The following results were obtained.

Atomic weight of nitrogen from "control" NH_4Cl	Atomic weight of nitrogen from "Norwegian" NH_4Cl
1. 13.983	5. 13.987
2. 13.994	6. 13.983
3. 13.981	7. 13.991
4. 13.974	8. 13.953*
Average 13.984	Average 13.987

* Analysis No. 8 was not included in the average. The analysis of this was unavoidably made a day later than the others; it was feared that the sample had taken up moisture from the air in the weighing bottle. The result would indicate this.

The "Norwegian" ammonium chloride gave an atomic weight of the nitrogen only 0.02 per cent. greater than that of the control. Since this is well within the limits of experimental error, the possibility of the existence of an isotope of nitrogen of atomic weight fifteen is disposed of here.

Conclusion: Although no indication of an isotope was found in the samples of nitrogen examined, it is hoped that the search can soon be extended to nitrogen from other sources.

H. P. CADY
HARRY UNANGST BEECHER
DEPARTMENT OF CHEMISTRY,
UNIVERSITY OF KANSAS

THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences held its autumn meeting at Schenectady, New York, on November 19, 20 and 21.

The academy was welcomed by Dr. Charles Alexander Richmond, president of Union College, and Dr. Willis Rodney Whitney, vice-president and director of research of the General Electric Company, and response was made by Dr. T. H. Morgan, president of the academy. The following papers were presented:

Note on C. S. Peirce's experimental discussion of the law of errors: EDWIN B. WILSON and MARGARET M. HILFERTY.

It is shown that the series of 24 runs of approximately 500 observations each which C. S. Peirce had made for the purpose of checking the normal curve of errors (and for other purposes) and which he interpreted as a satisfactory check of the theory do not on the modern theory of frequency functions of Pearson and others substantiate his claim because in every single series of the 24 the departures from the normal curve exceed the probable values of those departures and in many cases exceed them many times.

The occurrence of melezitose in honey: C. S. HUDSON.

The relation of chemical structure to the optical properties of some simple organic compounds: P. A. LEVENE. The configurations of several series of secondary carbinols and of a series of hydroxyacids have been correlated with that of a simple reference substance, namely, of lactic acid. From the data obtained in this manner, general relationships between structure and optical rotation have been formulated. The rotations of these substances are the resultants of two factors, namely, of the respective weights of the groups attached to the asymmetric carbon atoms and of their respective polarities.

The normal velocity of sound in free air: DAYTON C. MILLER. In 1918 Colonel R. A. Millikan, in charge of the Department of Science and Research of the Council of National Defense, requested the writer to undertake a study of the pressure effects produced in the vicinity of large guns in action, the effects which were supposed to be the cause of the malady commonly called "shell shock." The Case School of Applied Science granted a leave of absence from teaching duties from April, 1918, to November, 1919, and experiments were undertaken, at first in the laboratory and later at Sandy Hook Proving Ground under permission and authority of General C. C. Williams, Chief of Ordnance. The commanding officers were very sympathetic with these scientific experiments, and made literally all of the facilities of the proving ground available with only the restriction that the regular work of the proving ground should not be interfered with. Colonel Millikan assigned several enlisted scientific men as assistants, and at the proving ground any required help was provided. All conditions combined to provide a most extraordinary outfit for the study of sound effects of various kinds. The conditions could hardly be reproduced at any cost upon orders. Taking advantage of this remarkable situation, the researches were extended beyond the first purpose and led to four distinct sets of results. These relate to: (1) the pressure effects in the air around large guns in action; (2) the velocity of an explosion wave of great intensity; (3) the form and physical characteristics of the sound waves from large and small guns; (4) the normal velocity of sound in free air. After many months of laborious calculation on the large mass of observational data, the final reduction of the observations relating to the normal velocity of sound are now nearing completion, and this paper refers to this phase of the work. The observations were made by means of twelve microphones specially constructed for this purpose by the Western Electric Company. There was one set of microphones of very rugged construction, capable of recording sounds close to the largest gun, and a second set of six microphones of the greatest sensitivity, all of them made as nearly aperiodic as possible. Six microphones were used at one time, distributed over the field in any desired fashion, and the records were made by means of a six-string recording galvanometer of the type developed for the use of the American army in sound ranging. With this apparatus were combined various features of the author's Phonodeik apparatus, especially as regards the source of illumination, film box and shutters. For a study of the form of the wave front the six microphones could be placed at various points on a circle with the muzzle of the gun as center or along any radius of the wave front. In some cases one microphone was mounted on the muzzle of the gun itself and the others would be placed at distances of 50 feet, 100 feet, 200 feet, etc. For the long-range velocity determinations one microphone was placed at about 50 feet in front of the gun, another at 100 feet and others at distances of 200, 400, 1,000, 7,200 and 20,300 feet (the latter distance is a little less than four miles or about 6.2 kilometers). The time required for sound to traverse this distance with its normal velocity is about nineteen seconds. The recording apparatus was installed in the instrument room at the headquarters of the proving grounds. Seventy sets of measures were made relating to the velocity of the propagation of the sound wave, the source of the sound being a 12-inch mortar, an 8-inch rifle, a 10-inch rifle or a 14-inch rifle. At every velocity determination there were at least four sets of meteorological observations taken at different points over the field. The trace of the expanding wave front on a plane containing the line of fire is always a circle. The center of the circle moves forward from the muzzle of the gun along the axis with a velocity the initial value of which depends upon the kind and size of gun and the charge of powder. The velocity of displacement of the center diminishes rapidly, being an exponential function of the time. The radius of the circle at any given time after the origin of the wave is the distance sound would travel in air in this time with the uniform normal velocity of sound for the given meteorological conditions. In other words, the wave front develops in such a manner that if the distance which the sound is considered to have traveled is measured from the virtual instantaneous center instead of from the muzzle of the gun, the velocity of the wave front is constant in all directions and is always the normal velocity of sound under the given meteorological conditions. The physical significance of this view is that the virtual source of the sound and the developing wave front in its beginnings is in effect shot out of the gun, with a speed probably in excess of that of the projectile itself. The velocity of this sphere of condensed gas is rapidly damped by the atmosphere, and its advance is reduced exponentially to a zero value. The exponential equations of the observed quantities have been developed and a least-squares solution has been made. Using the numerical results, the greatest deviation of the calculated position of a microphone, and its field position, within the area of the explosive effects of the gun, is less than four inches. The final value of the normal velocity of sound in free air, under standard conditions (dry, still air, at 0° C. and barometric pressure of 76 cm) is 331.47 ± 0.10 meters per second, equivalent to 1087.51 ± 0.34 feet per second. This is exactly the theoretical value computed from the specific heats of air, and almost exactly the average of the principal determinations made since 1900.

A proposed memorial to J. Willard Gibbs: R. G. VAN NAME (introduced by Edwin B. Wilson).

The transformation spectrum of the ruby: E. L. NICHOLS and H. L. HOWES. (1) The spectrum of a ruby, heated to incandescence in a hydrogen flame, was found to have superimposed upon the general radiation a number of rather narrow emission bands. (2) The temperature range within which the bands are visible, *i.e.*, circa 600° C. to 775° C., corresponds to profound changes in the absorption of light and consequently in the color of the crystal. (3) These so-called transformation bands occur in sets having a constant frequency interval of $36.7 (1/\mu \times 10^3)$ of which sets all the known fluorescence and absorption bands of the ruby are also members. (4) The phenomena described in the present paper are strictly analogous to those previously observed in the incandescence of solids containing various rare earths as activators.

Electromagnetic compass systems for aircraft: J. D. TEAR. Earth inductor compass.—Vacuum tube amplifier systems for improving the sensitivity and reliability of the earth inductor compass have been developed with the cooperation of the U. S. Army Air Service. Magnetron.—There are two general methods of operating the magnetron as a compass. One method employs direct current and the other an alternating current supply. The first is particularly useful for precision measurements under conditions which can be reasonably well controlled; the latter is the more suitable for use in air navigation, as it affords reliable indications of direction in the presence of large changes in power supply and in other circuit constants. Ferromagnetic induction compass.—Comparative laboratory and field tests of numerous electromagnetic compass systems favor the ferromagnetic induction compass, which functions by virtue of the flux induced in a bar of permalloy, perminvar or other ferromagnetic substance possessing low coersive force. A flux-measuring device such as a magnetron or a rotating coil of wire is placed in a cavity within a bar and the bar is maintained in a position perpendicular to the vertical component of the earth's magnetic field by means of a pendulum. A mechanical coupling to a calibrated compass card is provided so that when the ship is on a chosen course the bar can be placed perpendicular likewise to the horizontal component of the earth's field. Any deviation of the ship from the chosen course results in there being induced in the bar a magnetic flux the direction and magnitude of which are indicated electrically.

Height of airplane above ground by radio echo: E. F. W. ALEXANDERSON. About a year ago several officers of the Wright field visited Schenectady and explained to us some of their problems. We were told that one of the most valuable aids to aviation would be a method for measuring the absolute height above ground. The experimentation in the air which was thus instigated has been a great inspiration, because the theories with which we first stepped on board the plane had to be thrown overboard as soon as we left the ground. Our equipment was a regenerative receiver with a separate oscillator and earphones. Our expectations were that the antenna oscillator would operate at its natural period determined by the total inductance and capacity of the circuit and that the proximity of the ground would modify the capacity so that the frequency would become lower as we approached the ground. What we found, however, was that a change of altitude of one half wave-length causes a complete cyclic change of frequency and that these cyclic changes repeat themselves at regular intervals of one half wave-length. There is thus a direct relation between the frequency and the phase of the echo wave. After this fact had been experimentally established the theory of operation immediately became clear. Translated into mechanics it can be stated as follows: The natural period of a pendulum is determined by the mass and the restoring force, but if the pendulum is subjected to periodic forces from outside, these forces must be added to or subtracted from the inherent restoring force, and the period of the pendulum will change accordingly. The echo wave acting upon the antenna exerts such forces from outside, and the phase of the echo wave will thus manifest itself in a positive or negative change of frequency of the antenna oscillator. As soon as this theory was understood it was easy to interpret the observations, and several flights were made with the same equipment during which I was able, blindfolded, to determine altitudes by an earphone up to 1,600 feet. How this principle may be applied for aerial navigation we are not yet able to say. Continuous graphic recorders may be used on large craft, and it may thereby be possible to identify the course flown with the maps and previous experience. Such graphic altitude logs may also be used for surveying. A probable further development is the use of two wave-lengths either alternately or simultaneously. We may for instance use a key by which the wave can be shifted from 100 meters to 92 meters. Twelve waves of 100 meters will occupy the same distance as thirteen waves of 92 meters. Thus if the corresponding wavy lines of the graphic record are in phase the aviator concludes that his altitude is 600 meters (2,000 ft.). If the wavy lines are of opposite phase his altitude is either 1,000 ft. or 3,000 ft. Another suggestion is to use two short antennas mounted permanently on the plane. If one is tuned for 10 meters and one for 11 meters the intervals of the maxima of the beat frequency will be the same as for a simple oscillator of 100 meters. If, on the other hand, the antennas are tuned only 2 per cent. apart the intervals will be the same as for a wave of 500 meters. Several convenient scales of altitude signals may thus be established by use of different beat frequencies. Thus the next to the strongest maximum of the first scale may light a blue light at 1,200 ft. and the strongest maximum a green light at 400 ft. Then the wave scale is changed so that a green light will indicate 240 ft. and a red light 80 ft. Final landing signals may then be given at thirty and at fifteen feet in response to maxima of the radio frequency. If these signals are combined with a mechanical device touching the ground at ten to fifteen feet it is conceivable—at least we are told so by our associates who are skilled aviators—that safe landings may be made in a fog without vision of the landing field.

Control of an arc discharge by a grid: A. W. HULL and I. LANGMUIR.

Preliminary studies of combustion in explosion type of engines: C. F. KETTERING.

Secondary X-ray spectra: F. K. RICHTMYER (introduced by Ernest Merritt). Accompanying many of the more prominent X-ray spectral lines are found, usually on the short-wave-length side, faint companion lines known variously as "spark lines," "second order lines" or more properly "satellites." These satellites do not fit into the general scheme of X-ray levels which has been so satisfactory in explaining the more prominent "first order" lines. Several important theories concerning the origin of these satellites suggest that they may be due to some type of double ionization. The author has studied the satellites of several of the L lines for the series of elements from strontium ($Z = 38$) to tin ($Z = 50$). It is found that within the limits of error of the measurements, the square root of the difference in frequency between a given satellite and its "parent" line is a linear function of atomic number, somewhat after the manner of Moseley's law. This suggests the possibility —to be tested by further experiments—that the satellites may be due to simultaneous two-electron jumps within the atom. However, the existing data concerning X-ray satellites are not adequate to serve as a basis for an acceptable theory as to their origin. Further experiments are in progress to make a systematic study of the wave-lengths of these satellites, their excitation potentials and their intensities relative to the first order lines.

Ionization in positive ion sheaths in neon: CLIFTON G. FOUND. Langmuir and Mott Smith have shown that the positive ion current to a plane electrode, placed in the positive column of a mercury discharge, is practically independent of the voltage, for voltages sufficiently negative that no electrons reach the electrode. In neon it has been found that this does not hold, but that the current increases rapidly as the voltage is made more negative than about -100 volts. The logarithm of this increase in current is a linear function of the applied voltage within limits. The increase in current can be accounted for by the production of a very small number of electrons at or close to the electrode surface. These newly formed electrons in passing through the sheath produce ionization which multiplies due to ionization by collision, thus causing a logarithmic increase in the positive ion current with increase in voltage.

Oscillations in an ionized gas: LEWI TONKS and IRVING LANGMUIR. When, from any cause, a deficiency of electrons occurs in some region of a uniformly ionized gas at low pressure, neighboring electrons flow in to excess and set up a local non-spreading oscillation. Positive ions behave similarly for deficiencies extending over a small region but oscillate with a frequency lower in the ratio of the square roots of the particle masses. These oscillations, however, decrease in frequency and change over to sound-like waves when the original deficiency extends over large regions. Extensive experiments with a hot-cathode mercury arc yielded oscillations quite definitely attributable to the plasma electrons. These oscillations were in the expected range of frequencies, namely, about 10^9 cycles per second. They were found with external electrodes on the tube wall and with internal electrodes both in and out of the path of the primary electrons, and their amplitude was independent of the electrode voltage. Their frequency varied with electron density roughly in agreement with the theory. Another oscillation of lower frequency than these may arise from primary electron oscillations stepped up by the Doppler Effect. Another oscillation detected with an external electrode seems to be intimately related to the presence of a negatively charged wire parallel and close to the emitting filament. For instance, the oscillation showed a rapid change of phase as the shadow of the wire on the tube wall was crossed and the amplitude pattern was symmetrical about the shadow. A low frequency and very critical oscillation at 1,380 kc may lie at the high frequency limit of ion oscillations calculated to lie at 1,500 kc.

The center of the universe: HARLOW SHAPLEY.

Thermionic phenomena with alkali metal films adsorbed on filaments at high temperatures: K. H. KINGDON and E. E. CHARLTON. A thoriated tungsten filament at 1700° K in an atmosphere of caesium vapor ($p = 10^{-4}$ barye) has a very small fraction of its surface covered by an adsorbed film of caesium which gives rise to small positive ion and electron emissions. If a small alternating electric potential is applied between the filament and a nearby collecting electrode, the extent of the adsorbed film is affected by the flow of caesium ions to the collector, and changes in the ion and electron emissions result. The effect is found to be greatest at a frequency of several hundred kilocycles. The variation with frequency is probably connected with a resonance oscillation of the positive ions around the potential minimum caused by electron space charge near the cathode.

The Hall effect in single crystals of metal: P. I. WOLD (introduced by W. R. Whitney).

The bearing of recent experimental results on the theory of metallic conduction: P. W. BRIDGMAN. New results have been obtained by Dr. Ufford, Dr. Oppenheimer and myself on the effect of pressure on the resistance of several series of alloys of different types. So far no exception has been found to the rule that the addition of a foreign element to a pure metal has the effect of increasing algebraically the pressure coefficient of resistance. The specific resistance also increases under the same conditions. Both of these effects are consistent with the picture of metallic conduction recently developed by Houston on the basis of the wave mechanics, namely, that resistance is due to a scattering by irregularities in the metallic structure of the waves which constitute the electrons. The introduction of foreign atoms into another space lattice would be expected to increase the irregularity. This is the explanation of the increase of specific resistance. On purely geometrical grounds any such irregularity would be accentuated by hydrostatic pressure, and this is the explanation of the more positive pressure coefficient. Further, a much more complete study than heretofore has been made of thermoelectric phenomena in a number of non-cubic single-metal crystals. Two essential features are to be emphasized: (1) The difference of Petier heat between different directions in antimony and bismuth is so great that it is difficult to see how the fundamental assumption of Sommerfeld, which was also the basis of Houston's theory, can be maintained—namely, that the energy of the electrons is nearly independent of temperature. (2) The symmetry relations of thermoelectric phenomena in bismuth and tin seem definitely not those deduced by Kelvin and Voigt. This would mean that the thermoelectric forces in a metal must be more complicated and different in character from the simple body forces which have hitherto been assumed. Apparently no theory has yet taken into account this aspect of the situation.

Raman effect in solids, liquids and gases: R. W. WOOD.

The radiation due to impacts of electrons against mercury vapor atoms: W. DUANE.

Quantum mechanics and radioactive disintegration: RONALD W. GURNEY and EDW. U. CONDON. For thirty years the "instability" of the radioactive nucleus has remained a mystery. But if the nuclear particles obey the laws of quantum mechanics, the spontaneous disintegration by the emission of a particle may ensue. For the wave mechanics endows particles with the new property of being able to pass through regions where their total energy would according to classical mechanics be less than their potential energy. Thus a nuclear particle always has a certain probability of penetrating the barrier of potential which confines it and of escaping from the nucleus. Experimental evidence for this new property is found in Rutherford and Chadwick's well-known paradoxical result for the scattering of fast alpha particles fired at a film of uranium. The theory gives decay periods from a fraction of a second to 10^9 years, depending on the velocity of the emitted alpha particle in accordance with the Geiger-Nuttall relation. A preliminary note by the authors on this subject appeared in *Nature* for September 22.

The theoretical interpretation of some familiar phenomena in hydrogen: H. D. SMYTH and E. C. G. STUECKELBERG. About fifteen years ago Bohr offered a theory of the structure of atomic hydrogen which met with amazing success and has furnished the basis and inspiration for the great advance in our knowledge of atomic structure since that time. But atomic hydrogen rarely is found in nature. In the usual form of hydrogen gas each molecule contains two atoms, although under high temperatures or electrical excitation some of these pairs of atoms can be made to break up. Consequently, many of the phenomena observed in experiments on hydrogen did not fit into Bohr's theory and were attributed to the diatomic form of hydrogen. They remained of great interest, however, on account of their importance to the theory of molecular structure and chemical combination. Thanks to the study of band spectra and some recent developments of quantum mechanics, we are now able to interpret many of these phenomena. The secondary spectrum has been explained by Richardson and others. We wish to explain the continuous spectrum and the effects of electron impact. To do so we construct the "potential energy curves" for the various "energy states" of the H_2 molecule and study the possible "transitions" between them. We find that one of these states is unstable, that is the potential energy decreases continually as the nuclear separation increases, and consequently the nuclei will always fly apart, giving atomic hydrogen. Moreover transitions from higher states to this state are accompanied by the emission of radiation of all wave-lengths greater than a certain lower limit, and the approximate distribution of energy over this continuous range of wave-lengths can be computed. It is found to agree with the experimental observations on the continuous spectrum. Thus the emission of the continuous spectrum is explained both qualitatively and quantitatively as related to the spontaneous dissociation of excited hydrogen. Now the dissociation of hydrogen by electron impact has been observed and is found at once to fit into the above scheme. If electrons have sufficient energy to "excite" the molecule to the unstable state or a higher state which may revert to the unstable state, atomic hydrogen is produced. But it has been shown experimentally that still faster electrons ionize the hydrogen molecules without dissociating them. Further study of the potential energy curves explains this effect and also most of the less striking results of electron impact experiments. We begin to believe therefore that something is known about the structure of the hydrogen molecule.

Spectra of nitrogen and its active states: K. T. COMPTON and J. C. BOYCE. Active nitrogen has been an interesting and puzzling subject of investigation for a number of years. It has been investigated chemically because of its property of uniting with many substances to form nitrogen compounds, in spite of the fact that nitrogen ordinarily is a very inert gas. It is this property of active nitrogen which is the basis of several methods for nitrogen fixation. It has been investigated spectroscopically, both by a study of the spectrum which it itself emits spontaneously and by the spectra which it is able to excite in other gases when admixed with them. Active nitrogen has been variously explained as atomic nitrogen, triatomic nitrogen or an excited metastable state of diatomic nitrogen. This paper presents what appears to be a complete interpretation of active nitrogen. It is based on three discoveries: first, the analysis of the band spectrum and the excited states of molecular nitrogen by Professor Birge, at the University of California, and others; second, the analysis of the line spectrum and excited states of atomic nitrogen by the present authors; third, the study of the intensities in spectra of various substances excited by active nitrogen by Doctors Cario and Kaplan in this laboratory. The analysis of the band spectrum shows that there is a long-lived and energetic metastable state of molecular nitrogen which contains between 8 and 9 volts of energy. The exact amount of this energy is still subject to some uncertainty. The line spectrum shows that atomic nitrogen possesses two metastable states of energies, 2.37 and 3.56 volts. A study of the spectra excited in nitrogen itself (the afterglow) together with the spectra excited in other gases shows that there are in active nitrogen entities of energies of approximately 2.4, 3.6 and 9 volts respectively. It seems certain therefore that the various phenomena and the properties of active nitrogen are due to the separate or the joint action of the two types of metastable atoms, normal atoms and the one type of metastable molecule. The quantitative evidence for these conclusions were presented to the academy.

A visual method of observing the influence of atmospheric conditions on radio reception:[1] ERNEST MERRITT and WM. E. BOSTWICK. There seems to be little doubt that radio signals may be transmitted from the sending to the receiving station along at least two different paths. The "ground wave" follows the surface of the earth in much the same way that shorter waves are known to follow a wire. The "sky wave" starts obliquely upward from the sending station and reaches the observer after being bent or reflected by the Kennelly-Heaviside layer of highly ionized air. Both are subject to absorption due to the conductivity of the air, and the sky wave may have its plane of polarization rotated because of the earth's magnetic field; for example, while the sky wave may start out with its electric field in the vertical plane, it may be so twisted by the action of the earth's magnetic field that it arrives with its electric force horizontal. Changes in the atmospheric conditions will affect the two waves differently, so that when they combine to produce a signal at the receiving station the result is very complicated and confusing, as is evidenced by the fading observed in broadcast reception and by the erratic changes in the apparent direction of the waves as indicated by the radio compass. While a change in apparent direction may not cause any annoyance when one is listening to a musical program or a political speech it may be a life or death matter for the pilot of an aeroplane. We need all the knowledge we can get of these changes in intensity and direction. Studies of fading and direction changes have heretofore been based upon observations of the *combined* effect of the ground and

[1] The investigation of which this forms a part has been supported by a grant from the Heckscher Foundation for Research at Cornell University.

sky waves. In the method to be described the two waves are observed separately. A further advantage of the method arises from the fact that it is visual—changes in intensity, phase and polarization are indicated by the motion of a spot of light, and the changes in the two waves can be followed simultaneously and from instant to instant. The method practically amounts to using two radio compasses, one pointed toward the sending station and the other at right angles to this direction. It can be shown that the latter can not respond at all to the ground wave but that if the sky wave has a component polarized with its electric force horizontal this receiver will respond. The other receiver responds to the combined effect of the ground wave and the vertical component of the sky wave. To make the method a visual one each receiver has been connected to one pair of plates of a cathode ray oscillograph. Without going into details the result is that a spot of light indicates by its horizontal movement the ground wave and by its vertical movement the sky wave. The oscilloscope will therefore ordinarily show a Lissajous figure, which may be either an ellipse or a straight line and which is usually changing both in shape and size. For a period of about six weeks during the summer and early fall observations were made nearly every day during the sunset period. The method has been used chiefly with the carrier waves of a number of different broadcasting stations and gives a graphic picture of the phenomena that is both instructive and fascinating. It is surprising to find that modulation, unless unusually strong, is hardly noticeable. Unusually loud jazz or a particularly strong voice will cause the figure to tremble and become somewhat indistinct. Observations were in progress during the broadcasting of Mr. Hoover's acceptance speech, and the rhythm of the sentences and words that were specially stressed could be readily noticed. But modulation is rarely a source of serious disturbance. Static on the other hand destroys the figure completely and makes the spot move in an erratic way that is beyond description. During the daytime the oscilloscope figure is usually a horizontal straight line of nearly constant amplitude. Toward sunset the line begins to tilt slowly and to change in length, or it may open up into an ellipse. These evidences that the sky wave is becoming of importance become increasingly noticeable, and often, just after sunset, there is a period of extremely rapid change in the figure—sometimes a continuous rotation—which we interpret as due to the rapid rise of the Heaviside layer that follows the setting in of darkness. Later, when night conditions have become established, the changes in the figure are usually of moderate activity and apparently quite erratic. The observations confirm the view generally held that fading may result from several widely different causes. In some cases—indicated by a continuously rotating figure—it is evident that fading is due to the changing polarization of the sky wave. In other cases it is just as evident that fading is due to interference. In such cases the width of the oscilloscope figure changes back and forth, often passing through zero, while its height remains constant. Sometimes the figure remains unchanged in shape for ten minutes at a time but expands and contracts. It would seem that this behavior, if not the result of actual changes in the energy radiated, must be due to absorption by a cloud of ionized air which affects both waves alike and which must therefore be near the sending station or the receiving station. We have had the opportunity on one occasion (September 8) to observe the disturbed conditions that accompany an auroral display. The extremely rapid and violent changes in the oscilloscope figures that were seen after the display began were all the more striking because of the fact that just a short time before the figure was so quiet that we had about decided to draw the observations to a close. While we have worked so far chiefly with waves in the broadcast band enough observations have been made with short waves to show that the use of the method with short-wave stations, either in this country or abroad, presents no serious difficulties. The method is even more satisfactory with code stations than with broadcasting stations, for the signals occur so rapidly that the figure persists from one to the next and there is no modulation to blur it. Although it is too early to draw any far-reaching conclusions from the results thus far obtained there is every indication that the new method of observation will prove of distinct value.

The oscilloscope as a means of studying flicker in light sources: FREDERICK BEDELL (introduced by Professor Ernest Merritt). The flicker in the light given by an alternating current lamp is often of sufficient magnitude to be obvious to the casual observer. A quick turn of the eye makes one conscious of it. Even when not obvious the flicker is not infrequently a source of unconscious annoyance. In each cycle or alternation of the alternating current, the candle-power of the light comes twice to a maximum value, just a little after the current reaches either a positive or a negative maximum. Thus, in a lamp operated on a circuit having a frequency of sixty cycles per second, the candle-power comes to a maximum value one hundred and twenty times each second. This effect has previously been studied by the author[1] and others by laboriously measuring the instantaneous changes in lamp resistance during an alternation, changes in lamp resistance being accompanied by corresponding changes in candle-power. Aside from the labor involved, an objection to this method is the inaccuracy due to changes in conditions during the time (several hours) that is necessary to obtain the data for a single curve. A theoretical study shows that these instantaneous changes in resistance cause a distortion[2] in the wave-form of current; that is, when the line voltage is a smooth sine-wave, the current is not a pure sine-wave but has superposed ripples of triple and higher frequencies.

[1] F. Bedell, "Measurement of Instantaneous Lamp Resistance," *Elect. World,* 371, Feb. 9, 1911.

[2] F. Bedell and E. C. Mayer, "Distortion of Alternating Current Wave Form," *Trans. A. I. E. E.,* 34: 333, 1915.

As a result of this distortion, the power absorbed by the lamp is slightly less than, instead of exactly equal to, the product of the current and voltage; in other words, the power factor is less than unity, although the resistance is non-inductive. A further result, which is of theoretical interest, is that vector diagrams, in the case of distorted currents,[3] can no longer be accurately drawn in a single plane as they are commonly represented in engineering calculations. The direct study of lamp flicker has been made possible by the Bedell-Reich Stabilized Oscilloscope; the variations are directly visible and no time is required for taking observations. In this instrument a curve is delineated by a spot of light moving on the fluorescent screen of a cathode-ray oscillograph tube. By a special device, described at a meeting of the American Institute of Electrical Engineers,[4] this spot moves across the screen with uniform velocity from left to right. It also has a vertical displacement proportional, at any time, to whatever quantity (in this case candle-power) is being studied. By persistence of vision, the moving spot thus appears as a curve showing the value of candle-power (or other quantity) from instant to instant. By a feed-back device in the oscilloscope the curve is held stationary in a fixed position, so that it may be traced or photographed. Designed for the direct observation of electrical quantities, the oscilloscope has already been used for observing variations in sound by the use of a microphone. It thus affords a means for the study of various types of sound reproducers. At a recent meeting of the National Association of Piano Tuners the use of the oscilloscope for the measurement of pitch, to an accuracy of one part in five thousand, was demonstrated by Dr. R. C. Burt and others. In the present study a corresponding use of the oscilloscope has been made for the study of light variations, by means of a photoelectric cell which gives a current proportional to the light that falls upon it. For this purpose a vacuum cell containing sodium deposited electrolytically through the glass proves most reliable. The method of studying light variations by means of the oscilloscope has only recently been developed; thus far no extensive applications of the method have been made. The experimental psychologist may find in it a means for the study of eye fatigue; the practical engineer, a means for selecting the lamps to be used in cases where flicker is most likely to be objectionable, particularly on low-frequency circuits. A study of the wave-form of candle-power is in progress.

Oil films on water: IRVING LANGMUIR (introduction by Charles Alexander Richmond, President of Union College; an educational Photophone film).

Exponential yield of positive ions by electron collisions in argon: KATHARINE B. BLODGETT (introduced by I. Langmuir). A hot cathode tube containing argon or neon at pressures above 1 mm of mercury will carry a current many times the saturation electron current from the cathode at voltages above the ionization potential of the gas. The current increases exponentially with the voltage, provided the electron emission from the cathode is held constant. Where the electron mean free path is short compared with the thickness of the sheath through which the cathode fall of potential takes place, the electrons leaving the cathode ionize by collision as in a Townsend discharge to yield a large positive ion current flowing to the cathode. This exponential increase of positive ion current with voltage is the same whether the current lies in the range 20–100 micro amp. or the range 1–20 amp. The currents in the higher range were determined by passing through the tube a condenser discharge which lasted too short a time to heat the cathode, and measuring the peak current which flowed.

On the absolute magnitudes of long period variables: HARLOW SHAPLEY.

A study of the Coma-Virgo cluster of extra-galactic nebulae: HARLOW SHAPLEY.

On meteoric matter near the stars: HENRY NORRIS RUSSELL. It has generally been assumed that solid meteorites may fall into the Sun. Calculation shows, however, that masses of stone or iron will be completely volatilized by the Sun's heat before they reach its surface, unless they were originally two or three feet in diameter. The gas resulting from the volatilization will, however, proceed with unaltered speed and fall into the Sun, unless repelled by radiation pressure. Adopting Shapley's estimate that 1,000 million meteors strike the Earth every day, and Kapteyn's determination of the total quantity of matter per cubic light year in interstellar space, it is shown that the average mass per meteorite can not exceed two milligrams, and that the total quantity of meteoric matter falling into the Sun is, at most, sixty tons per second. These values hold for meteors of interstellar origin. If the observed meteors belong to the solar system, they may be larger, but few will hit the Sun. The total amount of light which can be scattered by the meteoric gas depends on the ratio of radiation pressure to gravity. If this is small, little light is scattered; if great, the gas is driven away from the star. The maximum effect is produced when radiation pressure and gravity nearly balance one another. Meteoric matter near the Sun may scatter enough light to account for a small fraction of the brightness of the corona, but can not exert enough effective absorption in the spectrum to produce the equivalent of a single narrow Fraunhofer line. For the stars in general, conditions are similar, and it is concluded that meteoric matter, or gas arising from its volatilization, can account for such bands in the spectrum as have been observed at Harvard only in the case of a star immersed in very dense nebulosity, and probably not even then.

(*To be continued*)

[3] F. Bedell, "Non-Harmonic Alternating Currents," *Journ. A. I. E. E.*, 46: 1057, Oct., 1927.

[4] F. Bedell and H. J. Reich, "The Oscilloscope: a Stabilized Cathode-Ray Oscillograph with Linear Time-Axis," *Journ. A. I. E. E.*, 46: 563, June, 1927.