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PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY

MINUTES OF THE PHILADELPHIA MEETING

DECEMBER 28, 29, 30, 1926

The twenty-eighth Annual Meeting (the 142nd regular meeting) of the American Physical Society was held at the University of Pennsylvania, Philadelphia, Pennsylvania, on Tuesday, Wednesday, and Thursday, December 28, 29, and 30. The presiding officer was Professor Dayton C. Miller, President of the Society. The average attendance was about three hundred.

The annual joint session with Section B was held on Tuesday afternoon, with Professor William Duane, Chairman of Section B, presiding. The retiring Vice-President, Professor H. M. Randall, opened the joint meeting with an address entitled "Infra-Red Spectroscopy." This was followed by an address by Professor W. F. G. Swann on "The New Quantum Dynamics," and discussion of this topic by Dr. G. Breit and Professor J. H. Van Vleck. The attendance at this session was about four hundred.

On Wednesday evening, December 28, there was a dinner for the members of the Society and of Section B and their friends at the Hotel Bartram, attended by two hundred and four persons.

Annual Business Meeting.—The regular annual business meeting of the American Physical Society was held on Wednesday morning, December 29, 1926, at eleven o'clock. A canvass of the ballots for officers resulted in the elections for the year 1927 as follows:

For President;	K. T. Compton
For Vice-President;	Henry G. Gale
For Secretary;	Harold W. Webb
For Treasurer;	George B. Pegram
For Member of the Council, Three-year term;	Raymond T. Birge
For Members of the Council, Four-year term;	Paul D. Foote G. W. Stewart
For Members of the Board of Editors of the Physical Review, Three-year term;	G. Breit P. W. Bridgman L. W. McKeehan

The Secretary reported that during the year there had been 154 elections to membership. The deaths of 6 members had been reported during the year, 34 had resigned and 21 had been dropped. The total membership, including those newly elected, was 512 Fellows and 1341 Members, making a total of 1853.

The Treasurer presented his financial report for the year 1926. The Managing Editor presented the financial report for the Physical Review for the year 1926. In his report of the condition of the Review he stated that it had shown a loss for the past year, and was probably facing losses in future years. The financial reports were ordered printed and distributed to the members.

To enable the Society to provide adequate support for the Physical Review in future years, the Treasurer, on behalf of the Council, introduced the following resolution: *Resolved: That Article I, Section 1, of the By-laws be amended to read "The annual dues of fellows shall be fourteen dollars and of members ten dollars, payable on the 1st of January," this amendment to take effect January 1, 1928.* This resolution was passed by 44 affirmative votes to 7 negative.

Meeting of the Council.—At the Meeting of the Council held on December 28, 1926, three persons were elected to Fellowship, three were transferred from Membership to Fellowship, and twenty-nine were elected to Membership. *Elected to Fellowship:* F. W. Goucher, Karl F. Herzfeld, Fritz Zwicky. *Transferred from Membership to Fellowship:* Hugh L. Dryden, Carl H. Eckart, Francis D. Murnaghan. *Elected to Membership:* William H. Abbitt, Kenneth T. Bainbridge, Garnett F. Barnes, David G. Bourgin, Katherine Chamberlain, J. Davidson, Jr., Sophie W. Eldridge, C. W. Gartlein, Daniel E. Harnett, Marshall C. Harrington, Jos. E. Henderson, J. H. Hsu, Karl H. Hubbard, Carl Kenty, John J. Livingood, John B. Miles, Jr., L. W. Moench, P. M. Morse, Sister Mary S. Murray, Carl A. Pearson, R. J. M. Raven-Hart, C. M. Slack, Arthur P. Tanberg, W. Norris Tuttle, A. H. Wait, Harvey E. White, R. M. Williams, B. S. Woodmansee, W. Morris Young.

The regular program of the American Physical Society consisted of 77 papers, Numbers 1, 5, 11, 12, 17, 18, 19, 27, 43, 49, 50, 53, 66, 68, 70, and 73 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 absorption of beta-rays. J. A. GRAY and B. W. SARGENT, Queen's University.—An examination has been made of the absorption of the β-rays of radium E and uranium X in carbon, aluminum, copper, tin and lead. The former rays have the following approximate relative ranges (expressed in grams per cm^2), in these substances, viz., 62, 64, 71, 89 and 100. For the β-rays of uranium X, the corresponding numbers are 78, 81, 82, 95 and 100. As the relative ratios of atomic weight to atomic number are 79, 82, 87, 94 and 100, the experiments indicate that the energy lost in an atom by the β-rays of uranium X is, on an average, proportional to the atomic number.

2. A new theory of the origin of the actinium series. T. R. WILKINS, University of Rochester.—It is suggested that the variation of tne radii of pleochroic haloes in rocks of various geological ages can be explained if the actinium series is considered as coming from an isotope of uranium I (actino-uranium I) whose decay-constant is several times that of uranium I. These parent isotopes are assumed to have been in radioactive equilibrium originally but in geological time actino-uranium has largely disappeared and today forms but several percent of uranium. From a study of haloes, conclusions are drawn regarding the decay-constants of actino-uranium and the time since equilibrium. On the basis of such a theory, a considerable fraction of uranium lead would be due to actinium and the ages of rocks calculated either from lead or helium content will be in error—probably as much as 40% in the case of the oldest rocks.

3. Possible dependence of frequency of characteristic x-radiation on the temperature of the target. J. H. PURKS and C. M. SLACK, Columbia University.—Recent papers by H. S. Read (Phys. Rev. April and Nov. 1926) indicate that the absorption of x-rays depends upon the temperature of the absorber. This result has been interpreted as possibly due to a shift of the K absorption limit through about 11 volts. At the suggestion of Prof. Bergen Davis we have investigated a possible change of frequency of Mo $K\alpha$ with the temperature of the target. Water-cooled and standard Coolidge tubes were used. The energy was such as to make the target of the second tube white hot, the temperature being well over 1000°C, though it was not measured because of negative results. Narrow slits were used and narrow rocking curves obtained. Peaks could be located to 2 seconds of arc. The reflecting angle of calcite crystal for Mo $K\alpha$ is about 24000 seconds, hence there is no change of 1 part in 12000 due to temperature. If the K limit is shifted as Read's results indicate, it may be due to a destruction of the outer levels of the atom without any appreciable change in the (K-L) difference.

4. Investigation of metal films by x-ray analysis. KARL HOROVITZ, International Research Fellow, University of Chicago.—Using the focussing x-ray vacuum spectrograph described some time ago ("Science," Sept., 1926), a method was developed of investigating metallic films deposited on glass and other surfaces in a high vacuum by any kind of atomic rays. The metallic films are then analyzed directly where they are originally formed without changing the vacuum or contaminating the metals with gases. Deposits of potassium have been investigated at liquid air temperature. Very thin, coloured or black layers did not yield a diffraction pattern. Potassium mirrors about 0.15 mm thick gave a diffraction pattern corresponding to a body centered cubic lattice $a=5.15$. Other metals and different methods of forming the deposits are now being studied.

5. The polarizing angle for x-rays. C. S. BARRETT and J. A. BEARDEN, University of Chicago (Introduced by H. G. Gale).—The classical theory of x-ray scattering predicts 90° for the polarizing angle of scattering from either an electron at rest or an electron moving with the final velocity of the quantum process. Intermediate velocities, as postulated in the quantum theories of Jauncey, Compton and Woo, give a polarizing angle of less than 90° and dependent upon wave-length. Dirac (Proc. Roy. Soc. **A112**, 405 (1926) predicts 90° on the basis of the new quantum dynamics. Previous experimental determinations of the angle have not been decisive. Using filtered radiation from a tungsten x-ray tube operated at 190,000 volts the polarization angle was measured by the ionization method. With wave-lengths of 0.215, 0.24, and 0.37A (as measured by absorption) the polorizing angle was found to be 90° 30′, 91° 20′ and 90° 50′ respectively. Thus within the probable experimental error no shift from 90° or dependence on wave-length was observed. This is in agreement with the new quantum dynamics but not with the theories of Jauncey or Compton-Woo, which predict 83° 53′ and 84° 10′ respectively as the polarizing angle for 0.215A.

6. X-ray coloration of kunzite and hiddenite. P. L. Bayley, University of Rochester.—Absorption curves have been obtained from 2000 to 300 mμ for a pink sample of kunzite and a yellow green sample of hiddenite both before and after exposure to x-rays. The kunzite had only one weak wide absorption band at 540 mμ. The hiddenite had bands at 1670, 1000, 630, 438, 432, 378, and 368 mμ. After x-ray treatment, the hiddenite showed only a slight increase in absorption below 440 mμ. However, the x-rays colored the kunzite very similarly to the hiddenite but slightly more bluish green (as has been noted by others). Bands which were not present before radiation occurred at 910 and 625 mμ. The positions of maximum transmission were 730 and 540 mμ which were nearly identical with those of hiddenite. No trace of the hiddenite bands below 500 mμ could be found in the radiated kunzite. The fact that by x-radiation there can be produced in kunzite absorption in the region 1250 to 450 mμ which is so similar to that of hiddenite, would suggest that the green color in both materials is due to a similar physical cause. The methods of production need not have been similar.

7. X-ray diffraction measurements on some of the pure compounds concerned in the study of Portland cement. E. A. Harrington, Bureau of Standards.—Using the powder photographic method of x-ray analysis the crystal symmetry, lattice constants, and densities of Al_2O_3, Fe_2O_3, $Ca(OH)_2$, $3CaO \cdot Al_2O_3$, and $5CaO \cdot 3Al_2O_3$ have been determined. The values found for CaO, $CaCO_3$, and SiO_2 are added to complete the list of cubic, hexagonal, and rhombohedral crystals of important compounds in Portland cement research.

8. The crystal structure of magnesium di-zincide. James B. Friauf, Carnegie Institute of Technology.—Crystals of the intermetallic compound, $MgZn_2$, were prepared and the crystal structure was determined from x-ray data furnished by Laue and rotation photographs. The crystal was found to have hexagonal axes with $a=5.15$A and $c=8.48$A. The unit cell contains four molecules. The effect of absorption in the crystal in determining the wave-length giving a maximum intensity of reflection in Laue photographs was used to confirm the dimensions of the unit cell. The atoms have the positions:

Zn: $u, \bar{u}, 1/4; 2\bar{u}, \bar{u}, 1/4; u, 2u, 1/4; \bar{u}, u, 3/4; 2u, u, 3/4; \bar{u}, 2\bar{u}, 3/4; 0, 0, 0; 0, 0, 1/2$

Mg: $1/3, 2/3, v; 1/3, 2/3, 1/2-v; 2/3, 1/3, 1/2+v; 2/3, 1/3, \bar{v}$.

Where $u=0.830$ and $v=0.062$. The magnesium atoms have very nearly the arrangement that has been proposed by Bragg for the oxygen atoms in ice. The least distance between two magnesium atoms is 3.15A, between two zinc atoms, 2.52A, and between a magnesium and a zinc atom, 3.02A.

9. The relative probabilities of the photo-electric emission of electrons from Ag and Au. F. K. Richtmyer and L. S. Taylor, Cornell University.—Data previously reported by one of us (F. K. R., Phys. Rev. January, 1926) indicated that the ratio, R_L^K, of the number of $K+L+M+\cdots$ photo-electrons to the number of $L+M+\cdots$ photo-electrons decreases from about 7.5 in the case of Mo to about 5.1 in the case of Pb. These data were approximate and were not in agreement with any of the existing theories. The theories of J. J. Thomson and of de Broglie require values of R_L^K large than above and increasing more rapidly with *decrease* in atomic number. The theory of Kramers requires values of R_L^K of about 5.1 and *independent* of atomic number. More careful data has now been taken through the K absorption limit of Ag and Au, using narrow slits (about 5 x-units wide). The magnitude of the discontinuity in the mass absorption coefficients through the limit is determined with a precision of one percent. But the value of R_L^K computed from this discontinuity depends entirely on the magnitude of the correction for scattering. If a mass scattering coefficient, σ/ρ, of 0.8 be assumed for both Ag and Au, the value of R_L^K is 6.4—independent of atomic number as required by Kramers, but larger than predicted by him. If the Thomson (classical) value of σ/ρ be assumed (i. e., $\sigma/\rho=0.2$), then R_L^K for Ag is 6.0 and for Au is 4.4. Values of R_L^K cannot be determined unambiguously until better data on scattering coefficients is available.

10. A possible relation between radiation and ionization potentials of iron. OTTO STUHLMAN, University of North Carolina.—The critical potentials of iron, found in recent investigations by Thomas, Chu and Richardson and by Chalkline claim to possess the following term values in common, $M_{II\ III}$ at 54 volts, M_I at 93 volts and L_{III} at 706 volts. If we agree to retain the following (I) potentials, 11.1, 19. 4, 41.2, 54.6, 103.5, 169.4, as determined by Thomas and new (I) potentials of 5.72, 7.29, 11.14, and a (R) potential at 8.14 volts, then all critical (R) potentials published can probably be attributed to multiple impact.

11. The 29 volt critical potential of hydrogen. ROGERS D. RUSK, North Central College.—Low voltage arc characteristics for varying anode distances and gas pressures have been measured in hydrogen using a special tube containing two hot filaments and two nickel anodes. Striking and breaking potentials of one arc were observed when the region of that arc was illuminated by the glow from the other arc in the same tube at pressures below 0.2 mm. With increasing intensity of illumination the arc could be struck with great regularity at potentials down to the minimum maintaining potential for any given filament current, anode distance and gas pressure, but never lower. The lowest maintaining potential for the type of glow observed was 29 volts and it is suggested that this represents primarily a molecular excitation level capable of sustaining intense cumulative ionization and having a critical excitation period of the order of 10^{-8} sec. as indicated by the quenching effect of pressure change.

12. Spectral intensity distribution in a hydrogen discharge. E.W.TSCHUDI, Winthrop College, Rock Hill, S. C.—A cold-cathode discharge tube has an auxiliary tube attached from which cathode rays are projected against the main cathode. A photo-electric cell, attached to a monochromatic illuminator, is used to measure relative intensity distribution of H_γ and H_δ, respectively, from the main cathode through the cathode dark space into the negative glow with and without excitation of the auxiliary tube. When the main cathode is bombarded by the electron stream the intensity of spectral illumination in the negative glow is increased by about 20 percent. This increase does not result from the mere addition of an illumination which appears when the auxiliary tube is alone excited to the illumination of the main discharge, but may be attributed to the production of soft x-rays in the gas which are capable of exciting the gas molecules.

13. Excitation of spectra by atomic hydrogen. F.L. MOHLER, Bureau of Standards.—Hydrogen from a Wood discharge tube flowed into a tube containing metal vapor and the spectrum emitted by the mixture was photographed. Observations of Bonhoeffer (Zeits. f. Phys. Chem., **116**, 391 (1925)) with sodium and mercury are confirmed. Sodium and cadmium gave strong emission of their first resonance lines and no other lines or bands. Potassium showed the first resonance line faintly. Mercury gave the complete hydride band spectrum and also faint emission of the resonance line at 2537A. Caesium, magnesium, thallium and zinc gave no line or band spectra. The excitation energies of the observed lines and bands are, except for 2537 of mercury, less than 3.8 volts though many lines of lower energy did not appear. There are two possible explanations of the radiation. The metal atom may be excited in a three body collision with two hydrogen atoms. In this case the entire energy of recombination of hydrogen, 4.38 volts, should be available for excitation. The second possibility is that first a hydride is formed and that this reacts with H to form H_2 and an excited metal atom. The available energy of excitation is the energy of recombination of H minus the energy of formation of the hydride. The second theory seems to offer the best explanation of the observations.

14. The absorption of ultra-violet light by organic vapors. Alpheus W. Smith, Cecil E. Boord and C. S. Pease, Ohio State University.—This paper gives a preliminary report of work being done on the absorption by organic vapors in the ultraviolet. An aluminum under-water spark served as a source of continuous radiation. The spectra were photographed by means of a Hilger E2 quartz spectrograph and the vapors were inserted between the source of light and the slit of the spectrograph in glass tubes with quartz ends. The intensities of the absorption lines were determined by a Moll microphotometer. The following vapors have been studied,—benzene, diethyl ether, methyl normal amyl ether, and ethylene chlorohydrin. In each case the absorption spectrum consists of four or more prominent bands which are resolved into a number of lines of varying intensities. The photographic records from the microphotometer show that these bands are very similar in structure. Each band consists of a very prominent line with neighboring lines of less intensity lying on the side of the longer wave lengths. The observed lines are broad and also shaded toward the longer wavelengths. They have the appearance of unresolved band spectra. The most prominent of these lines lie at approximately $\lambda = 2590A$, $\lambda = 2530A$, $\lambda = 2470A$ and $\lambda = 2420A$. The intensity of the absorption changes with the composition and structure of the compounds. The other characteristics of the bands remain essentially unchanged.

15. New series in the spectrum of fluorescent iodine. F. W. Loomis, New York University.—Several new series are found in Wood's spectra of fluorescent iodine and their constants (d and γ) are measured. From these, $\bar{n}$, the vibrational quantum number of the fluorescent molecule before excitation, (taking $\bar{n}_0 = 0$ for simplicity) is calculated and in each case comes out nearly integral. Most of the series extend into the antistokes region as far as the order $p = -\bar{n}$. None of them extend further. Moreover the frequency of the origin of the band to which the resonance line of each series belongs, when calculated from d and the writer's values of the constants of the iodine absorption spectrum, agrees well, in every case, with the origin of a known band whose n'' is equal to the $\bar{n}$ previously calculated for the series. These results confirm the reality of the series and yield values of n' and n'' for each doublet in it. A plot of (n', n'') for all the fluorescent doublets which have been identified, suggests that the intensity diagram would show a pattern having maxima along roughly hyperbolic curves, analogous to that found by Birge for the β bands of nitrogen. Several of the fluorescent series have the same n' but very different m''s. Comparison of their intensities suggests that relative probabilities of transition do not appreciably depend on m'.

16. On the infra-red spectrum of mercury. Vladimir P. Lubovich, University of Colorado.—In the paper by McLennan and Shaver an account was given of a photographic investigation of the mercury spectrum from $\lambda = 6908A$ to $\lambda = 11137A$. The spectrum was photographed in the first order of a diffraction grating, higher orders being cut off with Wratten filter No. 22. The present work seems to prove that due to a transparent filter and incorrectly measured wave-lengths, higher order lines were ascribed to the infra-red spectrum. The conclusion is reached partly through the analysis of McLennan and Shaver's work, partly by means of a new photographic study of the mercury spectrum with a prism instrument. The investigation also includes the measurement of wave-lengths up to $\lambda = 13670A$. Beyond this limit four more lines are detected, the last one being in the neighborhood of $\lambda 27000$A. Nineteen lines are identified photographically apparently for the first time. Among the newly photographed lines the line $\lambda = 10141$A was suggested by McLennan and Shaver to be a doublet. The present work verifies the original observation of Paschen that it is a single line. In view of the contradictory results of previous investigations regarding the absorption of $\lambda = 10141$A by non-luminous mercury vapor the author reexamines this question with a result which confirms the conclusion of McLennan and Shaver that no absorption exists.

17. Absorption spectra in the extreme ultra-violet. J. J. Hopfield, University of California.—Absorption spectra of nitrogen, air, acetylene, and carbon monoxide have been obtained with widely varying pressure. They show selective absorption and a region of continuous absorption on the short wave-length side. This region again shows selective absorption and abounds in maxima and minima when low enough pressures are used. Acetylene shows band absorption beginning at $\lambda 2300$. At lower pressures maxima of absorption are found at $\lambda\lambda 1520$, 1480, 1430, and many other both narrow and wide bands to $\lambda 1000$. Nitrogen shows besides the bands already found by Sponer strong continuous absorption beginning at $\lambda 990$. Absorption occurs in the discharge tube also. The principal lines of the four ultra-violet series of N I are thus observed, and a group of lines $\lambda 1085$ due to ionized nitrogen. A few carbon lines were found when CO was used. These are probably the resonance lines of this element. The Cameron bands of CO are found in absorption and prove directly that these arise from the normal state. 0–0 to 0–4 are observed. Four or five bands of an apparently new system in CO begin with either $\lambda 1696.9$ or 1664.4 as the 0–0 band, and continue with $\lambda\lambda 1634.0$, 1604.9, and 1577.6 as consecutive members.

18. The ultra-violet band spectra of nitrogen. R. T. Birge and J. J. Hopfield, University of California.—The ultra-violet nitrogen system previously analyzed by us (Nature **116**, 15 (1925)) has been greatly extended to include 60 bands between $\lambda 1250$ and $\lambda 2025$. More accurate measurements prove that the assignment of this system to NO is unjustified. Moreover, it has now been found by Sponer (Nature, in press) in absorption in cold nitrogen. It is the resonance system of nitrogen, corresponding directly to the fourth positive group of CO. The other weaker progression found by Sponer in nitrogen, as we have since proved, is absorbed *only* in the discharge tube, and is in fact merely the usual absorption spectrum of CO. We have identified two other progressions of emission bands lying between $\lambda 1030$ and $\lambda 1520$. Both have the same lower electronic level as the above nitrogen system, and extend this level to $n = 18$. They locate two new electronic levels at 104,410 cm^{-1} and 103,660 cm^{-1}. The four electronic levels associated with the ultra-violet nitrogen systems are probably singlet levels, while the four levels associated with the familiar nitrogen systems are triplet. Transitions between the two types of levels are not in general to be expected, from theoretical considerations, and none have as yet been found in nitrogen.

19. Infra-red absorption by the N-H bond; in aniline and alkyl anilines. Joseph W. Ellis, University of California, Southern Branch.—The infra-red absorption spectra of aniline, five monoalkyl anilines and five dialkyl anilines have been recorded below 2.8μ by means of a self-registering quartz spectrograph. Prominent bands of absorption, occurring at 1.47μ and 1.04μ for aniline, appear with diminished intensity for monoalkyl anilines and disappear for the dialkyl anilines. A band at 2.8μ exhibiting changes, analogously to these two, has already been announced by F. K. Bell (J. Amer.Chem.Soc., **47**, 2192, (1925)). The frequencies in mm^{-1} of these three bands are expressible by the parabolic formula, $\nu_n = 375.8n - 18.3n^2$, and are believed to constitute a non-harmonic series of vibrations characteristic of the N-H bond. The series is analogous to one already attributed by the author to vibrations of the C-H bond. Two other bands, apparently associated with the presence of the N-H bond, occur at 1.20μ and 2.00μ

for aniline. The former is not detectable in the spectra of monoalkyl anilines because of overlapping bands, but the latter is shifted to 2.05μ. A quantum theory explanation is offered as to the origin of these bands on the basis of combinations of N-H and C-H frequencies.

20. A new method of determining the time of appearance as well as the time of duration of spectrum lines in spark discharges. J. W. BEAMS, National Research Fellow, and ERNEST O. LAWRENCE, National Research Fellow, Yale University.—Light segments a few centimeters in length obtained by a method described elsewhere (see previous abstract) emanating during various time intervals after the beginning of a spark discharge fall upon a very sensitive photo-electric cell. Plotting the observed photo-electric currents against the time intervals elapsing between the beginning of the spark and the production of the light segments, there are obtained curves having significant changes in slope. Abrupt increases in the photo-electric current determine the time of appearance of the various spectrum lines while decreases in the current indicate their disappearance. The above method is very reliable and gives the time of appearance of the spectrum lines with a high degree of precision.

21. The arc spectrum of germanium. C. W. GARTLEIN, Cornell University (Introduced by R. C. Gibbs).—The wave-lengths of the lines in the arc spectrum of germanium have been measured in the region above 1860A with an accuracy of at least 0.1A. From these measurements the relative energy levels have been worked out and the jumps corresponding to 56 lines have been identified. In the normal state the atom contains two (p) valence electrons which give rise to the lower levels ^3P, ^1D, ^1S, with the ^3P lying deepest, as is predicted by the theory of Hund. The next higher levels arise from the electron configurations (ps) and (pd). The energy levels have been correlated with the ultimate and persistent lines found by other investigators. The arc spectrum of Ge closely resembles the arc spectra of Si, Sn, and Pb.

22. Stages in the excitation of the spectrum of indium. JOHN G. FRAYNE, Antioch College, and C. W. JARVIS, Ohio Wesleyan University.—The indium metal was vaporized at a temperature of 650°C in an iron cylindrical anode within a quartz tube. Electrons from an oxide-coated Pt filament passed through a cylindrical grid into a force free space where they collided with the atoms of indium vapor. The spectrum was viewed end on through a transparent quartz window. At 3.3 volts the lines $2p_1-2s$ and $2p_2-2s$ appeared. At 4.2 volts the additional lines $2p_1-3d$ and $2p_2-3d$ appeared. At seven volts higher members of the series appeared. At 13.2 volts the spectrum became very intense and lines appeared in addition to the recognized series lines. At this potential a second electron may have been detached from the atom, assuming that ionization occurred at seven volts. At 23 volts many lines appeared in the visible and near ultra-violet but most of them have been recognized as air lines. Using voltages as high as 80 no other lines appeared. The lines from the $2p_1$ level were consistently stronger than those from the $2p_2$ level at temperatures ranging from 600° to 800° C. The latter level is considered to be the lowest and should give the strong lines of the spectrum.

23. On the spectra of boron. R. A. SAWYER, University of Michigan, and F. R. SMITH, Pennsylvania State College.—Spectra of boron in the region $\lambda\lambda$2300–5800 were obtained by the "vacuum spark" method, using electrodes of boron, and boron and carbon. The vacuum spark chamber was made of glass and so designed that considerable adjustment of the spark-gap could be made without opening the spark-box. The lines were photographed with a two-prism glass spectrograph and a Hilger 2E quartz spectrograph. After checking for impurities about ninety new lines were ascribed to boron. Starting with the term values of B I, B II and B III given by Millikan and Bowen, about twenty-five of these lines have been classified in series.

24. Energy level studies on metallic vapors using a high temperature tungsten furnace. O. S. Duffendack and J. G. Black, University of Michigan.—Following in general the method originated by Duffendack in 1922, an electrically heated tungsten cylinder is clamped horizontally between heavy water-cooled leads and enclosed in a large water-cooled copper cylinder provided with observation windows and containing pure hydrogen. An insulated U-shaped tungsten or molybdenum trough extends axially through the furnace and holds the material to be studied. Absorption studies on copper vapor yielded new absorption lines at 2618.37, 2824.39, 2882.81, 2961.19, 3010.87, 3194.09 and 5782.08 all originating in the metastable $^2D_{2,3}$ level in agreement with Shenstone's analysis, together with previously reported absorption lines and copper-hydride bands. The copper lines 3247, 3274, 5106, 5700, 5782 and several copper-hydride bands were obtained in emission. These five lines originate in the $2^2P_{1,2}$ level. Experiments proved that this state was reached by absorption of resonance radiation rather than by thermal excitation. No absorption lines originated in this level. The metastable $^2D_{2,3}$ level from which absorption lines were observed is reached by thermal action. These experiments were made principally to test the furnace. It is being adapted for investigations of resonance radiations, critical potentials, and other properties of elements at high temperatures. It compares favorably with other furnaces and avoids difficulties due to oxidation and impurities.

25. On the Zeeman effect and the structure of the arc spectra of Cu and Rh. L. A. Sommer, International Research Fellow, Harvard University (Introduced by E. A. Saunders).—Investigating the arc spectrum of Cu, Shenstone and the author are in agreement in the classification of the doublet term group ^2P, $^2\overline{D}$, ^2F which lies near the quartet term group ^4P, $^4\overline{D}$, ^4F, but reach different conclusions regarding the classification of the higher doublet term group ^2P, ^{2},$\overline{D}$ ^2F, and especially the term-groups *with negative term-values*. The author uses chiefly his own measurements of the Zeeman effect for the assignment of the terms, while Shenstone bases his designations mainly on line intensities. A more general formulation of the selection rule for k for jumps of one or more electrons is proposed. While the first (alkali-like) term-system (doublet-terms)corresponds to atomic states in which the 4_1 electron rotates around the rest of the atom with its ten 3_3 electrons, the second system (doublet and quartet-terms) is due to states in which the outer electron rotates around an inner shell consisting of nine 3_3 and one 4_1 electron. One set of lines in the visible is associated with the simultaneous transition of two electrons. Of about 660 measured lines of the Cu-arc more than half are combinations within or between the two term-systems. From the series limits it is found that the removal of the 3_3 electron requires a potential 10.9 volts, while the 4_1 is bound with the well-known potential of 7.6 volts. In the Rh spectrum 50 percent of the lines measured in the arc are arranged in a definite term-system by means of the Zeeman effect data.

26. Absorption spectra of iron, cobalt and nickel. W. F. Meggers, Bureau of Standards, and F. M. Walters, Jr., Carnegie Institute of Technology.—The underwater-spark absorption spectra, as well as the ordinary vapor absorptions, have been investigated by others, but not in sufficient detail in connection with the spectral structures for Fe, Co and Ni. Employing the apparatus and method described by Meggers and Laporte in the *Physical Review* for October, 1926, these spectra were reexamined throughout the visible and ultra-violet regions. Our spectrograms show 263 iron lines (2166 to 4404A), 340 cobalt lines (2137 to 4121A), and 225 nickel lines (2124 to 3858A) absorbed in the source. In each case, the majority of these are identical with the stronger lines of the arc-emission spectra, and practically all such lines are found to involve either the normal state or some low metastable state of the neutral atoms. The type of source used showed most of the metallic spark lines in emission but certain groups were present in absorption with low intensity. The latter involve the lowest energy states of the ionized atoms. With the aid of these data on absorption the known spectral structures for neutral and for ionized Fe, Co and Ni have been confirmed, and many new levels have been established.

27. Spectra of the high-current vacuum arc. Arthur S. King, Mount Wilson Observatory.—High-current arcs were used in a vacuum chamber at a pressure of about 5 mm of mercury, the arcs studied being those of iron, chromium, titanium magnesium, copper, and silicon, using electrodes of small diameter. The central vapor-stream of this arc, carrying 1500 amperes or more at 110 volts, is of intense brightness and shows a completeness of ionization usually obtainable only in high-potential sparks of very disruptive character. The spectrum is that of the ionized atom, lines of the second stage of ionization often appearing. The production of neutral-atom lines is evidently confined to the outer vapors of the vacuum arc, and only those arc lines which are little subject to broadening (usually low-temperature lines) retain sufficient density to register photographically. This arc is useful as a source of high excitation in a rarefied gas, operating without difficulty, and sufficiently bright to be photographed with high dispersion. The enhanced lines emitted, when of low energy-level in the ionized atom, usually show self-reversal, and in general the peculiarities of line-structure and the tendency to dissymmetry under high excitation are shown for enhanced lines in the same degree as the high-current arc in air shows these features for arc lines. These phenomena indicate the relative energy-levels and multiplet groupings of enhanced lines, also their degree of wave-length stability.

28. Some relations in the spectra of stripped atoms. R. C. Gibbs and H. E. White, Cornell University.—Starting with the known values of the arc and spark spectra of one electron systems in all three of the long periods it has been found possible, by using the regular and irregular doublet laws as guides, to recognize the first pair of doublets in the principal series for stripped atoms as far as $\mathrm{Mn_{VII}}$ in the first long period, $\mathrm{Zr_{IV}}$ in the second long period, and $\mathrm{Pr_{V}}$ in the next period. The first pair of inverted diffuse doublets with satellite have also been located for $\mathrm{Sc_{III}}$, $\mathrm{Ti_{IV}}$, and $\mathrm{V_{V}}$. These doublets possess very consistent frequency separations and the relative intensities of the lines are in agreement with the usual rule. Evidence is obtained indicating that in $\mathrm{Sc_{III}}$ we have the first instance, as originally predicted by Bohr, of a closer binding in a d orbit than in either a p or an s orbit. In fact, on the Moseley diagram the line for the $3d$ level crosses the lines for $4p$ and $4s$ levels in passing from $\mathrm{K_{I}}$ to $\mathrm{Sc_{III}}$. The relative closeness of binding of the $3d$ orbit becomes even greater in the case of $\mathrm{Ti_{IV}}$ and $\mathrm{V_{V}}$. The experimental data conforms very closely to both the regular and irregular doublet laws in the case of all first pairs of principal series doublets. Very consistent values for screening constants are obtained when the regular doublet law is applied to these doublets.

29. Two electron multiplets of the first and second long periods. H. E. White and R. C. Gibbs, Cornell University.—Three characteristic multiplets arising from two valence electron systems of the first and second long periods of the periodic table have been found to follow very well the so-called regular and irregular doublet laws. These multiplets are of the type $^3D_{1,2,3}-{}^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3D'_{1,2,3}$, and $^3D_{1,2,3}-{}^3F_{2,3,4}$, and have been extended in the first long period from $\mathrm{Ca_{I}}$ to $\mathrm{Cr_{V}}$, and in the second long period from $\mathrm{Sr_{I}}$ to $\mathrm{Cb_{IV}}$. The two electrons giving the above triplet levels are, in the initial state in $3d$ and $4p$ orbits while in the final state they occupy $3d$ and $4s$ orbits.

30. On metastable neon and argon. Richard Rudy, Research Laboratory, Nela Park.—The light from a Geissler tube (10 mm Hg, 100 mil-amp./cm^2) was sent through the positive column of a second tube (15 cm long, .007 to .05 mil-amp. cm^2). The absorption of 6402, one of the lines involving the metastable s_3 state, increased when the pressure was lowered from 8 mm downwards and beyond the minimum discharge potential. This absorption had no influence upon the volt-ampere characteristic ($<1/2$ per cent), the metastable states being reestablished after emission (resonance). Strong absorption was also found in the negative glow. Increase of temperature at constant density increased the potential gradient for currents <1 milampere by shortening the so-called life of the metastable states in the same proportion as it reduces the absorption in neon or mercury. Argon added to neon did not seem to change the absorption as long as the discharge was chiefly maintained by neon. The next higher group of lines $s_5\ 3p_9$, $s_5\ 3p_6$ etc. in argon are not absorbed (<4 percent) under conditions where $s_5\ 2p_9$ shows 90 percent absorption.

31. Low pressure electric discharge in intense electric fields. C. del Rosario, Bartol Research Foundation and Yale University.—Attempts were made to pull electrons out of a cold fine filament by means of the intense electric field produced at its surface when it is made the inner member of a cylindrical condenser. Most of the experiments were done in high vacuum of the order of 10^{-8} mm Hg as measured with an ionization gauge. The fineness of the filaments used ($5\times10^{-4}-10\times10^{-4}$ cm diameter) made it possible to obtain intense fields with smaller potential differences than those used by previous investigators. Different sizes of filaments were tried in order to dissect out the influence of the field and that of the potential difference on the current. Using a platinum-sputtered quartz filament, the platinum coating was torn off before electrons could be pulled out. With platinum filaments the field could be raised to 2×10^6 volts/cm without producing a current greater than 10^{-11} amp. The potential current curves of former observers could however be closely duplicated by admitting a little air into the apparatus. This fact together with the absence of any noticeable effect of the size of the filament on this curve suggests that the currents obtained by previous investigators may have been due to low pressure gas discharge.

32. A pseudo photographic effect of slow electrons. Jos. E. Henderson, Yale University (Introduced by W. F. G. Swann).—While using a magnetic spectrograph it was found that photographic plates subjected to a beam of slow moving electrons showed a dark line at the position calculated from the constants of the apparatus. This line was present on the plate even before development. In a further investigation 500 volt electrons were allowed to fall on different materials including glass, quartz, calcite, platinum, copper, nickel, silver, aluminum, zinc, lead and brass. The discoloration appeared on all of these. This discoloration seemed to be characteristic of the material being bombarded both as regards appearance and chemical behavior. The marking on the glass had a very metallic lustre but was readily attacked by strong alkalies. The line on the platinum was unattacked by the alkalies but was removed readily by aqua regia. The discoloration disappeared from the glass when it was heated above 450°C in air. From the nature of the apparatus it does not seem probable that a deposit could in any way be coming from the cathode. The apparatus employed gave an electron beam of comparatively high intensity, the current in the beam being several micro-amperes. Exposures of a few hours were necessary in order to get a good discoloration.

33. Quantum theory of the specific heat of hydrogen chloride. Elmer Hutchisson, University of Pittsburgh.—The new quantum mechanics indicates that the specific heat of simple dipole molecules like those of HCl may be calculated using half integer rotational and vibrational quantum numbers in the expression for the energy and using $p_m=2m$ for the a priori probability (Cf. J. H. Van Vleck, Phys. Rev., Nov. 1926). Recently Hicks and Mitchell have computed the specific heat of HCl at various temperatures and its entropy using energy levels obtained from band spectra data but with an a priori probability $p_m = 2m+1$. These values have been recomputed using the new quantum theory a priori probabilities. In this case it is found that the specific heat-temperature curve rises to a maximum above the classical value at about 12°K. There are not any experimental data at these low temperatures to confirm or contradict this maximum but at room temperatures the new specific heat curve agrees better with existing experimental values than that computed by Hicks and Mitchell.

34. A suggestion of an explanation of the long life of metastable atoms. G. BREIT, Carnegie Institution of Washington.—According to the recent theory of Schrödinger the term values of an atom are the characteristic values of E in his equation $[H, \psi] = E\psi$. The variable ψ when multiplied by its conjugate ψ gives the charge density. From this point of view the resultant electric moment of an atom due to the simultaneous presence of the states E_n, E_m is the element $q(nm)$ of the coordinate matrix q. The frequency of oscillation of the doublet is $\nu = 1/h(E_n - E_m)$. The above is Schrödinger's picture of radiation if $q(nm) = 0$. However, radiation may exist even in $q(nm) = 0$ corresponding to a coil aerial in radio for which the doublet also vanishes. Estimating the life of an atom on this basis, it is found to be of the order of almost a second. This is an agreement with the measurements [Dorgelo]. It is suggested, therefore, that the matrix mechanics represents only a first and rough approximation of the radiating properties of an atom and that Schrödinger's $\psi\bar{\psi}$ picture of electric charge density may be used to calculate radiation by means of classical formulas with retarded potentials even though matrix elements should vanish. A metastable atom is from this point of view analogous to a radio loop, while a non-metastable atom is analogous to an antenna.

35. Wave theory of the electron. W. P. ALLIS and H. MÜLLER, Massachusetts Institute of Technology.—The electron is considered as a wave of frequency $\nu = (mc^2 + eV)/h$ and wave number $\mu = c(m^2 - m_0^2)^{\frac{1}{2}}/h$ with which electricity is associated as energy is associated with an electromagnetic wave. Its group velocity $d\nu/d\mu$ is the velocity of the electron. The electricity is *always* "ether coupled." Uniform rectilinear motion or motion in certain orbits which are shorter than the wave-train are non-radiating. The quantum conditions are obtained as by de Broglie. The "quantum jump" is a continuous process in which charge gradually passes from the wave corresponding to the initial to that corresponding to the final state. During the process the waves form "groups" traveling with the velocity $\Delta\nu/\Delta\mu$ which obey the electromagnetic laws. In the Compton effect two plane waves form plane uniformly moving groups. The field must be zero on these groups. The scattered beam, superposed on the incident beam, is made to satisfy this condition and the conservation of energy and momentum relations result. In radiating hydrogenic atoms Δk groups move around the nucleus with the frequency $\Delta\nu/\Delta k$, and therefore radiate light of frequency $\Delta k \cdot \Delta\nu/\Delta k = \Delta W/h$. The indivisibility of the electron leads to the principle of selection.

36. The length of radiation quanta. ERNEST O. LAWRENCE, National Research Fellow, and J. W. BEAMS, National Research Fellow, Yale University.—Certain theoretical considerations of experimental facts lead to the conclusion that visible light quanta have lengths of the order of magnitude of 1 m. Closely allied to this conclusion, though quite independent of theory, is the length of time required for the photo-electric absorption of a light quantum by an electron, a time interval which has not been measured by experimental observation. By a refinement of a method previously described (J.O.S.A. & R.S.I., **13**, 597 (1926)) we have succeeded in producing flashes of light of the order of magnitude of 10^{-10} sec. duration, i. e., pulses of radiation a few centimeters in length. The average intensity of these flashes was roughly from a hundred to a thousand times greater than that of a 10 ampere arc. This fact in conjunction with a photo-electric cell of great sensitivity has enabled us to measure the photo-electric effects produced by these short pulses of light. Our results show that the magnitude of the photo-electric effect per unit incident energy is independent of the length of the light pulses, and therefore, that light quanta are less than 3 cms in length and electrons absorb radiation quanta photo-electrically in less than 10^{-10} sec.

37. Effect of a magnetic field on the dielectric constant. J. J. WEIGLE, University of Pittsburgh.—Assuming a molecule or atom possessing magnetic and electric moments perpendicular to each other the effect of a magnetic field on the dielectric constant has been calculated by the methods of the classical statistical dynamics. It is assumed that at high temperatures the classical theory leads to the same results as the new quantum dynamics. For the average electric moment in the direction of the electric field (perpendicular to the magnetic field) the expression obtained in the first approximation is $\mu^2E/3kT$ where μ is the electric moment, E the electric field intensity, k the Boltzmann's constant and T the absolute temperature. This expression is the same as that obtained if there were no magnetic field present and might explain the negative experimental results of L. Mott Smith and C. R. Daily (Phys. Rev. Nov., 1926). Thus it does not seem necessary to reject Langevin's theory of Paramagnetism as has been suggested (Huber Phys. Zeit. **27**, 619 (1926)).

38. The quantization of the rotational energy of the polyatomic molecule by the new wave mechanics. ENOS E. WITMER, National Research Fellow, Harvard University.—For the purpose of quantizing the rotational energy the polyatomic molecule may be regarded as a rigid body with three principal moments of inertia, A_x, A_y, A_z. Assuming A_z to be the greatest or the least of these three quantities, let $a=\frac{1}{2}(1/A_x-1/A_y)$, and $c=1/A_z-\frac{1}{2}(1/A_x+1/A_y)$. Then $a/c\leqq 1$. The new wave mechanics gives the following formula for the energy, E, as a function of the quantum numbers:

$$E=(h^2/8\pi^2)\{m(m+1)\tfrac{1}{2}(1/A_x+1/A_y)+n^2c+\textstyle\sum_{r=1}^{\infty}f_r(m,n)a^{2r}/(c^{2r}-1)\},$$

where $f_1=\frac{1}{8}[m^2(m+1)^2/(n^2-1)+2m(m+1)-3n^2]$:
The quantum numbers m and n are integers, and $n\leqq m$. The process of solution apparently enables one to determine as many of thecoefficients f_r as are desired. This formula is very similar to the one given by the classical quantum theory (cf. Witmer, Proc. Nat. Acad. Sci. October, 1926). The convergence of this series for values of a/c in the neighborhood of unity remains to be considered.

39. The significance and scope of the idea of frequency in physics. WM. S. FRANKLIN, Mass. Inst. of Technology.—Exponential (or periodic) solutions of the wave equation are essentially necessary when a bounded system is being considered; such solutions for extended media are merely simple and convenient. Periodic solutions for extended media are physically justifiable because wave disturbances generally originate in quasi-closed systems, and such solutions for extended media are useful because they are easily formulated mathematically and because the phenomena of dispersion, of interference and of diffraction are steady for periodic waves. The advent of the Bohr relation $W=h\nu$ raised the idea of frequency to an exalted position which was extremely puzzling from the physical point of view, and the Bohr relation accentuated the non-critical use of the idea of frequency which was widely prevalent before Bohr's theory came forth. The Schrödinger wave mechanics brings us sharply back to the recognition of frequency as an ideal, because Schrödinger's mechanics is based on a generalized wave equation of which the only mathematically feasible solutions are exponential solutions and because Schrödinger attempts to formulate only those solutions which originate in closed or quasi-closed systems.

40. Influence of temperature on selenium photo-sensitivity. ROBERT J. PIERSOL, Westinghouse E. & M. Co., E. Pittsburgh.—Previous results on the influence of temperature on selenium have covered a range above 0°C. Various investigators have interpreted these data as either due to metallic conduction or due to electrolytic conduction. Experiment has shown that the dark current of a certain selenium cell decreases from 1×10^{-3} amperes at room temperature to less than 5×10^{-10} amperes at liquid air temperature, while the light current (due to one hundred foot candles intensity) decreases from 6×10^{-3} amperes to about 5×10^{-3} amperes with the decrease in temperature. This points to the fact that the dark current is entirely due to thermal conduction. Since H. E. Ives has shown that on cooling potassium from room temperature to liquid air temperature, due to increase in work function, the photo-electric current is decreased about 25 percent; it would appear that the light current in selenium is due to photo-electric conduction. As noted, a selenium cell at liquid air temperature gives a ratio of 1×10^{7} between the current due to 100 foot-candles and the dark current, thereby forming the most sensitive photometric instrument known for the measurement of feeble light intensities.

41. Actino-electric effects in argentite. W. A. SCHNEIDER, Washington Square College, New York University.—Actino-electric effects are observed in argentite and it is shown that the seat of conversion of light into electronic energy occurs both at the contacts as well as at certain spots on the crystal. The effect is found to be absent if the crystal structure is destroyed. The actino-electric current-intensity curves show a peculiar secondary effect at certain intensities, varying for different samples, however. On investigation of the actino-electric e.m.f.'s with reference to varying times of exposure and constant times of recovery it is found that an exponential relation exists between them which can be represented by $i=ae^{-bt}$. The "b" however is not a constant but increases with time of recovery and is the determining factor in the dark current and photo-electric hysteresis of the crystal. It may be very intimately connected with the positive part of the primary photo-electric current as described by Gudden and Pohl.

42. Photo-electric emission as a function of composition in sodium-potassium alloys. HERBERT E. IVES and G. R. STILWELL, Bell Telephone Laboratories, Inc.—The entire series of alloys of sodium and potassium have been investigated with respect to the relative values of the photo-electric currents produced by light polarized with the electric vector in and at right angles to the plane of incidence. The pure metals when molten exhibit values below three for the ratio of the two emissions; the alloys show *three maxima* at compositions approximately 20, 50 and 90 atomic per cent of sodium, with values from 10 to 30 for the ratio; the minima between show low values approximating those for the pure metals. The maxima and minima of the ratio of emissions are due to complicated variations in magnitude of the two emissions compared.

43. Some properties of Geiger counters. R. D. BENNETT, National Research Fellow, Princeton University. (introduced by H. D. Smyth.).—In the course of an investigation of the properties of Geiger counters they were found to be sensitive under certain conditions to ultra-violet light. The points used were of the sphere type and of platinum. Apparently the action comes about by the release of a photo-electron from the surface of the sphere-point. The maximum effective wave-length was about 2725A, corresponding to a work function of 4.54 volts, nearly that for platinum. Measurement of the photo-electric effect from a platinum surface in air at atmospheric pressure indicated that the number of pulses recorded was of the same order of magnitude as the number of photo-electrons released. A measurement of intensities across interference fringes in the ultra-violet gave variations similar to those recorded by other methods. Photo-electrons from the wall of the chamber, positive ions or electrons from a filament at about 300°, or ions blown in with gas, have proved sufficient to excite this type of counter. The number of pulses recorded depends markedly on the applied potential and may vary fivefold within the active range of any particular counter. Counters of this type have been made having less than one "stray" per half hour.

44. The life history of an adsorbed atom of caesium. J. A. Becker, Bell Telephone Laboratories, Inc.—Previous work (Phys. Rev., August, 1926) indicated that when a caesium atom strikes a hot tungsten surface it may retain its valence electron, share it with the tungsten, or lose it completely. The adsorbed ions produce enormous changes in the thermionic and evaporation characteristics. A further analysis shows that the average life of an absorbed atom under equilibrium conditions is N/A, where N is the number of absorbed atoms and A the arrival rate. Both can be determined experimentally. When the filament is at 660°K and the arrival rate that corresponding to caesium at 20°C, the surface is completely covered and an atom stays on it for one second. For a temperature of 620°K, smaller arrival rate and complete covering the life is about one minute. At times "edges" separate the filament into two regions covered to about 1 percent and 15 percent. Several different experiments show that this edge must be about .03 centimeter wide. For part of this edge more caesium evaporates than arrives, and conversely. Hence atoms must move from one part of the edge to the other. Consequently the atoms must cover distances a million times their diameter.

45. Interpretation of data dealing with thermionic emission. W. R. Ham, Pennsylvania State College.—Equations for thermionic emission are of the form $i=AT^n\epsilon^{-b/t}$ the most commonly used values of n being $\frac{1}{2}$ or 2. The validity of this equation is determined by substituting values of i and T in the equation $\log i-n\log T+b/T=\log A$, and ascertaining whether a straight line is obtained when values of $\log i-n\log T$ are plotted against $1/T$. It is shown mathematically that a straight line may be obtained for all values of n from $-\infty$ to $+\infty$ including $n=0$ provided b is a suitable function of b_0 and T and therefore no improvement in accuracy of values of i and T or increase in their range can differentiate between various values of n. Hence to obtain a value of n experimentally, independent knowledge concerning A or b must be obtained. Using the value of b obtained calorimetrically by Davisson and Germer, together with their data for thermionic emission for tungsten, the equation $i=A\epsilon^{-b/T}$ is found to fit with great exactness. Values of b and A for certain other elements are computed on this basis. From a quantum standpoint according to Wien, a value $n=0$ demands that the concentration in metals of electrons available for thermionic emission at a particular T be relatively small.

46. Technique of the Dufour cathode ray oscillograph for the study of short time occurrences. G. F. Harrington and A. M. Opsahl, Westinghouse E. & M. Co., E. Pittsburgh (Introduced by C. E. Skinner).—In general, methods, circuits and procedure are set forth for using the Dufour plate-in-vacuum cathode ray oscillograph for studies of phenomena of such short time duration as to preclude the effective use of any other known oscillograph. Phenomena where such a method of analysis can be used to advantage are: dielectric breakdown in general, dielectric spark lag, characteristics of gaseous conduction, and behavior of electrical systems when subjected to surges. It is found that the time for the cathode beam to complete its path is so short that mechanical synchronizing devices are considered relatively unsatisfactory. Circuits are given for use in exciting the oscillograph, then initiating the transient condition to be recorded. It is also made possible to have voltage surges from the circuit being studied switch on the oscillograph and record themselves. The arrangement of apparatus is shown together with sufficient information so that it may be duplicated readily. Conditions and precautions are given for recording the coordinates that can be obtained conveniently with one cathode stream. These relations are: phase relations, voltage-time, current-time, voltage-current, voltage-current-time. The cathode ray oscillograph records these relationships accurately if proper care is taken with the circuits and checks and made to make certain that effects due only to the measuring circuits are eliminated.

47. A hot wire vacuum gauge. A. L. HUGHES and A. M. SKELLETT, Washington University, St. Louis.—A gauge was needed for following fairly rapid changes of pressure between .1 mm and .00001 mm. A 1-mil tungsten filament, 5 cms long, was mounted along the axis of a glass tube connected to the vacuum system. A current from a 4-volt storage battery was passed through the tungsten filament in series with an approximately equal and adjustable resistance R. With the highest attainable vacuum, the potential drop along the tungsten wire in the gauge was balanced against a 2-volt storage battery, using a galvanometer as an indicator, and varying R slightly to secure an exact balance. Using hydrogen to calibrate the gauge, it was found that the deviations from a balance were accurately proportional to the pressure over a range from .000007 mm to .28 mm. The lower limit can no doubt be decreased still further by taking special precautions to maintain constant conditions.

48. A new selective radiometer of molybdenite. W. W. COBLENTZ and C. W. HUGHES, Bureau of Standards.—Previous communications described samples of molybdenite having closely adjacent spots which generate positive and negative actino-electric current. Although practically no electric current is obtained on exposing the whole crystal to light either spot can be used as a radiometer. Recently discovered samples exhibit only one polarity, producing a large galvanometer deflection when the whole crystal is exposed to radiation of wave-lengths shorter than 1μ. In the darkened laboratory, connected with a d'Arsonval galvanometer, under a daylight illumination of 0.8 foot-candle the molybdenite crystal developed an e.m.f. equivalent to 1 f.c. $= 3\times10^{-6}$ volt. Connected with a high-resistance d'Arsonval galvanometer, deflections of 1.5 mm were observed in moonlight of only 0.008 f.c. Connecting the samples of molybdenite with a millivoltmeter, on exposure to the sun, under a normal illumination of 8,000 foot-candles, the deflection was 3 to 4×10^{-4} volt or 1 f.c. $=4\times10^{-8}$ volt; i. e., increasing the illumination intensity 8,000-fold decreased the intrinsic sensitivity about 130-fold. In spite of this lack of proportionality for high intensities (preventable perhaps by exposing only the most sensitive spot) this device has applications as a selective radiometer, rivaling the gas-ionic photo-electric cell in quickness of action and requiring no external battery.

49. The absorption of radio waves in the upper atmosphere. E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—The absorption of radio waves in the upper atmosphere, put to one side in the theory of Taylor and Hulburt because of its smallness, has been calculated on the assumption that it results from collisions between the electrons and molecules of the atmosphere. Formulas are derived for the dispersion and absorption of the variously polarized waves, and quantitative agreement is indicated with observed data of ranges and degradation of intensity with distance from the transmitter. It is pointed out that as these data become more extensive they may lead to more exact knowledge of the electronic and molecular pressures overhead.

50. Propagation of electromagnetic waves along co-axial cylindrical conductors separated by two dielectrics. N. H. FRANK, Massachusetts Institute of Technology.—A solution of the Maxwell equations for a harmonic electromagnetic wave propagating along co-axial cylindrical conductors separated by two dielectric media has been obtained. The velocity of phase propagation of this wave is given by

$$v^2=(c^2/\epsilon_1\epsilon_2)\ (\epsilon_1\ln\ (r_3/r_2)\ +\ \epsilon_2\ln\ (r_2/r_1))\ \div\ (\ln(r_3/r_2)\ +\ \ln(r_2/r_1))$$

if the conductors and dielectrics are considered perfect. c is the velocity of light in vacuum, r_1, r_2, r_3 the distances from the center of the cable to the outsides of the inner conductor, first dielectric, and second dielectric respectively. ϵ_1 and ϵ_2 are the dielectric constants of the first and second dielectrics respectively. An experimental investigation of this formula by an extension of a method employing the Lichtenberg figures (Phys.

Rev. **25**, 865, (1925)) using ethyl alcohol, rubber and air as dielectrics and copper conductors showed that the above formula was satisfied within an experimental error of about 2 percent. Although the Lichtenberg figures are obtained by the use of an aperiodic pulse, the application of the above relation to this case can easily be justified, since the velocity given by the formula is also the velocity of propagation of the wave front even when the dielectrics and conductors are not perfect.

51. Subfundamental piezo-electric vibrations in quartz plates. J. R. HARRISON, Wesleyan University.—With a new type of piezo-electric crystal mounting, it has been found possible to obtain piezo-electric reactions of very much lower frequency than that of the transverse fundamental, first described by Cady (Proc. I. R. E. **10,** 83 (1922)). The "transverse fundamental" is the frequency of the compressional wave in the direction of the largest dimension of the plate, both ends being free. The new mode of vibration is also different from any previously observed in that it is dependent to a large degree on more than one crystal dimension. The crystal mounting is so designed that the electric field is applied to two areas which are symmetrically disposed with respect to the longitudal axis of the quartz plate, and the polarities in the quartz are in opposite directions. With the electric field applied in this manner, piezo-electric crystals operate successfully either as resonators or as oscillators at this subfundamental frequency. The luminous glow emitted by crystals when resonating in a low pressure chamber, lately described by Giebe and Scheibe (Elektrotech. Zeit. **13,** 380), can also be observed at the subfundamental frequency, the luminosity presenting striking peculiarities which still await explanation.

52. Factors affecting the constancy of quartz piezo-electric oscillators. EARLE M. TERRY, University of Wisconsin.—A study has been made of the effect of mechanical stresses, temperature, and circuit constants upon the frequency of an oscillating plate of quartz connected in the usual way across the grid-filament elements of an electron tube, a tuned resonance circuit being placed in series with the plate. Frequency changes were measured by determining the change in pitch of the audio frequency beat note between this oscillator and a similar one furnishing a constant frequency. Various kinds of deformations were produced by resting the plate on a three point support and applying forces at a single point on its upper surface at different positions. For loads up to 500 grams the frequency change is of the order of one part in 500,000 per gram, the change being sometimes positive and sometimes negative, depending upon the type of deformation. The crystal was later placed in an enclosed chamber and subjected to air pressures of 20 atmospheres. The frequency decreased by approximately one part in 74,000 per atmosphere, the rate of change increasing somewhat with the pressure. A theoretical study has been made of four commonly used circuits in which the crystal is replaced by its electrical equivalent, as given by Cady, and an expression for the resultant frequency obtained, holding within the limits of experimental error.

53. Precise determination of frequency by means of piezoelectric oscillators. J. TYKOCINSKI-TYKOCINER, University of Illinois.—The oscillating current whose frequency is to be determined is inductively superimposed upon the oscillations of a piezoelectric oscillator. The plate current of the driving thermionic oscillating tube is compensated by a potentiometer arrangement so that the current variations can be observed by a microammeter. The relation between the plate current of the piezoelectric oscillator and the exciting frequency was investigated experimentally. The curves show a sharp current maximum and minimum with an intermediate steep line crossing the zero current abscissa. The point of intersection corresponds to resonance. If the exciting frequency equals exactly the fundamental frequency or a harmonic of the piezoelectric oscillator, no influence whatsoever is exerted upon the plate current. But a deviation of 1.15 of the frequency measured (294100 per second) can still be detected when the quartz crystal is clamped between two electrodes. With the crystal free, frequency variations less than one in a million are detected by a violent vibration of the microammeter pointer. The plate current variation in the measured circuit is of a different character and less pronounced.

54. High pressure powder contact rectifier. J. E. LILIENFELD and C. H. THOMAS, Davy Electrical Corp.—This rectifier makes use of the known contact combination, aluminum to cupric sulphide. It has been realized that the pressure is of importance with respect to the rectification, and therefore with a certain available compressing force, a definite contact area has to be maintained. It appeared later that highly compressed CuS powder offers just enough flexibility at its surface to secure intimate contact with the metal provided sufficient pressure is being maintained. The rectifier consists of cells made from a limited area about 25 square mm against a thin layer of CuS which has been forced into non-polarizing nickel cups. A compression force of about one thousand pounds is supplied by an *helical* spring. The resistance of the cell decreases until a critical pressure is reached. Every rectifier of the present size will deliver 2.5 to 3 amperes d.c. at 2 volts and on a lower amperage, higher voltage up to $3\frac{1}{2}$ volts. A difference of the characteristics is noticeable between a pure resistance and an inductance load. Oscillograms of the current through a resistance load show complete and distortionless full wave rectification, while those of the current through a new filter circuit of inductances and resistances show suppression of the ripple to less than one percent of the total voltage.

55. A correlation between the power loss, dielectric constant and conductivity of various glasses. LOUISE S. MCDOWELL and HILDA BEGEMAN, Wellesley College.—Values of power factor, dielectric constant and resistivity are given for six glasses of widely varying resistivity. In general the order of decreasing conductivity is found to be also the order of decreasing power factor and decreasing dielectric constant. Exceptions to this order are noted and an explanation of the correlation based on electron theory is proposed.

56. Mechanical forces between electric currents and saturated magnetic fields. VLADIMIR KARAPETOFF.—The general case considered is that of N independent electric circuits placed in a medium of variable permeability and subject to saturation, in parts or as a whole. The problem is to determine the component (in a given direction) of the mechanical force acting upon one of the electric circuits, upon a group of circuits, or upon a group of circuits with part of the magnetic medium rigidly attached to them. Use is made of the expression for the stored electromagnetic energy, W, of the system, assuming all the electric circuits to be first open and then closed one by one. Such a treatment necessitates a number of partial saturation curves, giving the linkages with the individual electric circuits when some of the other circuits are closed and the rest are open. A virtual displacement, δs, is then given to the part of the system under consideration, keeping the linkages or the currents constant, and the force, F, is determined from a comparison of the work done, $F \cdot \delta s$, and the change in the stored energy, δW. It is shown that the familiar reciprocal relationship for the mutual inductance, $M_{21} = M_{12}$, in a medium without saturation, can be generalized to a more involved integral expression for a saturated medium.

57. Thermal agitation of electricity in conductors. J. B. JOHNSON, Bell Telephone Laboratories, Inc.—Ordinary electric conductors are sources of random voltage fluctuations, as the result of thermal agitation of the electric charges in the conductor. The average effect of the fluctuations has been measured by means of a vacuum tube amplifier, where it manifests itself as a component of the phenomenon commonly called "tube noise." A part of the "tube noise" arises in the first tube and other elements of the apparatus; the remainder in the input resistance, with a mean square voltage fluctuation $(V^2)_m$ which is proportional to the resistance R of that conductor. The ratio $(V^2)_m/R$, of the order of 10^{-18} watt at room temperature, is independent of the material and shape of the conductor, but is proportional to its absolute temperature. In the range of audio frequencies, at least, the noise contains all frequencies at equal amplitudes. The noise of an input resistance of only 5000 ohms may exceed that of the rest of the circuit, so that the limit of useful amplification is at times set by the thermal agitation of charges in the input resistance of the amplifier.

58. The electrical resistance of metals as a function of pressure. A. T. WATERMAN, Yale University.—Assuming that the effect of hydrostatic pressure on the electrical resistance of metals is solely due to the accompanying volume change, the author's expression for the electrical resistance $R=CT^ae^{b/T}$ has been shown (Phys. Rev. 25, 4, p. 585) to be in agreement with experimental data on the pressure effect, provided the rate of change of b with volume is constant. Theoretical development of the influence of pressure on resistance, involving the effect of pressure on the chemical equilibrium postulated between atoms, ions and electrons within the metal, indicates that the pressure coefficient of resistance $1/R\, dR/dp$ is given by $\frac{1}{2}C+(1/2RT)(d^x/dp+\delta v)$, where $C=$ compressibility, $x=$energy change involved in the assumed reaction liberating electrons within the metal, and $\delta v=$a possible volume change accompanying the reaction. x may be expressed as the difference between the mean potential energies of an electron in the bound and in the free states. On calculating the compressibility (assuming only electrostatic forces) in terms of these quantities it appears that the change in resistance with pressure is chiefly due to a change in the mean potential energy of the free electrons. Furthermore, for elements in the same column of the periodic table, the rate of change with volume of the mean potential energies of both the bound and the free electrons is in approximate linear relation to the atomic number.

59. Molecular fields. DAVID G. BOURGIN, Lehigh University.—The treatments of statistical problems arising in physics which are based on direct extension of formulae, which are rigorously true for small values of n, have usually proved extremely complicated and have been discarded in favor of the methods of statistical mechanics. The recent statistical researches of Pearson provide a basis for development of a direct method which does not suffer from the objection of awkwardness. The advantages of this direct method are the greater transparency of the calculations and the fact that the number of necessary approximations may often be cut down or made more plausible. In the particular problem of molecular force fields, assuming random angular distribution under no impressed forces, an expression has been derived for the probability that the resultant field lies between F and $F+dF$. This fundamental expression has been evaluated for the case of a gas using current approximations. Some of the overlapping results of Holtsmark and Gans for this case are confirmed.

60. A general theory of the electrical properties of surfaces of contact. RICHARD D. KLEEMAN, Union College.—In a previous paper (Phys. Rev. **20**, 174–185 (1922)) the writer developed a theory of the e.m.f. associated with the part of a solution in contact with a metal plate. This theory is now extended to include the plate itself, and further generalized to apply to any two substances or mixtures in contact in any given state. The e.m.f. between two given points, one of which is situated in each substance, is expressed in terms of the coefficients of diffusion and the mobilities of the ions and molecules under the action of forces due to an asymmetrical distribution of matter and electricity, and externally applied electric fields. It is usually impossible to predict how these quantities vary from one part to another. But from the general nature of the equations obtained the existence of a number of effects some of them still unknown can be predicted. A systematic experimental study of these effects is being undertaken.

61. Theory of cell with liquid junction. Paul B. Taylor, University of Pennsylvania.—A simple integral is derived for the e.m.f. of the general cell with liquid junction in terms of transference numbers and molecular free energies. The transference numbers are made to depend upon the solution of a set of differential equations for the interdiffusion of two electrolytes each consisting of any possible mixture of ions. These equations involve the ionic mobilities and the molecular free energies, but not the free energies of the individual ions. It follows that the e.m.f. of a cell with liquid junction is not a function of ionic free energies and so can not possibly be manipulated to yield these quantities. Thus the values found in the literature purporting to measure hydrogen ion free energy, the so called Ph numbers, when based on such cells are quite unjustified. Henderson has given a formula, recently improved by Harned, for the p.d. of the liquid junction. This p.d. can not be found in terms of thermodynamic data (except at infinite dilution), but the formula modified to yield cell e.m.f. is a useful first approximation to a solution of the differential equations. A solution which may be considered a second order approximation has been derived.

62. The absolute zero of the externally controllable entropy and internal energy of a substance or mixture. R. D. Kleeman, Union College.—The internal energy of a substance or mixture may be divided into two parts, one of which is externally controllable, and therefore a function of temperature and volume, while the other part is not. The entropy may similarly be divided into two parts. It is shown that in thermodynamics we are only concerned with the controllable internal energy and entropy and that these quantities may have zero values. The temperature and volume corresponding to these zero values may be obtained by means of the theorem that the specific heat of a mixture kept at constant volume can only have positive values, which may be said to follow from our conceptions of temperature and heat content, and the postulate that the increase in pressure per unit increase in temperature at constant volume cannot be infinite, which will probably be readily admitted. It is then obtained that the controllable internal energy and entropy of a substance or mixture in the condensed state in contact with its vapour at the absolute zero of temperature have zero values. Formulae for the controllable internal energy, entropy, free energy and potential corresponding to any density and temperature may then readily be deduced.

63. On the dependence of ionic mobility on the nature of the medium. Henry A. Erikson, University of Minnesota.—If air ions pass through air containing impurities such as carbon dioxide or water vapor, it is found that the mobility diminishes as more of the impurity is added. The conditions involved are such as to lead to the conclusion that the change is due to the change in the medium and not to a change in the ions.

64. Variation with state of the optical constants of caesium. J. B. Nathanson, Carnegie Institute of Technology.—The optical constants of caesium were determined for the solid and liquid states, for wave lengths 5400, 5890, and 6410 A. Observations were made at 23°C and 33°C, the melting point of caesium being 26°C. The glass cell containing the caesium mirror was warmed by means of a small electrical oven enclosing the mirror and containing suitable apertures for the incident and reflected light rays. The method of observation was that previously employed. (Phys. Rev. **25**, 75 (1925).) The optical constants were computed by means of Drude's equations. When the metal changed from the solid to the liquid state, it was found that the angle of azimuth of restored plane polarization, as well as the phase difference between the components of the light vector parallel and perpendicular to the plane of incidence, changed very little, thus producing only slight changes in the values of the coefficient of absorption, k, the index of refraction n, and the reflecting power R. For example, for λ5400A and solid caesium, $k=3.74$, $n=0.308$, and $R=0.595$, while for liquid caesium, the corresponding values are 3.66, 0.310, and 0.588.

65. An unusual magnetostrictive effect in Monel metal. S. R. WILLIAMS, Amherst College.—Magnetically, nickel is a most interesting metal. No less so are its alloys as permalloy, for instance, demonstrates. Monel metal, an alloy of nickel and copper, has also some very interesting magnetic properties. Among these is the fact that it loses its magnetic properties in the neighborhood of 100°C. The Joule magnetostrictive effect was studied in both hot and cold rolled rods of Monel metal. Some behaved like cobalt and others like nickel. The most interesting effect was, that if a magnetizing field of about 1000 gauss was left impressed on the Monel metal rod, it would continue to shorten, although the field was not varied, until the heat from the coil finally penetrated and the two effects worked against each other. This after effect in Monel metal is four to five times greater than the change in length due to varying the imposed magnetic field, whereas the after effect in nickel is only about 1/20 of the main Joule effect. The biggest magnetostrictive effect in Monel metal is that due to time whne a certain field is applied and maintained constant.

66. Magnetic susceptibility of single-crystal elements. C. NUSBAUM, Case School of Applied Science.—A modified form of the Terry torsion balance is being used for the determination of the magnetic susceptibility of a number of single-crystal metals along their respective crystallographic axes. The sample is mounted on a specially designed table and may be rotated in the magnetic field around any given axis. An investigation has been made on tellurium which has a three-fold axis of rotational symmetry. Curves show the variation of the susceptibility with the angle of rotation as the crystal is rotated around any of its axes. A similar study is also being made of the single crystals of Cd, Bi, Sb, Sn, and Zn.

67. The effect of wave-length on the differences in the lags of the Faraday effect behind the magnetic field for various liquids. FRED ALLISON, Alabama Polytechnic Institute.—Through the employment of a method by means of which two magnetic fields can be applied and removed simultaneously, it has recently been found by Beams and Allison that in various liquids there is a lag of the Faraday effect behind the magnetic field. This lag varies with different liquids and the differences in these lags for several liquids were determined with a precision of 0.4×10^{-9} sec. The present paper extends the work to an investigation of the differences in the lags of the Faraday effect for several liquids when different wave-lengths of light are used. The liquids studied were carbon bisulphide, carbon tetrachloride, chloroform, benzene and xylene, the wave-lengths being the spark lines Mg4481, Zn4912,24, Mg5173,83, Cd5338,78. It is found in every case that the differences in the time-lags of the Faraday effect behind the magnetic field are inversely proportional to the wave-lengths of light used. The extreme variations observed in these time-lag differences range from 0.3×10^{-9} sec. for the longer wave-lengths to 7.5×10^{-9} sec. for the shorter waves, depending upon the two liquids compared, the precision of an observation being 0.3×10^{-9} sec.

68. Relation of heat transmission to humidity in insulating materials. L. F. MILLER, University of Minnesota.—The hot and cold plate apparatus, with guard ring, taking twelve inch square samples was used, which seems best for preserving the moisture content acquired at the different humidities. Measurements were made at the same humidities to which the sample was exposed. To avoid short circuiting thermocouple due to wetting, enameled Advance (formerly Ideal) and copper wires were employed. Special apparatus was used to humidify the room and moisture content was measured by weighing. As checks, three different instruments measured the relative humidity, one instrument being a continuous recorder. Materials investigated were: wood-pulp fibre, flax-fibre, cane-fibre and rag-paper felt, all approximately 1/2 inch thick. All thermocouples used were found to be reliable to 1/10°C. The temperature difference was not much over 10°C, which reduces the tendency of the moisture to move from hot side toward the cold side. Indication of results is that the heat transmission increases linearly as the moisture content. Up to 100 percent relative humidity there is an average increase in moisture content of about 15 percent by weight of dry sample weight and about a 15 percent increase in heat transmission for the four materials. At 100 percent relative humidity absorption is more rapid and moisture content much greater, with corresponding increase in thermal-conductivity.

69. Thermal expansion of graphite. PETER HIDNERT and W. T. SWEENEY, Bureau of Standards.—An investigation on the thermal expansion of longitudinal and transverse sections of artificial graphite (99.2 to 99.7 percent carbon) over various temperature ranges between room temperature and 600°C has recently been completed. The coefficients of expansion of graphite are low. For example, the coefficient of expansion of ordinary steel is about six times the coefficient of longitudinal sections of graphite and about four times the value for transverse sections between 20 and 100°C. The transverse samples expand considerably more than the longitudinal samples (approximately 45 percent). The coefficients of expansion increase with temperature. For both the longitudinal and transverse sections, the coefficients of expansion decrease slightly as the purity (carbon content) increases. The following table gives a resumé of average coefficients of expansion for various temperature ranges.

Average Coefficient of Expansion ($\times 10^6$) *per Degree Centigrade*

Section	20 to 100°C	20 to 200°C	20 to 300°C	20 to 400°C	20 to 500°C	20 to 600°C
Longitudinal	1.9	2.0	2.2	2.4	2.5	2.7
Transverse	2.9	3.0	3.2	3.5	3.6	3.7

70. Theory of the magnetic nature of gravity. CORNELIO L. SAGUI, Castelnuovo dei Sabbioni, Italy.—The only physical reality considered necessary is the electromagnetic field. A ray of light is considered as formed of a series of extremely small electrical resonators without ohmic resistance. In such a resonator a sine disturbance once started will go on without end. A transmitting medium for the energy is not considered necessary. The electromagnetic waves would consist of a sort of magnetic quanta moving to and fro. Matter would be built up similarly of electrical resonators, so that the gravitational force would be represented by the integral value of all the magnetic quanta of the elementary resonators moving to and fro about the body in a radial direction, at a distance which should be a function of the total number of resonators composing the body in question. Thus the gravitational field would not be infinite, but limited by the mass of the body itself. A ray of light going through a gravitational field of such a kind must modify its frequency within certain limits. A second modification of its frequency would result from the motion of the earth, in such a way that when the motion was in the same direction as that of the ray the frequency would become smaller.

71. Cosmic aspects of atmospheric electricity. LOUIS A. BAUER, Carnegie Institution of Washington.—There being at present no generally accepted theory to account for the origin and maintenance of the earth's negative electric charge, it is of peculiar interest to study the laws and modus operandi of the changes to which atmospheric electricity is subject during the day, year, and from year to year. These changes, which even on meteorologically-undisturbed days are on the order of the absolute values of the atmospheric elements themselves, show remarkable terrestrial and cosmical aspects; i.e., they are in general of the same character and sign at stations both in the northern and southern hemispheres. Recent world-wide observations give further confirmation of these striking facts. A brief discussion is also given of the relation of the atmospheric-electric results to recent measurements of the ozone content of the atmosphere, of the sun's ultra-violet radiation, of radio-reception, and of solar activity.

72. Measurements of the variation of residual ionization in air with pressure at different altitudes. W. F. G. SWANN, Yale University.—Under the auspices of the Bartol Research Foundation, measurements of residual ionization were made, in an iron sphere, at Colorado Springs and at the summit of Pikes Peak, for pressures ranging from atmospheric up to 1000 lbs. per square inch. In one set of experiments the iron sphere one inch in thickness was shielded by about 2 inches of lead and in the other set it was unshielded. Corresponding observations were reproducible with an accuracy of about 2 percent. The mean apparent absorption coefficient α (the coefficient calculated for the case of a vertical radiation) was $5 \cdot 2 \times 10^{-4}$ per meter of air estimated at atmospheric pressure, and it was the same to within a few percent of its value from whatever corresponding parts of the pressure ionization curve it was calculated. The increase in ionization per atmosphere increase in pressure decreased with the pressure but became sensibly constant at the higher pressures. The absolute increase in ionization per cc per atmosphere increase in pressure at the highest pressures was 0.75 for the summit of Pikes Peak.

73. Radiometric measurements on the planet Mars, 1926. W. W. COBLENTZ and C. O. LAMPLAND, Bureau of Standards.—Measurements with vacuum thermocouples intercepting only 0.01 of the area of the planetary image confirm previous observations, showing: the southern (summer) hemisphere warmer than the northern hemisphere; the dark areas hotter than the adjacent bright areas; the forenoon side cooler than the afternoon side (exceptions; sunset clouds, or dark area on east limb irradiated an hour before sunrise). Temperature differences between the center of the disk and the limbs (and poles) appear smaller than previously observed; probably seasonal, which was a month after Martian summer solstice instead of a month before as obtained in 1924. Owing to clouds and the "limb light" of the Martian atmosphere, estimates of temperatures on east and west limbs are too low. Afternoon clouds seemed denser than morning clouds—not necessarily a general condition. The following tentative estimates of Martian surface temperatures are given; as viewed on the central meridian, the south polar region 10° to -10°C; south temperature zone 20° to 25°C (clouds—10°C); center of disk 20° to 30°C; north temperature zone 0° to 20°C; north polar region -25° to -40°C; east limb (after being irradiated for an hour) -20°C, no phase -25°C, clouded -35°C; west limb (terminator) 0°C, no phase -10°C, clouded -30°C.

74. On the effects of dust, smoke, and relative humidity upon the potential gradient and the positive and negative conductivities of the atmosphere. G. R. WAIT, Carnegie Institution of Washington.—A discussion is given of simultaneous observations of atmospheric electricity, dust-content, and relative humidity obtained at the Watheroo Magnetic Observatory, Western Australia.—The dust-content series (by Aitken's counter) during February to April, 1924, gives consistent results indicating that the potential gradient is approximately doubled for increase of dust-content from zero to 10,000 particles per cubic centimeter and thereafter a very slow increase with increased dust-content. Thus one is not justified in extrapolating, as has been done, values for dust-free air when the data are obtained only for high dust-contents. Both positive and negative conductivities decrease about half when the dust-content changes from zero to about 5,000 particles per cubic centimeter and decrease very slowly thereafter with increased dust-content. The ratio of positive to negative conductivity, as might be expected, increases with increasing dustiness. The more extensive simultaneous observations of the atmospheric-electric elements and relative humidity, using data taken only at times of low dust-content, show that these elements are similarly affected by an increase in relative humidity, but to a lesser extent. The analysis shows that very few transformed large ions pass through the conductivity instruments without being recorded. The great importance of more observations of this kind in investigating the behavior of ions in air is pointed out.

75. Demonstration of an improved form of Rijke tube of high efficiency. A lecture experiment in acoustics. R. W. Wood, Johns Hopkins University.—By increasing the number of gauzes, a tube was constructed which continued sounding for two minutes or longer.

76. The direct comparison of the loudness of pure tones. B. A. Kingsbury, Bell Telephone Laboratories, Inc.—The intensities of 11 pure tones necessary to make them as loud as certain fixed levels of a 700 cycle test tone were judged by 22 observers, 11 men and 11 women. Frequencies from 60 to 4000 cycles were used and intensities from the threshold of audibility to levels somewhat louder than ordinary conversation. It was found that if the amplitudes of pure tones are increased in equal ratios the loudness of low frequency tones increases much more rapidly than that of high frequency tones although for frequencies above 700 cycles the rate is nearly uniform. As a loudness unit the least perceptible increment of loudness of a 1000 cycle tone was employed. In absolute magnitude this varies from level to level, but in the ordinary range of loudness it becomes constant. The variability of the data from which the averages were computed was separated into a factor expressing dissimilarity of ears and another expressing errors of observers' judgment. There was no level at which the variances were a minimum. Dissimilarity of ears causes more variation than errors of observers' judgment.

77. Physical and biological effects of high-frequency sound waves of great intensity. R. W. Wood, Johns Hopkins University, and Alfred L. Loomis, Tuxedo, N. Y.—This paper describes effects observed with sound-waves of 300,000 vibrations per second, obtained with a piezoelectric quartz plate driven by an electrical oscillator of 2 kilowatts output at 50,000 volts; thermic effects; elevation of the free surface of the liquid by the pressure of the waves; atomization of the surface with waves of great intensity; destruction of the red blood corpuscles in a living animal and other biological effects.

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