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PROCEEDINGS
OF THE
AMERICAN PHYSICAL SOCIETY

MINUTES OF THE NEW HAVEN MEETING, JUNE 23–25, 1932

The 179th meeting of the American Physical Society was held in New Haven, Connecticut on Thursday, Friday and Saturday, June 23, 24 and 25, 1932, upon invitation from Yale University. The registration for the meeting numbered 194. The scientific sessions were held in the Sloane Physics Laboratory and in the Osborn Zoological Laboratory. The presiding officers were W. F. G. Swann, President of the Society, Paul D. Foote, Vice-president, Karl K. Darrow, Bergen Davis, Herbert E. Ives, George B. Pegram and S. R. Williams.

Thursday morning was taken up with four parallel sessions of contributed papers, abstracts of which appear in these Proceedings. Thursday afternoon there were two informal conferences, one on Definitions and Units presided over by Leigh Page, and one on The Atomic Nucleus presided over by Henry A. Barton.

Friday morning was devoted to a symposium of four invited papers on "X-rays," abstracts of which are included in these Proceedings.

Saturday morning was given over to a joint session with the Applied Mechanics Division of the American Society of Mechanical Engineers which was meeting at Yale during the same three days. This joint meeting was a symposium on "Plasticity." Abstracts of the papers appear in these Proceedings.

The local committee provided very complete arrangements for the comfort, entertainment and enjoyment of the visitors throughout the meeting. The Physical Society dinner was held at the New Haven Lawn Club on Thursday evening with 145 guests present. There were no after dinner speakers and the dinner was followed by a complimentary presentation at the University Theatre of A. A. Milne's "The Perfect Alibi" by the Yale Dramatic Association. This was thoroughly enjoyed by every one.

On Friday afternoon the members were taken to a picnic at Double Beach, a delightful place on the shore where there were sea bathing, sports and dinner. Some members, who did not attend the picnic, went to the Boat Race at New London. Throughout the three days there were special teas, trips through the museums and the Sterling Library and sightseeing trips through the city provided for the visiting ladies and any others who wished to take advantage of them.

On Saturday afternoon there was a short meeting of the Physical Society at which President Swann and others discussed for the information of the membership some of the problems relating to publications and finance to which the Council has been giving much attention.

At the close of the joint session of the two societies on Saturday morning there was a unanimous rising vote of thanks given to Yale University and the local committee and to the Yale Dramatic Association for the splendid arrangements and entertainment provided for the visiting Societies during the three days of their meetings in New Haven.

Meeting of the Council. At its meeting on Friday, June 24, 1932, the Council elected one person to fellowship. Fourteen candidates were elected to membership. *Elected to fellowship:* Harold Pender. *Elected to membership:* H. E. Banta, John E. Davis, Georges Dejardin, G. W. Heitkamp, G. B. Kistiakowsky, Shoji Makishima, Ralph E. Nusbaum, Walter J. Osterhoudt, Tokutaro Sawai, Walter Soller, S. R. Toh, C. M. Van Atta, Juanita Witters and Stephen A. Zieman.

The regular scientific program of the Society consisted of forty-three contributed and seven invited papers. Numbers 7, 8, 9, 10, 21, 23, 33 and 39 were read by title. Number 12 was withdrawn at the request of the author and therefore the abstract does not appear in the Proceedings. The abstracts of the papers are given in the following pages. An *Author Index* will be found at the end.

W. L. SEVERINGHAUS, SECRETARY

1. Theory of variation of paramagnetic anisotropy among different salts of the iron group. J. H. VAN VLECK, *University of Wisconsin.*—Experimentalists find that nickel salts are magnetically isotropic to about one percent, but that those of cobalt have anisotropy amounting to around 30 percent. A theoretical explanation is given for this difference, which at first sight is puzzling because both the Ni^{++} and Co^{++} ions have F ground terms (respectively $d^8\ {}^3F$ and $d^7\ {}^4F$). Suppose the crystalline potential of the form $Ax^2+By^2-(A+B)z^2+D(x^4+y^4+z^4)+f(r)$ where the rhombic or second order terms are small compared to the "cubic" or fourth order ones, as indicated by the recent investigations of Jordahl, Penney, and Schlapp (Phys. Rev. May 15, (1932)). Then by joint adaptation of the Bethe group theory of crystal Stark effect and the Goudsmit-Slater method of diagonal sums it is shown that the energy diagram connected with the splitting in the crystal field is inverted for Co^{++} as compared to Ni^{++}, so that a state which is nearly isotropic magnetically is the ground state for Ni^{++}, whereas an anisotropic one is the normal level for Co^{++}. The inversion phenomena are also discussed in connection with other ions of the iron group in which it appears. The nearly perfect isotropy of manganous salts is trivial, as Mn^{++} is in an S state.

2. Monocrystal Barkhausen effects in rotating fields. F. J. BECK AND L. W. MCKEEHAN, *Yale University.*—The directions of Barkhausen effects in a single crystal disk of silicon steel, held stationary in a magnetic field rotating slowly in the plane of the disk, have been determined. Search coils at right angles picked up impulses proportional to selected rectangular components of the changes in magnetization. Measurements on an oscillographic record were made at two values of induction: 1480 and 645. Values of the angle Φ between the change in magnetization ΔI and the corresponding variation in the applied field, $(d\boldsymbol{H}/dt)\Delta t$ are determined for various positions of the applied field relative to the crystallographic axes. The normal to the disk made angles of 30°, 60°, 90° with these axes. For these low values of induction the effects are mainly transverse and are more nearly transverse for the greater value of induction. The average value of Φ is about 20° (ΔI lagging) for the lower value of B and is less than 5° for the higher value. Individual values of Φ for one setting differ by as much as 30°. The average magnetization apparently lags the applied field and makes a small angle with it. The direction and frequency of effects seemed unaffected by changing the direction of $\boldsymbol{H}$ in the plane of the disk.

3. Mechanical hardness influenced by magnetism. S. R. Williams, *Amherst College, Amherst, Mass.*—About a year ago, Herbert published a most interesting article on "magnetic hardening of metals," (American Machinist **74,** 967, 1931). Not only did he find that rotating a ferromagnetic substance in a magnetic field changes the hardness but that the same thing occurred for substances which are not ferromagnetic. This work of Herbert's confirms some observations on steel rods, made by the writer in 1924, (Williams, Trans. A. S. S. T., p. 362, 1924). The work of 1924 has been repeated and confirmed on a series of high carbon steel rods of different drawing temperatures. The study has been extended to a series of steel rods of different carbon content and hardness. The effect seems to be very clearly shown. Magnetostrictive effects have been the means for studying the changes in hardness due to magnetic fields.

4. The dielectric constant of liquid sulphur. H. J. Curtis, *Yale University.*—The dielectric constant and power factor of liquid sulphur was measured by a bridge method at four different audiofrequencies and over the temperature range 118°C to 350°C. The dielectric constant was found to be independent of frequency and equal to 3.520 ± 0.010 at 118°C. The specific polarization is independent of temperature between 118°C and 158°C and equal to 0.2528 ± 0.0008 $\mathrm{cm}^3\mathrm{g}^{-1}$. Above 158°C the polarization decreases directly as the reciprocal of the absolute temperature, showing that molecular association occurs with very strong binding forces between the molecules. This shows that liquid sulphur is definitely nonpolar. A method was developed for differentiating between that part of the power factor which is due to conductivity and that which is due to molecular friction. The former was found to be very large, especially at high temperatures, and the latter very small at all temperatures. This is a further confirmation of the fact that sulphur is nonpolar. The infrared spectrum of liquid sulphur contains definite absorption bands, which shows that its molecules are polar. It is difficult to understand this contradiction, since both measurements seem to give conclusive results.

5. Dielectric constant and particle weight. J. W. Williams, *University of Wisconsin.*—Svedberg has been successful with the determination of the size and weight of colloidal particles by observing their linear velocities when subjected to a centrifugal field. A similar result should follow from a study of their rotational velocities in an alternating electrical field. The method, an application of the dipole theory of Debye, depends upon the fact that owing to the frictional resistance of the medium to the rotation of the suspended particles a finite time is required for their orientation in the field. If the frequency dependence of the dielectric constant is determined for a system composed of electrically dissymetrical particles supended in a liquid medium there will be found to be a region in which the dielectric constant decreases as the frequency is increased. The theory expresses the size, and therefore the weight, of the suspended particle in terms of the observed critical frequency and the "viscosity" of the medium. The available data are as yet insufficient for the exact determination of the particle size because the systems involved fail to conform to the assumptions underlying either the law of Stokes or the Clausius-Mosotti relation. Nevertheless, calculations from them indicate that once it becomes possible to evaluate the true inner friction constant of the system important results may be obtained. The method readily distinguishes monodisperse and polydisperse sols.

6. Surface charge of large particles in liquids. Harold A. Abramson, *Columbia University, and* Hans Mueller, *Massachusetts Institute of Technology.*—It is proposed that an advance in the study of the constitution of the solid-liquid and liquid-liquid interfaces may be made by calculation of σ, the surface density of electric charge, in addition to the analysis of the potential difference, ζ, between the movable phases. For large particles σ can be readily calculated by an extrapolation of the Debye theory. This has been done for the negatively charged surfaces of graphite, glass, cellulose, "collodion" and paraffin oil, in the case of ions (valence 1:1; 1:2; 2:1; 1:4) not producing reversal of sign of charge. Although the ζ-concentration curves are rather complex, the σ-concentration curve in every case yields a simple curve resembling typical adsorption with an initial steep slope and with saturation at salt concentrations of about 0.01 molar. Curves of this type have been predicted by Stern. The character of the curves is determined by both ions. The slope at zero concentration varies markedly, particularly with the nature and valence of the anion; e.g., for glass in the order $\mathrm{I} > \mathrm{Br} > \mathrm{Cl}$, the differences diminishing as saturation approached. The method of calculation employed here to ascertain the nature and magnitude of the forces involved in adsorption of ions by "inert" surfaces at the liquid interface is justified by previous theory and experiment of the authors.

7. Some remarks on the physical constants of cells in connection with their size and shape. N. RASHEVSKY, *Westinghouse Research Laboratories, East Pittsburgh.*—In a paper presented at the Cambridge meeting, (Physics **2,** 303, 1932) a formula was deduced, giving the size of a cell in terms of its physical constants, such as, the coefficient of diffusion for oxygen, permeability, surface tension and rate of metabolism. From values for the diffusion coefficient D as found for muscle tissue, values of the order of magnitude of 10^{-3} cm for the size were found. Bacteria, however, are much smaller, and in order to account for their size, values for D about 1000 times as small must be assumed. It is interesting, that in a recent investigation Professor R. W. Gerard arrived at a similar conclusion from an entirely different point of view; namely, from the study of oxygen consumption. He discarded, however, the assumption of such a small D, as being not supported by any other facts, and interpreted his experimental results otherwise. Questions as to the possible reason of such a small D in bacteria are discussed in the present paper. Furthermore, some applications of the author's foregoing studies to the problem of shape of certain cells are made.

8. Electric phase angle of cell membranes. KENNETH S. COLE, *Columbia University.*—From the theory of an electric network containing any combination of resistances and a single variable impedance element having a constant phase angle independent of frequency, it is shown that the graph of the terminal series reactance against the resistance is an arc of a circle with the position of the center depending upon the phase angle of the variable element. If it is assumed that biological systems are equivalent to such a network, the hypotheses are supported at low and intermediate frequencies by data on red blood cells, muscle, nerve, onion membrane and potato. For some tissues there is a marked divergence from the circle at high frequencies, which is not interpreted.

9. A theory of surface conductance at an electrolyte-solid interface. KENNETH S. COLE, *Columbia University.*—An expression has been derived on the basis of the Maxwell-Boltzmann distribution and Poisson's equation for the tangential surface conductance of an electrolyte in contact with a charged plane surface. One part of this expression is analogous to the result given by Smoluchowski for a Helmholtz double layer, while the second part arises from the movement of the ions in the diffuse ion cloud under the applied electric field. The theory shows qualitative agreement with the data of Briggs for the conductance of univalent chloride solutions at a cellulose surface. For all but the most dilute solutions, the Smoluchowski term is negligible and the surface conductance is proportional to the charge density on the surface. The theory does not agree with the data for different anions and it is suggested that the decrepancy may be due to adsorption phenomena. There may be a movement of the adsorbed ions or of a diffuse ion cloud resulting from the presence of adsorption potentials at a distance from the interface.

10. Photographic reciprocity and intermittency defects near the long wave-length limit of plate sensitivity. BRIAN O'BRIEN AND VERNON L. PARKS, *Institute of Optics, University of Rochester, N. Y.*—Previous work on compensation of reciprocity failure in photographic spectrophotometry by intermittency defect imposed on light beam of higher intensity by interrupted exposure [Phys. Rev. **33,** 640 (1929), Phys. Rev. **37,** 471 (1931)] has been extended to the long wave-length limit of plate sensitivity (λ10,000A for one emulsion) where both defects become large. The four emulsions used, Eastman Process, Process Panchromatic, Contrast Bromide, and Infrared Sensitive 3Q, all exhibit large reciprocity failure. A tungsten incandescent source was maintained constant within 1/4 percent, and mounted on a carriage with range of movement of 50 meters for varying intensity. Fixed sectors were used with aperture ratios of 1/40 to 1/1212, running 28 flashes per second. Errors in measurement of sector apertures and exposure timing were less than 1/2 percent. Although reciprocity failures were as great as 0.92 in density, the difference in density produced on adjacent areas by continuous low intensity and interrupted high intensity exposure (for $It = \text{const.}$) in no case amounted to a difference in log exposure greater than 0.012, and average difference was less than 0.004. Although just within the limit of measurement this appears to be a systematic difference with reciprocity defect greater than intermittency defect, but difference, if real, is so small that it may be neglected in photographic photometry.

11. The absorption spectrum of sulfur dioxide. J. A. DUNCAN, *Columbia University (Introduced by Harold C. Urey).*—The absorption spectrum of sulfur dioxide has been photographed in the region $\lambda\lambda 2165$–2410A with a Hilger E185 quartz spectrograph having a dispersion of about 1A per mm. The bands are partially resolved into rotational band lines. In this work an effort has been made to analyze the rotational structure rather than the vibrational structure, since Chow (Bull. of the Am. Phys. Soc. Vol. 7 No. 2, 19, April 12, 1932) using lower dispersion is working on the latter problem. The more intense lines of some bands can be classified into branches having approximately constant second differences. These bands appear to fall roughly into two classifications; (1) bands consisting of only one branch resembling a Q branch; (2) bands consisting of two or more branches. It is found to be possible to include in this way nearly all the strong lines of these bands.

12. The alternation of intensities in the sodium bands. JOSEPH JOFFE, *Dept. of Chemistry, Columbia University.* Withdrawn at author's request.

13. The continuous absorption spectrum of chlorine. G. E. GIBSON AND NOEL S. BAYLISS, *The University of California, Berkeley, California.*—A photographic method was used to investigate the continuous absorption spectrum of chlorine at six different temperatures. The effect of increasing the temperature is to decrease the absorption coefficient at the maximum and to broaden the region of continuous absorption. The results were analyzed to obtain the individual contributions of the first two vibrational levels of the normal electronic state to the total absorption. Plotted against wave number, the absorption from the lowest level, ($v''=0$), has a form similar to that of a Gauss error curve, and the absorption from the next level, ($v''=1$), has two maxima. The results are in qualitative accord with a theory of continuous absorption developed by Gibson and Rice.

14. The origin of the mercury bands at 2480A. J. GIBSON WINANS, *University of Wisconsin.*—The mercury bands near 2480A were photographed under different excitation conditions with the purpose of determining their origin. A discharge through mercury vapor was produced in a quartz tube through external electrodes by a low voltage Tesla coil. A photograph of the 2476 band in the third order of a 21-ft. grating checked that of Miss Brozowska, (Zeits. f. Physik **63,** 557 (1930)). Five different tubes containing distilled mercury showed the entire group of eight bands. These bands were weakened by heat. From these observations the origin is some form of mercury molecule, the most probable being Hg_2 or Hg_2^+. Six lines of evidence favor Hg_2^+ over Hg_2: (1) observations on fluorescence, (2) comparison of intensities in mercury arc and electrodeless discharge, (3) comparison of the intensities of the 2476 and 2345 bands under strong and weak field excitation, (4) abscence of other bands of similar character in the mercury spectrum and the observation by Rayleigh that these bands do not appear in absorption, (5) classification of these bands as sequences $v'-v''=0\pm1\pm2\pm3$ which leads to a value for $D>0.5$ volts; (6) observed emission from state $v'=41$ corresponding to very high temperature molecules.

15. Observations on the fluorescence spectra of cadium vapor. W. CRAM AND J. G. WINANS, *University of Wisconsin.*—A broad band in the fluorescence of cadmium vapor has been previously observed between the limits 3050−2288A. Kapuscinski found that monochromatic light of wave-length in this band was absorbed and reemitted by the vapor. In the present experiment fluorescence was excited in cadmium vapor by light from a copper spark. The band was found to extend from 3050 to 2212A. Lines in the exciting light, of wave-length below 2288A, were reemitted by the vapor in the same manner as those observed by Kapuscinski. The spectrum of the electrodless discharge showed this same band but with different intensity distribution. These observations can be explained by the use of potential energynuclear separation curves which correspond closely to those given by Winans to interpret the absorption spectra of cadmium vapor.

16. Rotational Raman effect of gases. Charlton M. Lewis, *California Institute of Technology.*—The study of the Raman effect of gases has been extended to the pure rotation of the simpler hydrocarbons. Acetylene shows the same pattern of alternating intensities that was found by Hedfeld and Mecke in absorption. Ethane and ethylene, which have the form of the symmetrical and asymmetrical top, respectively, show more complicated fine structure; but in neither case is there evidence of more than one moment of inertia. The pure rotation spectrum of methane appears to be missing, or at least of a lower order of intensity than the rotation-vibration band already found by Rasetti. The P and R branches of this band are not very much weaker than the Q branch, while another mode of vibration, which yields an extremely intense Q branch, shows no P and R branches. These characteristics are largely in agreement with what is to be expected from an extension to the rotational Raman effect of Placzek's method of treating the vibration lines.

17. Raman effect in crystalline NH_4Cl. F. T. Holmes, *Lehigh University.*—Schaefer, Matossi, and Aderhold (Zeits. f. Physik **65**, 289 (1930)) have reported two broad Raman lines for NH_4Cl at 3155 and 3035 cm^{-1}. The author has found that in addition to these lines most of the characteristic frequencies found by Reinkober (Zeits. f. Physik **5**, 192 (1921)) in the infra-red appear in the Raman spectrum as rather broad lines. However the line at approximately 1700 cm^{-1} is very sharp. In addition to these, a set of four very weak lines has been observed in the region near 3155 and 3035 cm^{-1}. In consideration of the prediction by Pauling (Phys. Rev. **36**, 430 (1930)) of rotation of the ammonium ion in this substance at room temperature, it seems possible to regard the members of this set as vibrational-rotational lines. Intensity considerations indicate that they may be associated with the 3035 cm^{-1} vibrational shift. Making these assignments, and assuming $\Delta j = \pm 2$ with no "missing lines," the moment of inertia of the rotating group is calculated to be approximately 2.0×10^{-40}gm cm^2.

18. Zeeman effect in the $^2\Pi\ ^2\Sigma$ CaH bands. W. Peyton Cunningham, *Yale University.* (*Introduced by W. W. Watson.*)—The Zeeman effect in the $\lambda 7000$, $^2\Pi\ ^2\Sigma$ CaH band has been investigated at field strengths of 10,500, 18,200 and 30,000 gauss. For the Q branches the patterns are in excellent agreement with the predictions of Hill's formulas for doublet states. In the lines of the R and P branches, however, marked departures from these predicted patterns occur in the region of intermediate and high K levels. It is shown that the inclusion of the magnetic moment due to ρ, the sizeable component of l perpendicular to the internuclear axis is the Π_d levels, gives quite closely the needed corrections for these patterns. Calculation shows that for all these lines of high K values one block of components becomes so wide and diffuse as to be unobservable. Interesting variations with ρ and H in the observed narrower block of components for the region just above the crossing of the Π_d levels are discussed.

19. Zeeman effect of Pb III. J. B. Green and R. A. Loring, *Ohio State University.*—The Zeeman effect of Pb III has been studied at fields of about 40,000 gausses with the newly completed 30,000 line 21-ft. Paschen-Runge concave grating set-up at this laboratory, and the same general type of vacuum box used in our work on Sn. Of particular interest in this spectrum is the $6s6p$ configuration, which seems to violate all the rules laid down by the theory. The coupling is practically j-j in type, and accurate measurements of the four lines involved in the transition $6s6p - 6s7s\,^3S_1$ indicate that (1) the Pauli g-sum rule for the $^3P_1 + {}^1P_1$ is not accurately obeyed, the experimental value being 2.53 against the theoretical 2.50; (2) the g-value of $^3P_2$ which should be unaffected by coupling (taking into account perturbations within its own configuration) is 1.35 (exp) against 1.50 (theo.). The abnormal g-value must be attributed to perturbations by the neighboring $6p^2$ or $6s6d$ configurations.

20. Theory of quantum defect due to polarization, with application to multiplet anomalies in Al II. N. G. Whitelaw and J. H. Van Vleck, *University of Wisconsin.*—The formula $\Delta = (\alpha e^2 n^3 / 4chR)\overline{1/r^4}$ for the quantum defect Δ due to polarization is usually derived by introducing a model in which the atom-core is given *ad hoc* a polarizability α. Instead a derivation is given by perturbation theory in which inter-electronic interaction is considered explicitly. The above formula for Δ is found to be valid only if exchange terms are neglected and if the absorption lines ν(A.C.) of the atom-core are large compared to those ν(V.E.) representing transitions of the valence electron. The calculation enables one to determine the "perturbations," i.e., deviations from the formula, when there is close resonance between ν(A.C.) and ν(V.E.). The theory is applied to the $3smf\,{}^3F$ series of Al II, which Langer, Shenstone, and Russell have noted is perturbed by a $3p3d\,{}^3F$ term. The widening of the multiplets in the vicinity of the perturbation is caused by a partial robbing of the intruders wide structure, and can be calculated from the observed displacement of the multiplet centroids from hydrogenic values. The calculated over-all widths for the successive members are 5.1, 10.8, 37.2, (58.2 for intruding $3p3d$), 20.8, 7.3, 3.7, . . . against observed 4.9, 12.3, 40.4, (58.1), 17.8, 5.7, 2.4. The discrepancies may be diminished by the further consideration of higher order approximations.

21. A theorem on spectroscopic stability. R. M. LANGER, *University of Minnesota.*—Recent spectroscopic observations, especially some of the rare gas spectra (e.g., E. Rasmussen, Zeits. f. Physik **75**, 695, 1932) bring out symmetries in the oscillations of the term values of similar series. They suggest a connection between the departures of related terms from Ritz formulae. In fact such a connection can be deduced theoretically. The rare gas series exemplify one of several possible types of behavior. The usual calculations of energy levels assuming separate configurations lead to multiplet separations and smooth series which often disagree with experimental data. Since these incomplete solutions for discrete spectra differ from the correct ones by a unitary transformation the sum of the energies of mutually perturbing configurations is correctly given by the incomplete solutions. This leads to the very useful theorem that the displacements of interacting levels from their expected positions on smooth series curves must add up to zero. The power of this stability theorem depends on narrowing down the set of levels under consideration. It will help in estimating certain large displacements of terms in series which are not well marked and will also help calculate constants for irregular series. Probably the most helpful application of the theorem will be the criterion it gives for deciding whether one has all of the set of levels which are affecting one another. The important but difficult case of continuous spectra has not been considered.

22. The escape of imprisoned resonance radiation from a gas. CARL KENTY, *General Electric Vapor Lamp Co. Hoboken, N. J.*—Theoretical considerations lead to the view that a large concentration of resonance quanta diffusing through a gas would, on the basis of Doppler broadening only, give rise to a distribution function for excited atoms, with respect to atomic speed, which would lie between two limiting distribution functions: (1) Maxwell's distribution function, namely

$$f_1(S)dS = [4/(\pi)^{1/2}](S^2/w^3) \exp - (S^2/w^2)dS$$

where S is the speed of an atom and w is the most probable speed; and (2) a distribution function expressing a lower relative excitation of the high speed atoms, namely

$$f_2(S)\, dS = 2(S/w^2) \exp - (S^2/w^2)dS.$$

On the basis of either (1) or (2) the diffusion coefficient as well as the average square free path are found to be infinite provided the volume of gas is infinite; otherwise, the *apparent* values of these quantities will depend on the volume, increasing therewith without limit because of the importance of extremely long free paths. Coupling or other broadening occuring at higher pressures will presumably accentuate the effect of abnormally long free paths. The results are in qualitative agreement with imprisonment experiments of Zemansky and of Webb and Messenger, in Hg, and with the experiments of Found and Langmuir and of Kenty in Ne (in print).

23. Yield of fluorescent x-rays from the K shells of various elements. DONALD K. BERKEY, *University of Cincinnati.*—The fluorescent yield w from the K shells of an aggregate of atoms is defined as the ratio of the number of characteristic K quanta emitted to the number of quanta photoelectrically absorbed in the K shells. The author has measured this ratio by comparing the total intensities of the primary and fluorescent rays from various substances, using the ionization method devised by A. H. Compton (Phil. Mag. **7**, 961, 1929). The following results were obtained:

Element		w	Element		w
27	Cobalt	0.38	42	Molybdenum	0.78
28	Nickel	0.39	47	Silver	0.73
29	Copper	0.43	48	Cadmium	0.72
30	Zinc	0.46	50	Tin	0.67
33	Arsenic	0.53	51	Antimony	0.64
34	Selenium	0.56	52	Tellurium	0.60
38	Strontium	0.72			

These results show that the fluorescent yield increases to a maximum for elements in the neighborhood of molybdenum, beyond which it decreases. It is planned to continue this investigation for elements of higher atomic number than tellurium.

24. Fine structure in the x-ray *K* absorption edge of calcium in compounds. VOLA P. BARTON, *Goucher College, and* GEO. A. LINDSAY, *University of Michigan.*—The fine structure of the Ca *K* edge has been examined in several calcium compounds. A quartz crystal was used and the calcium compound was ground to a fine powder and suspended in a collodion film for an absorbing screen. In cases where the calcium compound could be used as reflecting crystal and at the same time as absorber, the results were found to be the same as with screens. Calcite and aragonite, the same chemically, show markedly different fine structure, thus indicating that not the chemical compound, but rather the crystal form, is the determining factor. This is in accordance with Kronig's theory. Dolomite, $\mathrm{Ca\,Mg(CO_3)_2}$, and ankerite, $\mathrm{(Ca, Mg, Fe)CO_3}$ have the same crystalline form as calcite, and show the same fine structure for Ca, but the appearance for Fe in ankerite is different. This is not so satisfactory for the theory, for the iron and calcium atoms are similarly placed in the same crystal, and the ejected electron in passing through the crystal should experience the same variation in potential.

25. Further experiments on x-ray reflections from quartz crystals oscillating piezoelectrically. J. M. CORK, *University of Michigan.*—By both the Bragg method and the Laue method, quartz crystals at rest and oscillating piezoelectrically have been further studied. Starting with a relatively thick crystal and using a finely collimated x-ray beam the structure of the Laue spots could be readily observed. For oscillating crystals and also for polished crystals at rest the spots are double in structure. Etching the crystal with H Fl results in single spots for the non-oscillating crystal. The perfection of the surface is revealed by observing line breadth and intensity when the crystal is employed in a Siegbahn vacuum spectrograph at a wavelength of 5.5A; and for short x-ray wave-lengths on a Bragg spectrometer of 55 cm radius. In no case was line breadth or intensity sensibly altered by piezoelectric oscillation of the crystal. Results obtained are compatible with the elastic vibrational theory already proposed, (Fox and Cork. Phys. Rev. **38,** 1420 (1931)).

26. X-ray wave-lengths by ruled grating. R. B. WITMER AND J. M. CORK, *University of Michigan.*—With a ruled glass grating, measurements have been made of the wave-lengths in the *L* series emission spectra for elements from Ti (22) to Zn (30); and in the *K* series for elements from C (6) to Si (14). The grating employed (whose constant was $d=0.00166309$ mm) was ruled by Siegbahn on his new machine and gave excellent reflections. The experimental arrangement was identical with that employed in the precision determination of the *L* series wave-lengths of molybdenum (Cork, Phys. Rev. **35,** 1456, (1930)). This method has the important advantage that for the complete series of plates the position of the grating is in no way altered. The results obtained for the shorter wave-length lines are greater by about 0.3 percent than the corresponding wave-length measurements obtained by the crystal method. Crystals that have been employed for the longer wave-length range are mica, sugar, and palmitic acid. The individual results obtained with these crystals are shown to be so eratic that a comparison with the results obtained with the grating method is meaningless. The change in the relative intensity and the form of the α_1 line with change in atomic number is shown. Additional data using different incident grazing angles are being taken to observe any possible variation in wave-length with angle of incidence. (Prins and Hanawalt, Nederlandsch Tijdschrift voor Naturkunde **12**, 1 and 15, 1932).

27. Additional theory of plane gratings for x-rays. ROY C. SPENCER, *University of Nebraska.*—The positions of the diffracted virtual images of a source as seen in a plane grating placed at a distance L are given by $L' = L \sin^2\theta/\sin^2 i$ where i and θ are the grazing angles of incidence and diffraction. For use with x-rays the incident beam is confined between two equal slits of width S distant L apart with the grating close to the second slit. The diffracted beam produced backwards appears to be confined between two slits of width S' and distance L' apart where $S' = S \sin\theta/\sin i$ and L' has the value given above. The intensity of a cross section of the diffracted beam is a trapezoid, the constant part having a width S' and each side an angular width S'/L'. The former varies directly as $\sin\theta$, while the latter varies inversely. Assuming a parallel beam, the angle between the maximum and the first diffraction minimum is λ/S'. The ratio of this diffraction width to the geometrical side width is $\lambda L'/S'^2 = \lambda L/S^2$, a constant of the slit system. This should not exceed unity. The combined effect of geometric and diffraction widths may be studied using a sodium flame and two slits.

28. The gamma-ray spectrometer. M. C. HENDERSON, *Yale University.*—The method first used by Rutherford and Andrade (Phil. Mag. **27**, 854, 1914; **28**, 263 (1914)) to measure the wave-lengths of the radium gamma-rays and later adapted by Steadman (Phys. Rev. **36**, 460 (1930)) to the Geiger point counter has been improved and some preliminary results obtained. The Geiger-Müller tube counter has been adopted as the detector. It has proved easily possible to resolve and measure the 20 and 35 x.u. radium B and C gamma-rays. With 30 mg of radium, the 35 x.u. line causes 4.7 discharges per minute out of a total of 16.5. All counting is automatic and runs 24 hours a day. The resolving power is low but it will be possible to resolve lines about 5 x.u. apart without further changes in the apparatus. The lower limit of wave-length that can be measured without disturbance from the central beam is about 20 x.u. The interrelated effects of source thickness, slit width, crystal setting and slit setting upon the theoretical gamma-ray intensity transmitted through the slit can be plotted as a series of three-dimensional models, which will be shown. The method of coincidences, so successfully applied to cosmic rays, has been tried to record gamma-rays, with encouraging results and it is being further developed. Steadman's results (loc. cit.) are not confirmed.

29. The threshold counting voltage of the Geiger-Müller tube and some related phenomena. D. COOKSEY AND M. C. HENDERSON, *Yale University.*—The voltage at which a Geiger-Müller tube begins to count is determinable to 0.1 percent. The dependence of this threshold voltage upon chamber and wire dimensions, material and nature of the surfaces, temperature of the wire, and pressure and kind of gas has been investigated. It is found that the threshold voltage for proper counting is independent of the wire and wall materials. For any chosen pressure and wire size the threshold voltage so varies with the chamber diameter that the field at the surface of the wire remains constant. This threshold field depends on the gas and its pressure, passing thru a minimum at low pressures in a similar manner to the sparking potential. Knowing the threshold field, the formula: field = voltage/(a log b/a), where a and b are the radii of the wire and chamber respectively, enables the counting voltage to be calculated for any desired dimensions and gas pressure. For small wires, less than 0.075 mm diameter, the threshold field is inversely proportional to the diameter but diminishes less rapidly than this for larger wires. Raising the temperature of the wire while counting lowers the threshold voltage. One iron wire continued to count in air up to a dull red, above which temperature spurious discharges masked the proper counts.

30. New determinations of the ranges of α-particles from polonium, uranium I and uranium II. F. N. D. KURIE, *Yale University.*—The cloud chamber method described by the author in the abstracts of the New Orleans meeting (1931) has been used to determine the ranges of α-particles from polonium, uranium I and uranium II. The experiments on polonium were undertaken to test the method, but the results are in such good accord with previous values that they may stand alone. The range of polonium α particles at 0°C and 760 mm pressure is 3.690 ±0.005 cm. A graphical method has been devised for separating the number-distance curves of the two uraniums, which consists in plotting the data on probability paper. The plot then becomes three intersecting straight lines, the midpoint of the short connecting line giving the relative proportions of the two kinds of particles. The ranges of the uranium particles at 0°C and 760 mm pressure are respectively: $R_{U\,\mathrm{I}} = 2.58 \pm 0.015$ cm, $R_{U\,\mathrm{II}} = 3.11 \pm 0.01$ cm. The polonium range is derived from 335 tracks, the uranium ranges from 594 tracks. The uranium ranges are in complete agreement with the results of Laurence (Phil. Mag. **5**, 1027 (1928)), got by methods more likely to be in error than those used here.

31. Generalization of wave mechanics suggested by higher order terms in the classical electrodynamic equation of motion, and its influence on β-particles ionization for velocities approaching that of light. W. F. G. Swann and A. Bramley, *Bartol Research Foundation of The Franklin Institute.*—Classical electrodynamics gives, for small velocities, an equation of electronic motion of the form

$$\frac{e}{6\pi a c^2}\ddot{x} - \frac{e}{6\pi c^3}\dddot{x} + \text{etc.} = E + \frac{[uH]}{c} \qquad (1)$$

where a is the classical electronic radius. In the present paper, the equation is solved and for the cases which are relevant gives rise to

$$\frac{e^2}{6\pi a c^2}\dddot{x} = E + \frac{[uH]}{c} + f(D)E \qquad (2)$$

where $f(D)$ is a determined function of the operator d/dt. We now build a Schroedinger equation for ψ with the right-hand side of (2), replacing $E + [uH]/c$ as used in the ordinary developments, but with d/dt replaced by ∂/dt, which for the field of a high-energy β particle of velocity v becomes $-v\Delta$. The perturbation, instead of involving only the scalar and vector potentials ϕ, and U, which can be expressed in terms of it, involves also a series of spatial derivatives of ϕ. Application to the ionization of an atom gives for q the number of ions per centimeter of path, an expression which, with increasing β-particle energy, first diminishes, then increases, and finally diminishes towards zero. The first decrease followed by increase corresponds to the conclusions of Oppenheimer, as yet apparently unpublished. The final decrease comes from the new features introduced. It predicts a decrease of ionization for β-particle energies greater than about 10^{10} volts.

32. An interpretation of cosmic-ray phenomena. Thomas H. Johnson, *The Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.*—Schindler's measurements form the basis for a more specific theory of the process of ionization by cosmic rays than had hitherto been possible. To explain his data the following assumptions are made. (1) The primary rays contribute nothing *per se* to the ionization but produce secondary rays such as electrons and protons from the material through which they pass, the production coefficient β_m being a characteristic of the medium. (2) The absorption of the primary rays can be represented by a single exponential function with a coefficient ν_m characteristic of the medium. (3) The absorption of the secondaries can be represented by an exponential function, with a coefficient $\mu_m{}^n$ which is characteristic of both the absorbing medium m and the medium n in which the secondary ray was produced. The ionization at distance x behind the interface nm is given by

$$I = \frac{A\beta_m}{\mu_m{}^n - \nu_m}\left(e^{-\nu_m x} - e^{-\overset{m}{\mu}_m x}\right) + Be^{-\overset{n}{\mu}_m x}.$$

The constants have been determined to bring agreement with the data in the case of the air to lead, air to iron, iron to lead, and lead to iron transitions. The absorption coefficients of the secondary rays determined in this way agree with the energies measured by Millikan and Anderson. The relation of these ideas to other experiments is also discussed.

33. Study of getter action of phosphorus. HENRY J. MILLER, *Emporium, Pa.*—The clean-up of commercial 50 watt 230 volt vacuum incandescent lamps by phosphorus has been investigated and compared with the clean-up in lamps of the same type evacuated by laboratory methods by means of a third external electrode measuring the ratio of positive ions to electrons flowing to this electrode while the filament voltage is gradually raised from zero to a value somewhat above normal rating. The clean-up initiated by the thermionic current flowing between filament terminals progresses with maximum efficiency at filament potentials which, for lamps with getters, agree with the volt value of maximum ionization efficiency of 150 volts found by Mayer for air and nitrogen (Ann. d. Physik **45,** 1 (1914)). Commercial lamps without getters do not clean up. Lamps without getters evacuated by laboratory methods clean up but at higher potentials than the corresponding lamps with getters (175 to 200 volts). The clean-up curves of lamps with getters and without getters suggest the interpretation of the observed clean-up as "chain-reaction" according to Bodenstein. (*Preuss. Akad. Wiss. Phys. Math. Kl.* 1928, p. 490).

34. The Kerr electro-optical effect in carbon dioxide. C. W. BRUCE, *University of Virginia,* (*Introduced by J. W. Beams*).—Measurements have been made on the variation with density of the Kerr electro-optical effect in CO_2 using a method similar to that of Stevenson and Beams (Phys. Rev. **38,** 133 (1931)). The measures were taken at a constant temperature of 34.6°C. The density was varied from 0.05 to 0.288 gm/cc and was computed from pressure readings by use of Amagat's data. The results of Stevenson and Beams were confirmed for the range (0.08 − 0.18) over which they worked. A comparison made between the variation of the Kerr constant as determined experimentally and as computed from the relation $B \propto [(n^2+2)^2(\epsilon+2)^2]/n$, taken from the Langevin-Born theory, shows good agreement. The data for the index of refraction used in the above relation were that of Phillips (Proc. Roy. Soc. **A97,** 225 (1920)), and for the dielectric constant was that of Keyes and Kirkwood (Phys. Rev. **26,** 754 (1930)).

35. The initiation of electrical discharges in effectively ion free gases. J. W. BEAMS AND JOHN W. FLOWERS, *University of Virginia.*—A study is made of the factors that initiate the discharges described by Street and Beams (Phys. Rev. **38,** 416 (1931)). In carefully dried and filtered gases (air, hydrogen, nitrogen, helium) at atmospheric pressure, it is possible to apply 5×10^5 volts per cm between spherical brass electrodes for 10^{-6} sec. without electrical breakdown, provided the gas is kept "swept" as free as possible of ions by auxiliary fields. However, when ultraviolet light falls upon the cathode a field of 4×10^4 volts per cm starts the discharge in less than 10^{-7}sec. The maximum field depends upon the conditions of the surface of the electrodes and is of the same order of magnitude as that required to produce breakdown in a vacuum, which is known to be started by field currents from the cathode (Wood, Phys. Rev. **5,** 1 (1897); Hull and Burger, Phys. Rev. **31,** 1121 (1928); Snoddy, Phys. Rev. **37,** 1678 (1931)). When a steel point and plane were substituted for the brass spheres in the above experiment the field at the surface of the point could be made at least 10^7 volts per cm for 10^{-6} sec. without breakdown if the point was positive. However, breakdown started in less than 10^{-6} sec. if the point was made the cathode and the field raised to only 10^6 volts per cm. In a vacuum fields of 8×10^7 volts per cm were applied to the pointed steel or tungsten anode for 10^{-7} sec. without breakdown. Similar results were obtained with gaseous pressures less than 0.01 mm.

36. Ionization of helium, neon and argon under impact of their own positive ions. CHARLES J. BRASEFIELD, *Yale University.*—The number of electrons liberated from neutral rare gas atoms under impact of their own positive ions was measured as a function of the kinetic energy of the ions. It was found that helium was ionized at 100 equivalent volts; neon at 90 and 130 volts; and argon at 55 and 95 volts. It is thought that the higher ionizing potentials in the case of neon and argon are the result of impacts of doubly charged ions. The error in these measurements is hard to estimate but is thought to be within ±10 volts. If we assume (1) that half of the kinetic energy of the impacting ion is available for ionization and (2) that the energy required to liberate an electron is approximately the sum of the energies necessary to liberate it separately from its own core and from that of the impacting ion, we might expect ionization of the rare gases under impact of their own positive ions to occur at approximately the following values: in helium at 98 volts, in neon at 86 and 125 volts and in argon at 63 and 87 volts.

37. New devices for recording Kennelly-Heaviside layer reflections. HARRY R. MIMNO AND P. H. WANG, *Harvard University*.—Two new pieces of apparatus for layer height measurement have been built and tested. The first device is merely an improved form of the "long film" type of oscillograph, ordinarily used in pulse transmission experiments. In order to increase the resolving power without wasting or tearing the photographic paper tape, the oscillograph has been constructed with a magnetic clutch, shock absorber, and magnetic brake. The second device is a high speed chronograph, designed to give an accurate record of layer heights over an extended period of time. A complete history of the reflections produced by 2000 successive pulses is recorded in compact form on a strip of photographic paper, 90 cm long and 12 cm wide. The time scale may be varied from 5 minutes to 24 hours. The received pulses modulate a glow lamp, producing a small, sharply-defined dot on the moving paper. The resolving power appears to be somewhat better than that obtained with the best galvanometer oscillographs. A cathode-ray oscillograph is used to monitor the reception. The high speed chronograph has other applications, outside of the radio transmission field.

38. A new type of vacuum or circulating pump. E. L. HARRINGTON, *University of Saskatchewan*.—A new type of vacuum or circulating pump employing a helical tube made to rotate about the axis of the helix is described. Its action depends on a pumping liquid which fills the lower bends of the helix and crowds out the gas being pumped as the helix is rotated. There is a provision for the return of the pumping liquid to the first coil of the helix as the latter continues to rotate. The liquid may be chosen to suit the work at hand. Among the advantages claimed for the pump are the following: mercury vapour is not employed, heating and cooling elements are not required, adapted equally well to corrosive and non-corrosive gases, vapors and liquids, constant personal attention is not needed, it may be started or stopped instantly without the use of stop-cocks, and its action is reversible.

39. The form of potential barrier at the surfaces of conductors. A. T. WATERMAN, *Yale University*.—The method of treatment described by the writer (Phys. Rev. **38,** 1497–1505 (1931)) has been used to investigate the form of potential barrier inside as well as outside the surface of a conductor in equilibrium with its electron atmosphere, assuming continuity of potential and electric intensity at the boundary. The results indicate that there is a sharp rise in the barrier of about 4 or 5 volts within a distance of several Angstrom units in the immediate neighborhood of the surface (assumed plane), about one fifth of the rise occurring inside the conductor. The rest of the potential curve rises more gradually. Similar treatment for the form of barrier between plane parallel electrodes shows this to consist of a potential "plateau." To be consistent with contact potential as defined by the Kelvin experiment, on bringing the electrodes together there is a flow of electrons into the less electropositive metal, the potential barrier becomes a "hill" of decreasing height, until it disappears in a point of inflection at contact. Similarly the potential "trough" within a thin conducting film flattens out and disappears as the thickness of the film approaches zero. The case of a thin film deposited on base metal is difficult to solve, but gives promise of accounting for some of the peculiarities observed in such cases.

40. The caesium-oxygen-silver photoelectric cell. C. H. PRESCOTT, JR. AND M. J. KELLY, *Bell Telephone Laboratories Inc.*—The active cathode surface of the caesium-oxygen-silver photoelectric cell appears to be a film or surface concentration of caesium of atomic dimensions adsorbed upon a matrix of caesium oxide and silver containing free caesium and a small amount of silver oxide. The spectral characteristics of the photoelectric response depend largely upon the thickness of the surface film of free caesium. This film thickness is determined by the caesium concentration in the underlying matrix and is maintained by a diffusion equilibrium. Variations in the amount of caesium upon the surface were made either by exposing the standard finished cathode to small amounts of oxygen and allowing the response to recover by diffusion of free caesium from the underlying material, or else by allowing small amounts of additional caesium to deposit upon the standard surface. With increasing thickness of the caesium surface film the characteristics of the spectral response appear to vary continuously from a low response (with amounts of surface caesium far below the normal) which decreases with wave-length (from 6000A to 10,000A) to a high response for the normal surface with a selective maximum at 7500A−8000A, and finally to a low response with a maximum approaching 6000A.

41. Some photovoltaic properties of $Cu:Cu_2O\,|Pb(NO_3)_2$ solution | $Cu:Cu_2O$ photocells. WILBUR E. MESERVE, *Cornell University* (*Introduced by Ernest Merritt*).—The light sensitive electrodes were prepared by chemical methods which produce a uniform coating of copper oxide of any desired thickness. Two identical electrodes were placed in a 1 percent solution of $Pb(NO_3)_2$, the back of the light exposed electrode being insulated from the electrolyte. Measurements were made of the photo-e.m.f. produced by the cell when illuminated by sinusoidally interrupted light of variable frequency. By impressing the output of the cell on a resistance coupled amplifier of proper design, which takes no current from the cell and thus reduces polarization and internal chemical changes to a minimum, the frequency response was determined with the use of the stabilized cathode-ray "oscilloscope." The spectral sensitivity of the cells was determined with sinusoidally interrupted light from a monochromator and checks with that which has been determined with steady illumination. The angle of phase shift of the photo-e.m.f. with respect to the interrupted light was also measured and was found to first increase and then decrease with frequency, the maximum angle occurring at about 500 cycles. The internal capacity of the cell as an electrolytic condenser was found to nearly double when one electrode was illuminated by strong sunlight.

42. The isotopic weight and packing fraction of H^2. K. T. BAINBRIDGE, *Bartol Research Foundation*.—The mass of neutral H^2 is 2.01353 ± 0.000064 obtained from comparison of the mass of $(H^1H^1H^2)^+$ with He^+ on fourteen spectra secured with the mass-spectrograph recently described. The eqivalent packing fraction of H^2 is 67.6. On the assumption that the nucleus is composed of two protons and one electron the energy of binding is approximately 2×10^6 electron-volts but if the H^2 nucleus is made up of one proton and one Chadwick neutron then the binding energy of these two particles is 9.5×10^5 electron volts. $(3H^1)^+$ and He^+ provided the dispersion measurements for these spectra and the presence of $(H^1H^2)^+$ can only introduce a negligible correction. Lines of mass 4.0285 on the spectra were attributed to $(H^1H^1H^2)$ ions because (1) no lines of comparable intensity appeared in this position when commercial hydrogen was used, (2) under the conditions existing in the discharge tube the probability of formation of $(2H^2)^+$ was much less than for $(H^1H^1H^2)^+$, (3) the mass is less than the mass of $(4H^1)^+$ by an amount outside of the limit of error. The two enriched samples of hydrogen used were prepared by Brickwedde, both had been tested spectroscopically by Urey and Murphy and one was a sample of Bleakney's.

43. The isotopes of uranium. T. B. WILKINS AND W. M. RAYTON, *University of Rochester*.—The existence of an isotope of uranium (AcU_I) of shorter life than U_I as the parent of the actinium series was predicted in 1926 (Wilkins, Nature **117**, 719 (1926)). An alpha-ray range of 3.2 cm and period 2.5×10^8 yrs., then assigned, were confirmed by Rutherford's interpretation of Aston's mass-spectrogram of lead. (Nature **313**, 1929.) A mass-spectrogram of uranium failed to reveal even U_{II}. In the present work the alpha-rays from a thin sputtered film of uranium fell on a special photographic emulsion. The number of grains in individual tracks was counted. Two main peaks are indicated in the frequency curve at 9 and 11 grains and clearly marked humps at 13 and 16. The peak at 11 is slightly higher than at 9. Polonium gave a smooth curve with peak at 13. Hence Laurence's ranges of U_I and U_{II} are confirmed (Phil. Mag. **5**, 1027 (1928)), but two and possibly three additional isotopes of a less active series are indicated. The study of the relative activities of these two series may lead to a simpler method of determining the ages of rocks.

Nos. 44 to 47 are abstracts of invited papers which made up a symposium on x-rays.

44. The spectrum of scattered radiation. J. A. Gray, Queen's University.—It is generally assumed that, when homogeneous x-rays are scattered through an angle θ, the modified band has both an average wave-length and a wave-length of maximum intensity given by the equation

$$\lambda_m = \lambda + h/mc\,(1-\cos\theta) \;\ldots\ldots\ldots\; (1)$$

So that if $\lambda+\delta\lambda$ = average wave-length of scattered rays

$$\delta\lambda = (R/R+1)\cdot h/mc\,(1-\cos\theta)$$

$$-\ (R/R+1)\times 0.0243\,(1-\cos\theta)\mathrm{A}.$$

where R = ratio of integrated intensity of modified band to that of the unmodified line.

I have carried out experiments at different times since 1913 to obtain values of $\lambda+\delta\lambda$, but always with heterogeneous rays. A brief description of the method follows. The primary rays passed through two slits and fell on the radiator, the scattered rays passing through a second set of slits into an ionization chamber where their intensity was measured. Three readings were taken, the first with no absorber, the second with an absorber in the path of the primary rays, position A say, and the third with an absorber in the path of the scattered rays in position B say. It is essential that the ratio of the two last readings should be determined as accurately as possible. This ratio will be called A/B.

An analysis of some results obtained in 1922 is given in Table I, the average value of θ being $\pi/2$.

Table I.

Abs.	A/B	P	P'	μ/ρ	μ'/ρ	λ	$\delta\lambda$
0.304	1.13	0.327	0.289	3.68	4.08	0.63	0.023
0.608	1.24	0.152	0.123	3.09	3.44	0.59	0.022
0.912	1.32	0.079	0.0598	2.79	3.09	0.57	0.021
1.216	1.40	0.043	0.0307	2.59	2.86	0.56	0.020

The first column gives the mass of the aluminum absorber in g/cm^2. When the absorber is placed at A, the ionization is P times as great as it is with no absorber; when placed at B, P' times as great. From P and P' the values of μ/ρ and μ'/ρ are obtained. From μ/ρ, λ is obtained from tables. It is given to two figures. $\delta\lambda$ is obtained from relative values of μ/ρ and μ'/ρ' by assuming that μ/ρ varies as λ^3.

It will be seen that $\delta\lambda$ is less than 0.024A, the value it should apparently have if all the scattered radiation is modified.

The radiator was paraffin wax, 1 inch square in cross section. Assuming a value of $R=8$, $\delta\lambda$ should be of the order 0.021A, if the primary rays are homogeneous. As the table shows these rays are not homogeneous. The effect of using heterogeneous rays is shown in Table II. A primary beam has been assumed to consist of rays of wave-lengths 0.4, 0.5, 0.6, 0.7, 0.8 and 1A respectively, the scattered rays ($\theta=\pi/2$), having wave-lengths 0.424, 0.524 etc. and relative intensities 0.05, 0.20, 0.25, 0.25, 0.20,and 0.05 respectively. This assumed beam has similar properties (absorption coefficients) to the one with which the results of Table I were obtained.

Table II.

Abs.	A/B	P	P'	μ/ρ	λ	$\delta\lambda$
0.304	1.11	0.318	0.286	3.77	0.63	0.020
0.608	1.20	0.138	0.115	3.23	0.60	0.020
0.912	1.27	0.0693	0.0543	2.92	0.58	0.019
1.216	1.35	0.0380	0.0282	2.69	0.56	0.018

It will be noticed that $\delta\lambda$ decreases as the thickness of the absorber is increased. A comparison of the figures in the two tables indicates that $\delta\lambda$ for homogeneous rays of wave-length 0.6A is about 0.026A for the radiator used, and, if we assume $R=8$, that the average wave-length of the modified rays is 0.029A greater than λ and not 0.024A, the value given by Eq. (1).

In later experiments, I have attempted to see if $\delta\lambda$ varied with the thickness of the radiator, using heterogeneous rays. One set of results is given in Table III.

TABLE III.

Abs.	Radiator	A/B	P	P'			
0.303	1 sheet	1.20	0.220	0.183	5.00	0.7	0.028
0.303	2 sheets	1.18	0.220	0.187	5.00	0.7	0.025
0.303	12 sheets	1.16	0.220	0.190	5.00	0.7	0.023

The radiator consisted of sheets of filter paper soaked in paraffin wax, the mass of the former being 0.07 g/cm^2 and of the latter 0.10 g/cm^2. For $\theta=\pi/6$, A/B was found to be equal to 1.01.

The variation of $\delta\lambda$ with thickness of absorber is again shown in Table IV, the radiator being one sheet of waxed filter paper.

TABLE IV.

Abs.	A/B	P	P'	λ	$\delta\lambda$
0.067	1.07	0.538	0.503	0.86	0.032
0.134	1.14	0.330	0.293	0.80	0.030
0.268	1.18	0.250	0.216	0.70	0.026

It will be noted that $\delta\lambda$ decreases as the thickness of the radiator and of the absorbing material increases. It is concluded that a thorough spectroscopic examination, both photographic and electrical, must be made of the radiation scattered by thin radiators. It is recommended that all such measurements should be verified by the above absorption method, and that this method be applied to gases, particularly hydrogen, helium and other rare gases, the two former as they give us the nearest approximation to free electrons. It is also of great importance to determine the ratio R accurately.

45. X-ray evidence for high electron momenta in atoms and in solid bodies. J. W. M. DuMond, *California Institute of Technology*.—The work of the author in collaboration with H. A. Kirkpatrick, furnishes evidence for the interpretation of the breadth and structure of the modified line in the spectrum of scattered x-rays as a Doppler broadening caused by the momenta of the electrons in the scattering body. A test of the correctness of this interpretation was made by studying the variation in the shifted line breadth at half maximum as a function of the primary wave-length and also as a function of the scattering angle. The behavior of the shifted line breadth with both these variables is shown to be entirely consistent with the doppler interpretation of its origin. Very sharply defined homogeneous scattering angles could be obtained thanks to the geometry of the multicrystal spectrograph used in this work. The wave-lengths tested covered a range from 700 x.v. to 200 x.v. The Doppler interpretation of the broadening of the shifted line is shown to be in good accord with quantum mechanics. The profile of the Compton line can be interpreted as a distribution curve expressing the relative probability of scattering by electrons of component momentum, px, resolved along on axis, x, which very nearly bisects the angle formed by the incident and scattered beams of radiation. The distribution of electrons in linear momentum has been obtained by this method for carbon and beryllium scatterers and appears to be entirely consistent with the distribution to be expected quantum-mechanically as computed from formulae of Pauling and Podolsky for hydrogenic momentum distributions. The application of these hydrogenic distributions by the introduction of screening factors gives of course only a rough approximation to the momentum distribution in the free carbon atom. It gives nevertheless a distribution curve very similar to that deduced from the experiment save that the maximum of the curve occurs at somewhat lower momenta in the theoretical curve for the free carbon atom than in the experimental curve for a solid carbon scatterer. This is exactly what is to be expected since in solid carbon the proximity of neighboring atoms requires higher momenta of the outer electrons than they would possess in a free atom.

46. Status of x-ray wave-lengths. J. A. Bearden, *The Johns Hopkins University.*—The determination of x-ray wave-lengths by crystal gratings requires a knowledge of the constancy of the grating constant of crystals from various sources, and as precise a determination of this constant as is possible. Recent measurements (Phys. Rev. **38**, 3089, (1931)) have shown that the grating constant of calcite crystals from various sources varies less than 1 part in 200,000. The average true value of the grating constant was found to be $d=3.02810$A at 18°C, and the effective value for the first order diffraction $d_1=3.02769$A.

The most precise methods of measuring the diffraction angles appear to be the photographic and double crystal spectrometers. For true symmetrical lines it can be shown that the two methods should give results of the same order of precision. In the case of asymmetrical lines the double crystal method has a distinct advantage in that measurements can be made on the peak of the lines, or from the shape of the lines corrections can be applied to take into account the close components. The importance of measuring x-ray wave-lengths by the double crystal method is shown by the results obtained on the K series of copper and iron where most of the lines are asymmetrical.

Since the ruled grating measurements of x-ray wave-lengths are about 0.25 percent higher than the crystal values it is important to know which value is correct. Studies of the diffraction by ruled grating when used for measuring x-ray wave-lengths have as yet given no explanation of the observed difference. However, the following facts appear to support the crystal value rather than the ruled grating results. (1) Allison (Am. Phys. Soc. Washington 1932) has examined calcite crystals which gave the theoretical rocking curve width and diffracted intensity for a perfect crystal. (2) Tu (Phys. Rev. **40**, 662 (1932)) finds no evidence for mosaic structure. (3) The agreement between Planck's constant h determined by the limit of the continuous x-ray spectrum and other methods. (4) Inconsistency of fundamental constants if the grating wave-lengths were accepted as absolute. (5) Dispersion of x-rays.

47. Fine structure in x-ray absorption spectra. J. D. Hanawalt, *The Dow Chemical Co., Midland, Mich.*—The fine structure in x-ray absorption spectra which extends over a region of several hundred volts to the short wave-length side of the principal absorption edges of many elements has been explained in terms of the simultaneous transitions of two or more electrons due to the absorption of a single quantum. However, this interpretation is not consistent with the experimental facts which are brought out by a study of the effects of the physical and chemical state of the absorbing atom on the fine structure, and by a study of the effect of temperatures changes on the fine structure. These facts are: (1). The fine structure of a polyatomic vapor and of the same material in the solid state are usually similar, though the solid exhibits an additional structure not seen in the vapor spectrum. (2) The fine structure of a polyatomic vapor may differ from that of the solid. (3) Fine structure of more than a few volts separation from the main edge is not observed for any monatomic vapor. It is important to note that the structure which is exhibited by monatomic vapors if of such small energy value as to be satisfactorily explained by the Kossel theory of the transitions of the ejected electrons to various of the virtual orbits of the atom. (4) Fine structure is not observed in the spectra of the polyatomic vapors Se_8 and AsH_3. (5) The fine structure exhibited by Hg in $HgCl_2$ in solid and in vapor forms has the same energy separations from the principal edges in both its L_{III} and its L_{II} spectra. (6) An element in different chemical compounds may show different types of fine structure. (7) In the series As, $AsCl_3$, As_2O_3, As_2O_5, AsH_3 the principal edge has the same wave-length for the vapors, while there are shifts of 5.5 ± 1.5 volts for the solids. (8) The fine structure in the K absorption spectra of Fe becomes fainter as the temperature is raised and at 800°C has almost entirely vanished. (9) There is a shift of the fine structure discontinuities in the direction of longer wave-lengths as the temperature is raised. For a change from 20°C to 800°C the magnitude of this shift is 5.0 ± 2 volts at a point 115 volts from the K edge. Statements 8 and 9 are illustrated in Fig. 1.

Kronig has shown that the principal experimental facts concerning fine structure may be understood from the theory of the quantum mechanics of electrons in crystal lattices. The theory shows that not every value of velocity is possible to the motion of electrons traveling through a crystal lattice, but rather that there exists an energy spectrum consisting of alternating zones of permitted and forbidden energies. In the case of the isolated atom the electron is ejected from the atom and in addition might be given *any* value of kinetic energy. However, in a crystal lattice the x-ray quantum can only eject an electron from the atom and thereby become absorbed if it gives the electron such a value of kinetic energy as to bring it into one of the permitted energy zones. Thus one will expect variations in the absorption coefficient on the short wave-length side of the main edge related to this sequence of permitted and forbidden energy zones. Kronig shows that for a one-dimensional sequence of periodic potential barriers the forbidden levels fall together with the energy values $W_n = n^2h^2/8ma^2$, where n takes integer values, h is Planck's constant, m is the electronic mass, and a is the distance between successive potential barriers. From this equation, if the lattice constant a increases through thermal expansion the energy zones shift toward the zero level. The magnitude of this shift for Fe agrees with that experimentally observed. Also, the greater distorsion of the periodicity in the lattice at high temperature causes a smearing of the sharp boundaries between permitted and forbidden energy zones and so causes the vanishing of the fine structure.

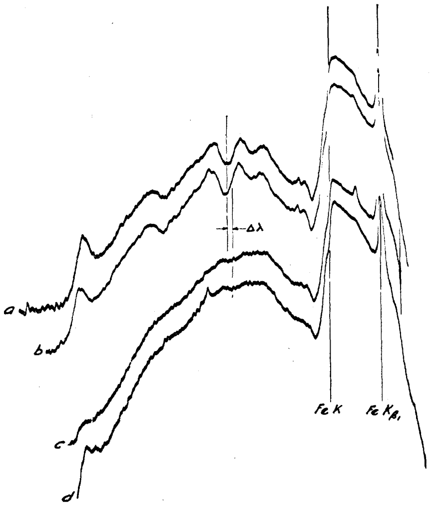

Fig. 1. Microphotometer traces of the *K* absorption spectra of Fe.
(a) 20°C, (b) 20°C, (c) 770°C, (d) 840°C.

The reciprocal lattice constant squared form of the energy has since been verified in other ways. Lindsay has shown that the fine structure of K in the crystals KCl, KBr, and KI has the same character for each crystal but that the energy separations from the main edge of the corresponding discontinuities in the three spectra are inversely proportional to the squares of the lattice constants. Coster and Veldkamp have demonstrated this same principle by a comparison of the F-C cubic metals Cu, Au, and Pt. They have also found by a study of a Au-Cu mixed crystal that the fine structure discontinuities of the Au L_{III} spectra have shifted to higher energies and the discontinuities of the Cu *K* spectra have shifted to lower energies by just such amounts that in the mixed crystal they have the same values. They have also shown many interesting facts concerning the intensity of the fine structure.

Recently Kronig has extended his theoretical considerations by investigating in how far it is possible to relate the individual minima of the fine structure, similarly as the lines of an x-ray powder diagram, to the various reflections of the electrons on the lattice planes, and has shown that a decisive agreement between theory and experiment is not obtained in this way.

Nos. 48 to 50 are abstracts of papers which made up a symposium on plasticity.

48. On the problem of the solid state. F. Zwicky, *California Institute of Technology.*—A discussion will first be given of these particular questions which constitute the problem of the solid state. One of the most characteristic phenomena exhibited by real crystals is a peculiar coexistence of perfection in certain respects and imperfection in others. This behavior of crystals may be traced back to the fact that the properties of crystals can roughly be divided into two groups, structure insensitive and structure sensitive, of which the latter group is responsible for hysteresis effects.

The problem of the solid state essentially consists in understanding the coexistence of structure sensitive and structure insensitive properties. After it was realized that the theory of the ideal lattices had nothing to offer in the way of a rational explanation of these phenomena, two different attempts were made in order to arrive at a solution.

The first attempt is based on the observation that in general crystals during their growth and existence are very severely affected by certain disturbing effects, such as thermal and mechanical stresses, liberation of dissolved gases, etc., which hinder the formation of ideal crystals. These facts suggest the assumption that all structure sensitive properties are due to *accidental imperfections*. Although this view has many points to recommend itself it cannot be regarded as a solution of the problem of the solid state. The main objection to the *imperfection theory* is that as we grow the crystals more and more carefully the less their structure sensitive properties conform with those which we derive from the theory of ideal crystal lattices.

The second attempt is based on the observation that the physical properties which are peculiar to the crystalline state are extending over distances far greater than the effective action radii of individual atoms and molecules. They therefore suggest the existence of certain *cooperative effects* which are exhibited only if atoms and molecules are present in very great numbers. With this observation in mind the author has undertaken a systematic study of cooperative phenomena whose physical origin is essentially related to forces depending on the distances as $1/r^2$, $1/r^3$, and $1/r^4$ and also on the exclusion principle. Mathematically speaking we are confronted with the problem of conditionally convergent series. If we consider ideal crystals only, intrinsic equations of state for crystals can not exist, as the mentioned cooperative effects introduce effects of the boundaries, no matter how large the crystals are. For this and other reasons a *secondary structure* of crystals is tentatively introduced. The conception of the secondary structure resolves many of the difficulties encountered by the older theories. It also allows us to draw many new conclusions and to predict a great number of phenomena as yet unknown. Finally theoretical and experimental work which has been done so far on the secondary structure will be discussed; special consideration will be given to the problems related to the mechanical and electrical strength of crystals. It also will be shown that the secondary structure, if its exists, will necessitate a generalization of the classical theory of elasticity inasmuch as it renders insufficient the representation of strains and stresses by tensors.

49. Magnetism and plasticity. FRANCIS BITTER, *Westinghouse Research Laboratories, East Pittsburgh, Pa.*—It is the purpose of this paper to show how the above phenomena may be used to throw light on each other. To a first approximation the magnetization of a ferromagnetic sample depends on four factors: the shape of the sample (including such geometrical details as cracks, grain boundaries, etc.), the magnitude of the applied field, its orientation with respect to the crystallographic axes, and the nature of the lattice distortions. If three of these factors are known, the fourth is calculable from the magnetization.

As an illustration the experiments of F. Schmidt (Dissertation Dresden 1931) are discussed. This author measures the induction in iron alloys in a constant field as a function of elongation up to the breaking point. He finds that the induction has a maximum during the elastic expansion, another when the material begins to flow, and a third just before rupture. These maxima indicate either a very peculiar dependence of induction on lattice distortion in iron (which is being further investigated theoretically), or an irregular dependence of lattice distortion on total elongation. Either conclusion would have interesting consequences. Once a satisfactory relationship between lattice distortion and magnetization is established, it becomes possible to make strain analyses with magnetic tools, even during the processes of flow. Becker and Kersten (Zeits. f. Physik, **71,** 553 (1931); **64,** 660, (1930)) have done important work in this direction.

The second part of the paper shows that the unsatisfactory magnetic properties of the outside layers of rolled samples results at least in part from the peculiar distribution of stresses and fibering along the surfaces just under the rolls.

50. Internal dissipational resistance to distortion in solids and its correlation with other physical properties. R. L. WEGEL AND H. WALTHER, *Bell Telephone Laboratories.*—Measurements of two internal dissipation coefficients expressed as equivalent viscosities have been made on samples of a variety of solids including glass, hard rubber, relatively pure metals and alloys. The resonant bar method was used, observing elongational and torsional vibrations within the frequency range 500 to 50,000 cycles per second, and at strain amplitudes 10^{-6} to 10^{-8} cm/cm. At these amplitudes *viscosity* is independent of strain amplitude but not of frequency. In two samples of glass viscosity is inversely proportional to frequency for both extension and torsion, which shows the energy loss per cycle to be independent of frequency and that according to current terminology the mechanism is *hysteretic*. On the assumption that the material is isotropic and that dissipation is associated only with shear, the usual expression for Young's modulus, generalized for vibrations to include viscosity, is $E+ie=9k(N+in)/(3k+N+in)$ in which the imaginary components in each case are products of viscosity and radial frequency. The imaginary components of each elastic coefficient are found experimentally to be very small compared with the real parts, from which it follows that

$$E/N = 2\,(1+\sigma); \qquad e/n = 4\,(1+\sigma)^2/3$$

in which σ is Poisson's ratio which has a negligible imaginary part. In the glass samples these ratios should be different but experimentally turn out to be equal, suggesting the likelihood that dissipation (nonthermodynamic) is associated with compression to the same extent as with shear. In high purity aluminum samples viscosity varies with frequency to the power $-4/3$ approximately and in nickel to the power $-1/2$ approximately. Other materials follow similar power laws lying between these limits in the frequency range investigated. This suggests that in all except perhaps glass there are within the samples, owing to their structure, relaxation mechanisms having relaxation times of the order of magnitude 10^{-3} to 10^{-5} seconds. The gross plastic relaxation time is usually minutes or hours or more. It is convenient to regard the internal dissipation coefficient of a solid as a complex viscosity, each component of which in general varies with frequency as it does in the case of a gas or a liquid.

Viscosity of solids at room temperature increases with extreme rapidity with temperature, a trend opposite to that in liquids. In steel alloys tested viscosity increases slowly with hardness (Rockwell) up to about the point of brittleness, after which the increase is enormous. During the aging process of lead alloys viscosity changes rapidly. In Pb-Ca (0.04 percent) the increase is over 300 percent, while the electrical conductivity changes by a matter of only 10 percent. In one sample over a year old the change is still in process. With the same heat treatment high purity lead decreases about 20 percent in a week or so, and then remains constant. A test of viscosity should be a useful guide in connection with the development of special alloys when better correlation with other physical properties is available.