two known satellites on which to base comparisons. The base term for the relative distances in each satellite system is 10 except in the case of Mars where it is one. Distances under Bode's law (represented by the series 4, 7, 10, 16, 28, 52, 100, 196, 388 and 772) are included not only for comparison of the results with those of the new law but also because that law gives very good values for some of the planetary satellites as well as for those of the sun. Likewise the distances under Dr. Caswell's law are included. These are obtained as explained in his article in SCIENCE.[1]

The new "Planet X" has been officially reported in a circular from the Lowell Observatory as having a distance from the sun of 40 to 43 astronomical units. Therefore double values have been included in the table until a more accurate determination of the distance is made. Enceladus, the second satellite of Saturn, does not, apparently, belong to any of the three series, but it is here included for completeness. The orbit of Themis is not accurately determined, but it seems that there may be a faint satellite at about the distance given. If in the satellite system of Mars 10 be taken as the relative distance for Deimos, better values will be obtained for the Bode and Caswell series, but the value of one was adopted for Phobos instead because of the near correspondence of the distance of that satellite to that set by Roche's limit. Ceres, the largest of the asteroids, is included in the table although it may belong to a system of harmonics rather than to the fundamental series. Referring to the table, it is seen, of course, that not all of the successive terms of the new law are represented in any one satellite system nor are the same terms represented in different systems.

It is important to notice that Bode's law gives fairly good values for at least five of Jupiter's satellites, for four of those of Saturn and for three of those of Uranus. This fact seems to be overlooked in nearly all modern popular discussions although it was referred to in some articles fifty years ago. Sir James Jeans,[3] like many others, has said ". . . it seems more than likely that it [Bode's law] is a mere coincidence with no underlying rational explanation." Yet Bode's law is an approximation for several terms both of Dr. Caswell's law and of my own, and Dr. Caswell[1] believes that his series "suggests the possibility that the orbits of the planets may be 'quantized' somewhat after the manner of the electronic orbits in the Bohr atom." The quantum principle is important in wave-theory, and my own solution resulted from studies in that field. The new series can be derived by taking the fiction, employed in the mathematics of a vibrating sphere, of a double source of wave-action of suitable strength at the center of the sphere and by modifying this concept to that of two sources of wave-action whose distance apart is relatively small in comparison with the length of the waves set up in the surrounding medium. Then, by disregarding the distance apart of the two sources, it is possible to develop the series by superposition. This assumes that the solar system can be treated somewhat on the order of the Schrödinger[4] atom rather than that of Bohr. A French writer, Lieutenant-Colonel Delaunay,[5] also believes wave-action is important in this problem. Finally, Victor Goldschmidt, of Heidelberg, according to Dr. Malisoff,[6] has shown that "a mathematical treatment strictly analogous to the phenomena of *standing waves in sound,* the distribution of lines in spectra, the progress of crystallization and similar phenomena gives the same law of harmonic relations of distances not only for the planets but also for satellites." Referring to Goldschmidt's[7] original article, I find that he has represented the distances of the planets as follows: Mercury 3.90; Venus 7.10; Earth 10.0; Mars 16.7; Jupiter 50.0; Saturn 100; Uranus 200; Neptune 300, and (following his method) "Planet X" 400. Dr. Caswell[1] has given it as his opinion that "on the whole the agreement is good, and can scarcely be accidental." After considering all this evidence independently arrived at by different investigators I am disposed to agree with him and offer as my opinion that Bode's law, as a first approximation, may have its origin in actual causal phenomena.

J. B. PENNISTON

SEATTLE, WASHINGTON

THE NATIONAL ACADEMY OF SCIENCES

AT the annual meeting of the National Academy of Sciences, held in Washington on April 28, 29 and 30, the following papers were presented:

The structural basis of the integration of behavior: G. E. COGHILL (introduced by C. Judson Herrick). The development of behavior in a lower vertebrate, in which

[3] Sir James Jeans, "The Universe around Us," p. 20, 1929.

[4] Arthur Haas, "Materiewellen und Quantummechanik" (p. 81 in Eng. trans. by L. W. Cobb, "Wave Mechanics and the New Quantum Theory," London, 1928).

[5] Lieutenant-Colonel Delaunay, "Problèmes Astronomiques," Paris, 1920.

[6] William Marias Malisoff, "Some New Laws for the Solar System," SCIENCE, n.s., 70: 328–329, 1929.

[7] Victor Goldschmidt, "Über Harmonie in Weltraum, ein Beitrag zur Kosmogonie," *Annalen der Naturphilosophie,* 5: 51–118, Leipzig, 1906.

movements can be observed from the first muscular contraction to the adult condition, is a process of expansion of a pattern which is from the first always integrated. Within this integrated total pattern partial patterns such as reflexes emerge with varying degrees of individuality of their own. This is accomplished by a progressive restriction of the field of adequate stimulation of the partial patterns as well as of the patterns themselves. This law is also exemplified in the structural development of the nervous system, and apparently holds for higher vertebrates and man. It is the unifying principle which brings order out of the chaos which has hitherto prevailed as regards various categories of behavior, such as simple reflexes, chain reflexes, conditioned reflexes, instincts, habits, trial and error.

Localization of function in the nervous system: C. JUDSON HERRICK. Analytic functions, such as specific reflexes, are performed by precisely localized organs. Synthetic or integrative functions seem to pertain to the organism as a whole. But these too have organs; they are not disembodied; and our problem is: What is this apparatus? Genetically, specific local reflexes arise within and are derived from mass-movements or total reactions (Coghill). Parallel with elaboration of these localized reflex arcs, special integrating apparatus is developed—the diffuse nervous felt-work, or neuropil. This is the parent tissue from which the mechanisms of all higher nervous functions are differentiated—correlation, association, learning, memory, intelligence. This apparatus of the personality as a whole has location in space, but the pattern of this localization is radically different from that of specific reflexes, and the pattern of performance is different.

Observations on asphyxia bearing upon the adjustment of respiration to diminished pressures of oxygen at great altitudes: YANDELL HENDERSON and ELLEN M. RADLOFF. Healthy men who ascend such mountains as the Himalayas, requiring several weeks, develop an acclimatization which permits them to be comfortable and even to make great physical exertions. If, on the other hand, the ascent to such altitudes is made in a few hours by balloon or railroad train, as in the Andes, intense mountain sickness, physical incapacity and even death may result. The study of the process of acclimatization has shown that the volume of breathing per unit of gaseous exchange in acclimatized men corresponds to the decreased pressure of oxygen. The primary increase of breathing might be due either to accumulation of lactic acid and other incomplete combustion products or to a primary effect of low oxygen inducing over-breathing and thus rendering the blood temporarily more alkaline than normally. The results of our investigation of the changes in the blood in dogs during asphyxia favor the latter conception.

Virus disease and the central nervous system: SIMON FLEXNER. By a virus disease is meant one induced by a micro-organism so small that it has not been rendered visible by the most powerful microscope. Such micro-organisms or viruses are, because of their minute size, capable of passing through the pores of earthenware filters, which hold back ordinary bacteria. This property has led to these viruses being called "filter passers" or "filterable viruses." Viruses produce disease in plants and in many, if not all, orders of animals. The particular interest which they have for us to-day depends upon the fact that they are not only responsible for severe diseases among mammals, including man, but that the diseases are often attended by symptoms indicating involvement of the central nervous system. Poliomyelitis, or infantile paralysis, is an excellent example of this condition; another is rabies, or hydrophobia. In smallpox, measles and certain other virus diseases of man it occasionally happens that the central nervous system is affected, in which case the gravity of the original disease is intensified. In domestic mammals virus diseases attended by nervous complications are found among horses (Borna's disease), rabbits, guinea-pigs, dogs (distemper), etc. In certain instances the virus diseases of the lower animals are communicable to man (*e.g.*, psittacosis, or parrot disease); on the other hand, virus diseases of man can be communicated to the lower animals (*e.g.*, poliomyelitis, typhus fever, yellow fever). We are just beginning to learn the frequency with which the central nervous system is involved in the virus diseases of man and of animals. It appears that the viruses themselves may be divided into two classes: (1) those which tend to attack the central nervous system predominantly, and (2) those which attack other organs with greater intensity and frequency than the central nervous system. The first class of viruses produces diseases which are in essence affections of the central nervous system; the second class, diseases in which affections of the nervous system are more in the nature of complications than of essential disease.

Biological studies of the tubercle bacillus—(1) *Instability of the organism—Microbic dissociation:* S. A. PETROFF (introduced by Hans Zinsser). It has been increasingly evident during recent years that bacteria along with the other living forms are subject to modification. From the accumulated evidence in the last fifty years it seems that the tubercle bacillus, which has been considered by many investigators as one of the most stable micro-organisms, is also subject to modification. No explanation has been offered as to the cause of the morphological, cultural and virulence variations. In this paper we shall discuss the instability and microbic dissociation of the tubercle bacillus, for the study of which new methods and media have been devised. (*a*) Three types of colonies have been dissociated from the avian tubercle bacilli. One is perfectly round, smooth and appears like moth-ball, is easily emulsified, grows best on alkaline media and is highly pathogenic for chickens. The second type is flat, moist, with smooth surface, and is emulsified with difficulty. The third type is flat and dry, the center giving the appearance of small pebbles. This colony is also difficult to emulsify. The second and third types are not so virulent for chickens as the first. (*b*) Three types of colonies have been isolated from a

bovine tubercle bacillus culture grown on special gentian-violet egg media. One is perfectly round, smooth, moist, appears as moth-ball, emulsifies easily and grows best on alkaline media. Morphologically it is composed of small intact rods, and granules are absent. The organism is highly pathogenic for guinea-pigs and rabbits. The second type is flat, with a moist smooth surface and raised center. It grows best on acid media. The rods are longer and beaded. It produces less extensive tuberculosis in laboratory animals. The third is flat, dry and the structure appears like small pebbles. It emulsifies with difficulty in salt solution and is only sometimes pathogenic for guinea-pigs and rabbits. (*c*) From the BGG cultures, we have dissociated two extreme types of colonies. One is large, flat, with large folds, appears very waxy, grows best on acid media and is not pathogenic for guinea-pigs or rabbits. The second is a large flat colony, the center appears like honey-comb and the periphery is veil-like. It grows best on alkaline media and is pathogenic for guinea-pigs and slightly for rabbits. (*d*) The human tubercle bacillus has not been completely dissociated. It seems that this organism presents large numbers of variant colonies, which are quite unstable. Some of these colonies have been successfully reverted, one into the other, by a special method of cultivation. It seems that the tubercle bacillus as compared with other organisms is also quite unstable. The studies indicate that the factor of instability must be taken into consideration when discussing any problem in tuberculosis.

The architecture of living cells. Optical sectioning with the ultra-violet microscope: FRANCIS F. LUCAS (by invitation). This paper describes a new tool for biological research. It is the ultra-violet microscope perfected and reduced to practice. With new technique it is possible to section optically living normal and malignant cells and to photograph them at very high magnifications and with a degree of resolution never heretofore achieved. The average living cell is about 1/3,000 inch in diameter. This living cell, itself invisible to the unaided eye, is "sliced" into sections spaced about 1/100,000 inch apart and photographs of each section are taken without materially interfering with the normal behavior of the cell. In the average cell thirty or even more photographs may be taken on uniformly spaced optical planes. At magnifications as high as 5,000 diameters the interior architecture of living cells is photographed. By virtue of the invisible monochromatic ultra-violet light which is used the resolving ability of the system is about twice that by other known means. The apparatus is briefly described and illustrated and photographs are included of the structure of normal and malignant living cells. Several photographs show the sectioning method applied to living brain cells.

The sense of hearing in fishes: KARL VON FRISCH (introduced by R. G. Harrison). Fishes (minnows, *Phoxinus laevis*) can be trained to react to sounds of whistles, tuning-forks, etc. They are fed from a glass rod and at the same time the training sound is given. The sense of sight is eliminated by blinding. After some days the fish gives a very typical reaction to sound. It snaps and seeks for the food at once when the sound is given, before the food is put into the water. The upper limit in minnows is between 4,000 and 7,000 v.d. The low limit could not be found. The lowest tuning-fork (16 v.d.) gives good results. The acuteness of the sense of hearing is about the same as in man under similar conditions, that is, when he is completely immersed in a large aquarium. Minnows can be trained to distinguish between different sounds, a feeding sound which means food, and a warning sound which means a punishment (a light blow with a glass rod). The best fish could distinguish perfectly the two sounds of a minor third (290 and 345 v.d.) in a long series of experiments. Fishes from which the utriculi, semicircular canals and ampullae have been removed have entirely lost the sense of equilibrium; nevertheless they can be trained to sounds as easily as normal fishes, in the same time, within the same limits, and the acuteness of the sense of hearing is the same as in normal fishes. The reactions of such fishes are especially impressive. When they are lying on the bottom of the aquarium and the whistle is blown, they rise very vigorously and swim through the aquarium turning somersaults again and again. Fishes with both lagenae and sacculi removed are fully in equilibrium; but it is impossible to train them to sounds higher than 130 v.d. To low sounds training is possible. The fish without sacculus and lagena can even distinguish between different sounds in the low region as well as normal ones. Therefore lagena or sacculus, or both, are the organs for the perception of middle high and high sounds. Whether the low sounds are perceived by means of the skin or the lateral line organ has not yet been definitely determined. All the reactions described here are shown in moving pictures during the lecture. These experiments, performed together with Dr. Stetter, are to be continued.

Action currents in the auditory nerve in response to acoustical stimulation; experiments demonstrating the correspondence between sound and nerve impulse: ERNEST GLEN WEVER and CHARLES W. BRAY (introduced by E. G. Conklin). By placing an electrode on the cat's auditory nerve near the medulla, with a grounded electrode elsewhere on the body, and leading the action currents through an amplifier to a telephone receiver, the writers have found that sound stimuli applied to the ear of the animal are reproduced in the receiver with great fidelity. Speech is easily understandable. Simple tones, as from tuning-forks, are received at frequencies which, so far as the observer can determine by ear, are identical with the original. Frequencies as high as 3,300 cycles per second are audible. Numerous checks have been used to guard against the possibility of artifact. No response was obtained when the active electrode was placed on any other tissue. After destruction by pithing of the cochlea on the electrode side, the intensity of the response was diminished; after destruction of the cochlea on the other side as well, the response ceased. The response ceased

when the circulation to the head was restricted by pressing the vertebral arteries, and returned when normal circulation was restored. Likewise, the response ceased when a steady direct current was applied to the nerve, and returned when the direct current was removed. This result, that the frequency of impulses in the auditory nerve varies according to the frequency of the stimulus, does not bear out the expectation based upon the recent experiments on other sensory nerves, where it has been found that frequency of impulse varies according to intensity of stimulus. Moreover, the correspondence shown between sound and nerve impulse requires an abandonment, or at least an essential revision, of the modern formulation of the Helmholtz theory of audition.

Accumulation of electrolytes in valonia: W. J. V. OSTERHOUT. Electrolytes often seem to contravene physical laws by diffusing against a gradient and reaching a greater concentration inside a living cell than outside. This seems to take place in the marine alga *Valonia macrophysa,* which forms large cells up to the size of a pigeon's egg. This may be accounted for (to a large extent at least) by the fact that the inside of the cell is more acid than the outside. A theory based on this has been successfully applied.

Compensating extrachromosomal types in Datura and their use as testers: A. F. BLAKESLEE, A. D. BERGNER and A. G. AVERY. A compensating chromosomal type is one in which parts from two different aberrant chromosomes compensate to form the equivalent in genic content of a whole normal chromosome. These two compensating chromosomes together, therefore, may replace a normal chromosome, and their non-compensating parts be left over as extra chromosomal material to cause morphological changes in the plant affected. Since in such compensating types each of the aberrant chromosomes contains parts from two different normal chromosomes, a chain of seven attached chromosomes is found at reduction. If a compensating type is crossed with pollen from a race derived by segmental interchange between any of the chromosomes involved in the two compensating chromosomes, then a chain of nine chromosomes results at reduction and all the normal sex cells of the hybrid will have the chromosomal constitution of the pollen parent. Thus, without cytological study, one can be certain of the chromosomal constitution of the offspring from such hybrids with compensating types. The use of such types has enabled us to demonstrate crossing over of genes between chromosomes in attached chains and to transfer genes from one chromosome to another without the necessity of chromosomal study. Methods for obtaining new compensating types have been developed. Thus in the offspring of a plant with a circle of six attached chromosomes, from one to three distinct compensating types should be expected, dependent upon the nature of the segmental interchange involved in the circle.

Incubation period of peach yellows as affected by point of inoculation: L. O. KUNKEL (introduced by R. A. Harper). Those who have studied the transmission of peach yellows by budding and grafting report a long and variable incubation period for the disease. Smith found that the first symptoms usually appear from one to two years after trees are inoculated. The writer's experiments show that under ordinary greenhouse conditions the incubation period of yellows can be reduced to a minimum of about six weeks if vigorous young seedlings are used and the trees are inoculated at some distance above the ground level. Transmission is certain, and the incubation period shown by different individual trees is quite uniform in length under these conditions. The importance of inoculating trees above the ground level depends on the fact that the virus of peach yellows moves quickly down but rather slowly up the peach stem. It has been found to move down more than ten times as fast as it moves up. If inoculations are made at or very near the ground level, as is the case when trees are budded according to the usual nursery practice, the incubation period often extends over many months. The tops of such trees remain healthy for a long time because of the slow upward movement of the virus. A knowledge of the importance of the point of inoculation in determining the length and uniformity of the incubation period of peach yellows will greatly reduce the time and work necessary for testing various species of insects that are suspected of spreading this disease.

The character and causes of the extreme fluctuations in the abundance of the American mackerel: OSCAR E. SETTE (introduced by G. H. Parker). The remarkable fluctuations in the American mackerel fishery have long awaited a scientific explanation. During the last century the annual catch has been as large as 120,000,000 and as low as 4,000,000 pounds. During recent years, the annual yield has been between 30,000,000 and 50,000,000 pounds. Older theories ascribe the great changes in catch to variation in the availability of the mackerel to fishermen, but recent investigations by the U. S. Bureau of Fisheries have shown that variations are due almost entirely to actual changes in the number of mackerel in the sea. The reason for the great difference in the abundance of mackerel is that some spawning seasons fail to produce many mackerel while others are much more successful. When many mackerel result from spawning, the stock is built up and the sea is full of mackerel for the following years. When, on the other hand, there comes a series of years during which no new mackerel are added to the schools, the stock of older mackerel dwindles as the result of fishing and natural deaths, so that a period of scarcity sets in when the fishery suffers lean years until another good brood is hatched and grows to market size. The relatively large catches of recent years were due to the remarkable numbers of mackerel which resulted from the spawning of 1923, for this brood has accounted for three quarters of the commercial catch in the last five years. Other broods were virtually negligible, though those of 1921 and 1927 have contributed a few mackerel and the 1928 brood shows promise of making more substantial additions to

the stock. Investigations on the spawning grounds have shown that the variable success of different broods does not depend as much on the number of eggs spawned as on the survival of the newly hatched young mackerel fry. Oceanographic work is now being carried on to determine what conditions in the sea cause high survival rate in some years and catastrophic mortality in others.

The bird life of Mt. Duida, Venezuela: FRANK M. CHAPMAN. Although it was discovered about 1750, Mt. Duida, near the headwaters of the Orinoco, Venezuela, was first ascended by an American Museum of Natural History expedition in 1928. It was found to be part of a hitherto unknown tableland of approximately 250 square miles in extent with an elevation of from 4,200 to 7,800 feet. The fauna and flora of this area was of the subtropical zone and composed in large part of new species, but with a marked affinity to the life heretofore known only from Mt. Roraima, 400 miles to the east. About one fourth the bird-life of this subtropical tableland has been derived from tropical ancestors still existing in the tropical zone at its base. These birds are usually larger and darker than those from which they have been derived and thus represent the influence on the organism of higher altitude and greater humidity acting under isolation. About one half the avifauna shows a more or less close resemblance to species occupying the corresponding life zone in the Andes, often at a distance of a thousand miles or more. The existence of these representative forms in such widely separated regions is explained by the theory that their common ancestors, or connecting forms, have disappeared from the intervening area. The remaining fourth of the avifauna is too distinct to afford evidence of its immediate ancestry and, it is possible, may be representative of the bird life of the great tableland of which Mt. Duida and Mt. Roraima are a surviving part.

The aerological results of the Greenland Expeditions of the University of Michigan: WM. H. HOBBS (introduced by John C. Merriam). The three Greenland Expeditions of the University of Michigan had for their primary object the study of the surface and upper-air currents near the border of the great ice-cap of Greenland—the glacial anticyclone. In 1926 a temporary base was established on the Maligiakfjord in latitude 66° 55′ north, 50 kilometers in from the sea and 100 kilometers distant from the inland-ice margin, where some 84 pilot balloon ascents were carried out. In 1927 a permanent station was established in an excellent position on Mt. Evans at the head of the Söndre Strömfjord. This station is in the same latitude as that of 1926, but is 120 kilometers from the coast and only about 30 kilometers distant from the edge of the inland ice. It was maintained in continuous operation for two full years. Pilot balloon ascents at Mt. Evans were made on all clear days, numbering 776, and were carried to an average altitude of 7,000 meters. Two exceptional runs on June 6 and August 6, 1928, were carried to altitudes of 29,000 and 27,000 meters respectively. This paper includes a summary discussion of results and a comparison of these with 35 balloon runs carried out by the Norwegian Meteorological Institute at Mygbukta in latitude 23° on the Greenland east coast.

A microscope-centrifuge (illustrated): E. NEWTON HARVEY and ALFRED L. LOOMIS (introduced by E. G. Conklin).

Certain scientific aspects of air transportation (illustrated): JOSEPH S. AMES.

Biographical memoir of John Trowbridge (to be read by title): EDWIN H. HALL.

Biographical memoir of Charles F. Chandler (to be read by title): MARSTON T. BOGERT.

Drop of potential and state of ionization near the cathode of a mercury arc: K. T. COMPTON and E. S. LAMAR. The exploring electrode method of Langmuir and Mott-Smith has been employed to investigate conditions in the region of the cathode of a mercury arc, supplementing a preliminary investigation by Killian (*Phys. Rev.* 31: 632, 1928). The cathode was designed so as to minimize the wandering of the cathode spot over the surface of the mercury. A movable exploring electrode was used whose thermal dissipating power was sufficiently great to prevent its melting while in the cathode region. The observations yielded values for space potential, the mean kinetic energy of the electrons and the electron concentration over distances ranging from .411 to 1.943 cm from the cathode. Space potential was found to be constant over this range and of value about 10 volts with respect to the cathode. If we allow a few tenths of a volt for contact differences in potential, then the indications are that the value of the cathode fall is quite near to the ionization potential of mercury. The assumption that in field free space the current is carried by diffusion of electrons permits estimates of the values of the electron mean free paths which are in fair agreement with those which would be expected from other experiments. The average energy of the electrons, in equivalent volts, is constant at 0.98 volt for distances between 0.8 and 2.0 cm from the cathode. At closer distances the average energy rises rapidly, being, for example, 1.3 volts at 0.51 cm and 1.7 volts at 0.38 cm. The electron and ion concentrations increase as the cathode is approached. Typical values are 0.34 $(10)^{12}$ electrons (or ions) per cm^3 at 1.94 cm, 1.5 $(10)^{12}$ at 0.79 cm and 2.9 $(10)^{12}$ at 0.44 cm. The reflection coefficient of the electrons at the surface of the tungsten collector is about 0.4. The above values are for 4.8 ampere arcs. If the current is increased to 11.0 amperes, the cathode drop is unchanged, the average energy of the electrons is slightly decreased and their concentration is increased at least ten fold. With the higher currents there is also a region of slightly reversed field just beyond the cathode fall space.

The "reaction-isochore" equation for ionization within metals: EDWIN H. HALL. In the relation

$$U = KT^2 \frac{d\ln K}{dT} \qquad (1)$$

called by Nernst the "reaction-isochore" equation, U is

the heat given out when a reversible isothermal reaction is carried on with the system maintained at constant volume, so that no external work is done. K is the "equilibrium constant" of the reaction, a quantity which does not change while the reaction is carried on isothermally. This equation has a firm thermodynamic foundation for reactions that can be reasonably conceived of as performed under certain conditions, first described by van't Hoff. The author has long held that these conditions can not be conceived of as holding for the process of ionization within a solid metal, and he has therefore ignored equation (1) in his speculations concerning ionization, making certain hypotheses and reaching corresponding numerical conclusions without regard to any limitation imposed by this equation. He now finds that, for every one of the many metals studied, his numerical conclusions are consistent with an equation,

$$U = f \cdot KT^2 \frac{dlnK}{dT} \qquad (2)$$

identical with equation (1) except for the presence of a numerical factor, f, in the second number. The value of f ranges from about 1.33 in nickel to about 3.13 in manganin, but for any one metal, though perhaps not entirely independent of temperature, it changes little if at all between 0° C. and 100° C.

Accommodation coefficients and heats of neutralization of gas ions at electrodes: K. T. COMPTON and C. C. VAN VOORHIS. When positive ions of a gas strike an electrode and become neutralized there are energy interchanges which result in heating of the electrode. Knowledge of this heating is important both in the interpretation of the physical phenomena which are involved and also in the practical design of gas discharge devices. With the aid of a thermocouple, and using this thermocouple as an exploring electrode in the ionized atmospheres of arcs at low gas pressures, we have studied the following factors which contribute to this heating: (1) the fraction of the incident kinetic energy of the ion which is delivered to the electrode (accommodation coefficient); (2) the fraction of the energy given to the ion by an applied electric field which is retained by the ion in spite of collision with gas molecules while approaching the electrode; (3) the portion of the apparent positive ion current to the electrode which is in reality due to electrons liberated from it under the influence of ultra-violet light, metastable atoms and positive ion impact; (4) the true "heat of neutralization" of the ion at the surface. The new and most important result of this work is the discovery that a considerable fraction of the kinetic energy of an impacting ion is retained after impact by the neutralized atom. The remaining fraction, which is delivered to the electrode as heat, is analogous to the "accommodation coefficient" which is recognized in the impact of ordinary gas molecules against a heated surface. In general these accommodation coefficients appear to approach unity for ions (or molecules) of high molecular weight. Our values are about 0.45, 0.7, 0.8 for ions of He, Ne and A, respectively. The existence of an accommodation coefficient less than unity, as thus proved by energy measurements, implies also that mechanical momentum is imparted by ions to electrodes in much larger extent than has hitherto been suspected. There are several observations on electrode arcs, which have been rather obscure, which seem thus to find a ready explanation. Of the four factors mentioned above as the objectives of our work, the first three are relatively so large in their effect that we have as yet been unable to arrive at definite conclusions regarding the fourth—the true heat of neutralization of an ion—whose determination would settle some interesting speculations regarding the mechanism of electric arcs.

The deformation of ions and the various types of chemical linkage: K. FAJANS (by invitation). One distinguishes usually two main types of chemical linkage, the polar or ionic and the non-polar or covalent linkage. The polar linkage is typified by the inorganic salts, such as sodium chloride; the non-polar linkage by the bond between the two atoms in the hydrogen molecule or by the linkage between the carbon atoms in the diamond and in organic compounds. According to the modern conception of atomic structure the ionic linkage in sodium chloride is produced by the transfer of one electron from the sodium atom to the chlorine atom. The electrostatic attraction between the resulting positively charged sodium ion and the negatively charged chlorine ion holds them together to form a molecule or a crystal lattice. In the non-polar linkage the two atoms are assumed to be joined together by a pair of electrons shared by both atoms, and revolving round their nuclei. Between these two main types of chemical linkage there exists a whole series of transition types. Beginning with the ideal ionic linkage these transition types can be understood as the result of the polarization (deformation) to various degrees, of the electron shell of the anion by the electric field of the cation. The degree of this deformation and consequently the deviation from the ionic linkage and the approach to the non-polar linkage is greater when the radius of the cation is smaller, its charge higher and when the deformability of the anion is greater. This approach to the non-polar linkage is also more pronounced for cations which do not show the rare-gas structure than for cations with this structure.

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