electrometer of 12 seconds period with exposures from 2 to 40 seconds, demonstrates the possibility of satisfying all these conditions, so that the strictly ballistic method has no systematic errors large enough to detect in the presence of a 1% erratic error. For large deflections, ballistic applications of a potentiometer show departures of about 1% from linearity, but even then, calibration by the potentiometer enables this electrometer to compare ionization currents accurately.

39. An extension to the photographic study of the infra-red solar spectrum. HAROLD D. BABCOCK AND W. P. HOGE. Mount Wilson Observatory.—Nearly fifty years ago Abney photographed absorption lines in the solar spectrum out to λ9867. Although the bolometric observations of Langley and Abbot reveal hundreds of lines beyond Abney's limit, no photographic record appears to have shown them. Using emulsions containing neocyanin prepared by Dr. C. E. K. Mees, the coarser features of the solar spectrum have been photographed out

to λ11760 with a prism spectrograph, yielding measurements on 25 lines beyond λ10000. With a concave grating giving a dispersion of 4.75A per mm, 52 lines have been measured between λ9867 and λ10925. A new region over 1000A wide is thus photographically accessible with instruments of greater resolving power than that previously used in the infra-red, while with low power spectrographs nearly 2000A can be added to the photographic range. The study of this region is part of a detailed examination of the solar spectrum beginning at λ6900 which is now in progress, in the course of which nearly 400 lines previously unrecorded have already been measured. The fourth member of the Ritz-Paschen series of hydrogen, λ10049, has been positively identified in the sun, where it is wider than $H\alpha$, though probably not so black.

40. The function of a horn in acoustics. MARCUS O'DAY, Reed College.—Webster, in laying the basis for his theory of horns, sets up the equation of continuity for a varying cross-section but uses the ordinary equation of motion $\partial p/\partial x+\rho\partial u/\partial t=0$. Here p = pressure, S = cross-section, u = particle velocity, ρ = density. The writer points out that this is a point relation and that by the same method as used by Webster for derivation of the equation of continuity, he gets as the equation of motion $\partial(pS)\partial x+\rho\partial(uS)/\partial t=0$. Elimination between this and the equation of continuity gives as the equations of propagation $\partial^2(pS)/\partial t^2=c^2\partial^2(pS)/\partial x^2$ and $\partial^2(uS)/\partial t^2=c^2\partial^2(uS)/\partial x^2$. Thus for an infinite horn the amplification is independent of the particular manner in which the horn flares. The function of a horn therefore seems to be that of a pure resonator.

41. Interference of reflected light. PAUL S. EPSTEIN California Institute of Technology. It is well established that the molecules, atoms or free electrons of a mirror casting back light are in a state of molecular agitation. We are, therefore, inclined to expect this motion to influence the reflected light. If the incident light is of high spectral purity the thermokinetic effect of the mirror might decrease the purity and make the range of interference shorter. An experiment recently tried by Rocard and de Rotschild had, however, a negative result: after six reflections from a silver mirror the range of interference was not appreciably reduced, though these physicists expected it to fall to one fourth of its original value. In view of this a theoretical investigation of the properties of reflected light was undertaken. A straightforward computation leads to the result that molecular agitation has no influence either on the frequency or the phase of reflected light, provided that the reflecting layer is thin compared with the range of interference. The result of Rocard and de Rotschild is, therefore, in agreement with theoretical predictions.

42. Photoelectric control with mirror reading instruments. KARL LARK-HOROVITZ AND GEORGE W. SHERMAN, Purdue University.—Constancy of a measured quantity is maintained by using mirror reading instruments combined with photoelectric (or selenium or Thalofide) cells in the following arrangement: a beam of light of a certain width is reflected from the mirror unto a photoelectric cell; any deviation from a definite position through fluctuations in the quantities measured cause changes in photoelectric current (p.c.). These changes in p.c. operate by means of a triode a relay and start mechanical devices compensating the fluctuations. The cell is shielded by a plate with three divisions: one side being completely transparent, the other side being completely light tight, whereas the middle part allows only one half of the incoming light to pass through. The photoelectric cell is placed so that the position of the mirror to be maintained corresponds to the middle part of the plate; deviating to either side cause then changes of the p.c. in opposite directions. Using a Weston "zero center and galvanometer" relay one single cell is then sufficient to compensate fluctuations in any direction correlating in a unique way deflections of the mirror and p.c. The temperature of electric furnaces has been controlled with thermocouple and galvanometer: an actual fluctuation of 80°C (at 600°C) was eliminated to less than 1°C. The high tension in an x-ray circuit can be controlled using a high tension electrometer with the cell to regulate the primary impedence compensating any fluctuations occurring on the high tension side.