We can say, however, in view of the results of work initiated by Dr. A. P. Mathews, that the vital processes in nervous tissue become retarded. This is indicated by the lowered carbon dioxide production exhibited by a nerve exposed to cocaine. Niwa[19] (1918) states that "there is a close relationship between the rate of nerve metabolism and the state of excitability of the nerve" and that "anesthesia in general is probably brought about by interference with the tissue metabolism." This does not differ greatly from Verworn's theory of anesthetic action.

While practise in this case, pending the perfection of theory, proceeds with a tolerable degree of satisfaction, we still await the demonstration of the ideal local anesthetic. This form of anesthesia, however, is extending its usefulness through an ever widening field. Few are the types of major operations which can not now be successfully conducted under its sole employment, always provided that numerous external conditions are satisfied. Among the advantages ascribed to it when thoroughness of operative procedure is not thereby sacrificed are its high degree of safety and rapidity of induction, the exclusion of shock and often of after-pain, the necessity for fewer assistants, the shortening of convalescence, and the absence of post-anesthetic complications. An additional factor of importance is the better mental attitude with which many patients approach such a procedure rather than an operation involving the surrender of consciousness. Some enthusiasts go so far as to say that many an operation assumes the character of a social rather than a surgical occasion, the patient perhaps smoking throughout and enjoying a good meal directly thereafter.

While we are not so advanced that serious ceases are made thus attractive, the day of ideal surgery will doubtless be hastened by the replacement of older for better local anesthetics.

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[19] Niwa, Shuichi, *Jour. Pharm. and Exp. Therap.*, 1919, 12, 323.

PHENOMENA IN THE ULTRA-VIOLET SPECTRUM, INCLUDING X-RAYS

At the recent St. Louis meeting of Section B, of the American Association for the Advancement of Science, there was held a symposium devoted to a comparative discussion of the phenomena involved in the ultra-violet "light" and "X-ray" spectra. The following abstracts of the papers have been prepared by the authors:

A. Quantum Emission Phenomena—Radiation, by David L. Webster, Massachusetts Institute of Technology.

This paper contained a review of the laws of excitation of radiation by electron impact in the best known cases in X-rays and light, in which it appeared that the most essential difference is the existence in light of the so-called "single-line spectrum" which is unknown in X-rays. The phenomena are explainable on any theory of stable electron positions, such as the Bohr theory, if we assume: (1) that in the normal atom all positions involved in X-ray production are full (Kossel), and (2) all positions above the one corresponding to the series term 1.5S are empty (Van der Bijl).

Such theories are very unsatisfactory for absorption phenomena, especially since absorption is a continuous process but results in the production of photoelectrons, each with an absorbing oscillator and a gradual accumulation up to the value required for the photoelectron. If energy is thus stored it seems probable that it would be available to help in the production of X-rays or light by impact, and to produce other effects to be expected from it. But no such evidence of it can be found. The storage hypothesis is made only because it is demanded by the law of the conservation of energy. But this law has been observed only statistically, and the best way to reconcile these phenomena of electron impact with other radiation phenomena seems to be to assume that the law holds only statistically and does not apply to every oscillator at every instant.

B. Quantum Emission Phenomena-Electrons, by R. A. MILLIKAN, University of Chicago.

Experiments on the potentials necessary to apply to just prevent the escape of photoelectrons from different metals, combined with measurements on the contact E.M.F.'s between the same metals demonstrate, not that the energy *absorbed* by an electron which is being photoelectrically ejected is $h\nu$, but rather that the *kinetic energy* with which the electron *escapes* from the atom under the influence of incident radiation of frequency ν is $h\nu$, and hence that *the absorbed energy must always exceed $h\nu$ by the amount of the work necessary to detach the electron from the atom.* In other words the absorption of energy can not take place *quantum-wise* at all

The energy which must be absorbed to cause the escape of an electron must always be more than a quantum and may exceed that amount by any fractional part thereof. It is only the kinetic energy of the escaping electron which is always an exact quantum.

The emission of electromagnetic radiation may or may not take place quantum-wise. Characteristic or fluorescent radiation appears to be emitted quantum-wise but scattered radiation is not so emitted.

C. Spectrum Series, by WILLIAM DUANE, Harvard University.

There is presented for discussion the following four topics: (*a*) The combination law applied to the series spectra of ordinary light, and a somewhat similar law for characteristic X-rays; (*b*) the meaning of these laws in terms of the energy of the radiating atom from the point of view of the theory of radiation in quanta; (*c*) the law of constant angular momentum as used by Bohr in explaining some of the details of series spectra; (*d*) Bohr's theory applied to characteristic X-rays, with special reference to critical absorption data.

(*a*) It has been found empirically that the frequencies of vibration (or the wave numbers) corresponding to the lines in series spectra may be represented as the differences between any two of a set of terms, which may be denoted by symbols of the forms $(1S)$, $(1P)$, (mP), (mD), (mF), $(1s)$, (mf), etc. These terms may approximate to, but do not exactly equal a certain constant divided by the square of a whole number. The differences between the correct values of various pairs of terms, however, appear to represent the wave numbers with great precision.

Turning to X-rays we find that the form of the "terms" is much more complicated. It is possible, however, to obtain empirically a relation between the X-ray emission and absorption frequencies that resembles the above combination law. Mr. Shimizu and I recently published[1] the results of experiments, which indicate that an emission frequency equals the difference between two absorption frequencies. From the data for the K and L series of tungsten, it appears that the law is correct to about one fifteenth of a per cent. Since we presented this research to the Physical Society some measurements by Dr. Stenstrom of the absorption frequencies in the M series of uranium and thorium have come to hand, and these together with de Broglies' values for the L absorption frequencies and Seigbahn's values for the L emission frequencies furnish data by which the law can be tested. The calculations indicate that the differences between the L and M absorption frequencies equal the frequencies of some of the L emission lines to within one per cent.

Theories of the mechanism of radiation such as that suggested by Bohr lead to laws similar to the combination law, and Kossel has deduced from these conceptions relations between the emission frequencies themselves. One of these relations is that the difference between the $K\beta$ and the $K\alpha$ frequency equals the $L\alpha$ frequency. This relation is not exact, however, for $K\alpha$ represents a group of lines and recent experiments have shown that $K\beta$ also is not a single line. We get a much closer agreement, if we take the frequencies of the individual lines in the groups.

(*b*) For a long time spectrum analysis remained a purely descriptive science, containing data of extraordinary accuracy, it is true,

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[1] *Physical Review,* July, 1919.

but of very little fundamental significance. Recently, however, this data has furnished evidence of great importance as to the structure of matter and the mechanism of radiation. This is largely due to two fundamental laws: Planck's law of radiation in quanta, and Bohr's law of constant angular momenta.

According to the first law the amount of energy radiated from an atom is proportional to the frequency at which it is radiated, the constant h being the factor of proportionality. In other words the atom changes from one state into another when it radiates, and the difference between the energy it possessed before and after the radiation equals the frequency of vibration multiplied by h, thus:

$$h\nu = W_1 - W_2.$$

According to this conception the terms in the combination law represent the energy of the atom in its various states of equilibrium divided by h, plus, of course, an additive constant.

The complete expression of the law is

$$\tau h\nu = W_1 - W_2,$$

where τ denotes any whole number, but spectrum lines corresponding to values of τ greater than 1 have not been observed. They may be very faint, except, perhaps, in the infra red spectrum. The chance of τ's being greater than unity (in black body radiation) is very small for high frequencies of vibration.

Extraordinary success has attended the application of Bohr's theory to the case of a single electron revolving about an atomic nucleus. In this theory the angular momentum of the electron equals some whole number multiplied by a universal constant, $h/2\pi$, thus

$$mva = \tau(h/2\tau).$$

The value of the universal angular momentum may be regarded as chosen to fit the facts, *i. e.*, to give the correct value for the Rydberg fundamental frequency, or we may assume, with William Wilson, that a certain integral equation, occurring in the theory of quanta, expressed in generalized coordinates, namely,

$$\int pdq = \tau h,$$

applies to the revolving electron. Since the force acting on the electron is a central force, the angular momentum p is constant, and, if we take the integral over a complete period during which the angle q varies by 2π, we have

$$2\pi mva = \tau h.$$

As an example of the application of Bohr's theory let us consider the values of the Rydberg constant for hydrogen and for ionized helium. In each case a single electron revolves about an atomic nucleus. The theory assumes that the attraction between them is given by Coulomb's law, and from this together with the two laws mentioned above the various unknown quantities can be calculated, including the frequency of the emitted radiation. Since the helium nucleus is nearly four times as heavy as the hydrogen nucleus, the common center of gravity, about which the electron and the nucleus revolve, is slightly nearer the center of the helium nucleus, than is the case with hydrogen. Bohr predicted that on account of this fact certain lines in the hydrogen spectrum should have wave-lengths slightly longer than certain lines in the enhanced helium spectrum, and experiments prove this to be true. Further, the ratio of the mass of the electron to that of the hydrogen atom, and the ratio of the charge to the mass of the electron can be calculated from accurate measurements of the wave-lengths of these lines. The values of these ratios calculated from data obtained by Pashen are very nearly the same as the values deduced from other methods of experiment. In fact, granting the general truth of the theory, they are, perhaps, the most accurate estimates we have of these important ratios.

The Rydberg constant for the spectra of ordinary helium, in which we may suppose that there is one electron revolving in an inner ring about the nucleus, appears to be slightly less than that for the spectrum of ionized helium. Bohr's theory would seem to account for some such decrease in the value of the constant, for the influence of this electron on electrons in outer rings is slightly greater than would be the case, if it were actually in the nucleus itself. The theory, applied to cases where more than one electron revolve about the nucleus, does not appear as yet to be thoroughly satisfactory.

Bohr's theory has been applied to the characteristic X-ray spectra with some success in particular cases. For instance, Sommerfeld's calculation of the frequency difference between the lines in the Kα group by means of elliptic orbits, etc., seems to represent the facts to a considerable degree of precision.

In general the theory does not indicate the distribution of the electrons among the various orbits, and this distribution must be determined by other considerations, or else it must be chosen to fit the X-ray data. The latter procedure has been followed by Debye, Kroo, Wiggard and Sommerfeld. The calculation of the frequency of the α_1 line in the K series by Sommerfeld seems to agree with the facts to a remarkable degree of accuracy. None of the formulas, however, appear to give the frequencies of all the lines in the X-ray spectra.

It might be interesting to calculate the frequencies of the critical absorption associated with the K series, using a distribution of electrons similar to that adopted by Lewis and Langmuir in their theory of a static atom. In this theory the inner shell contains two electrons, the second shell contains two layers of 8 electrons each, the third, two layers of 18 each, etc. Translating this distribution from the static atom over into the dynamic atom I shall assume that the inner orbit of one quantum ($\tau = 1$) contains 2 electrons; that outside this are two orbits of two quanta ($\tau = 2$), one just outside the other and each containing 8 electrons etc.

K ABSORPTION FREQUENCIES

The table contains the data. Two columns of calculated values are given, one corrected for the mutual influence of neighboring rings of electrons on each other and one uncorrected. The observed values represent our measurements of the critical absorption frequencies,[2] which are the highest X-ray frequencies known to be characteristic of the chemical elements. Except for aluminium the observed values differ from the calculated values by less than the correction for the influence of the rings on each other. Considering that none of the quantities used in the calculations have been taken from X-ray data, the agreement may be regarded as good, especially for the chemical elements of high atomic number.

The above distribution of electrons does not give the proper values for the frequencies of the emission lines of chemical elements of low atomic numbers, so that the problem can not be said to have been solved.

$$
\begin{aligned}
\frac{\nu}{\nu_0} = {} & 2(N - \tfrac{1}{4} - \phi_1)(1 + \tfrac{1}{4}\beta_1^2 + \tfrac{1}{8}\beta_1^4 + \cdots) \\
& - (N - \phi_2)^2(1 + \tfrac{1}{4}\beta_2^2 + \tfrac{1}{8}\beta_2 + \cdots) \\
& + \Sigma \frac{n}{\tau^2}(N - n_1 - n_2 - \cdots - s_n - \phi)^2 \\
& - \Sigma \frac{n}{\tau^2}(N - n_1 - n_2 - \cdots - s_n - \phi + 1)^2.
\end{aligned}
$$

$$\beta = \frac{2\pi e^2}{ch}(N - \phi).$$

$$n_1 = 2,\ n_2 = 8,\ n_3 = 8,\ n_4 = 9,\ n_5 = 9,\ \cdots.$$

$$\tau_1 = 2,\ \tau_2 = 2,\ \tau_3 = 3,\ \tau_4 = 3,\ \cdots.$$

ν_0 = Rydberg Fundamental Frequency

Chemical Element	Atomic Number	ν/ν_0 Calculated (Uncorrected)	ν/ν_0 Observed	ν/ν_0 Calculated (Corrected
Aluminium....	13	116.7	114.8	118.5
Phosphorus ...	15	157.0	158.4	163.9
Manganese....	25	479.2	482.8	500.8
Bromine	35	968.9	993.6	1000.0
Rhodium	45	1696.0	1711.0	1717.0
Caesium......	55	2584.0	2648.0	2643.0
Terbium......	65	3752.0	3803.0	3812.0
Tungsten	74	5056.0	5109.0	5118.0

D. The Origin of Radiation, by A. W. HULL, of the Research Laboratory of the General Electric Co.

The rapidity with which our theories of atomic structure have advanced during the last ten years has left the impression that each new contribution was a new theory, and that one must choose between these appar-

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[2] *Physical Review*, December, 1919.

ently conflicting theories. The purpose of this paper is to show that these contributions not only do not conflict, but that all of them are essential parts of a picture, which is nearer completion than most of us realize. The main contributions may be summarized as follows:

Ritz showed that by assuming the nucleus to be magnetic, so that the force determining the vibration of the electron depends on the velocity instead of the position of the electron, one obtains a frequency law involving only the first power of the frequency, in accordance with observations.

The essential part of Bohr's beautiful theory is the mechanism by which he accounts for Ritz's combination principle namely, that the frequency of radiation depends not on where the electron is, or where it came from, but upon both.

J. J. Thomson added the idea that Bohr's stable orbits, and the quantum relations connected with them, are due to a skeleton structure of the nucleus and not to any discontinuity of energy.

Sommerfeld extended Bohr's theory to atoms of higher atomic weight, and has drawn a beautiful picture. His main contribution is the idea that the orbit may be either a circle or an ellipse of definite eccentricity, which accounts with extreme precision for the separation of doublets both in X-ray spectra and the hydrogen spectrum.

Langmuir showed that all known chemical properties are satisfied by an atom with relatively stationary electrons, arranged in concentric shells about the nucleus.

By combining these contributions, namely, the magnetic nucleus of Ritz, Bohr's stable orbits, Thomson's skeleton nucleus, Sommerfeld's elliptical orbits, and Langmuir's stationary electrons, we arrive at a composite picture which represents our present knowledge remarkably well. The rotating point electron is replaced by a ring-shaped electron. The constant angular momentum of the rotating electron is replaced by constant magnetic moment of the ring. In the case of hydrogen and ionized helium the ring surrounds the nucleus, and the picture is identical with Bohr's. In the case of the other elements the rings lie on the surface of concentric shells, in positions corresponding to Langmuir's cells. The condition of constant angular momentum of each ring electron holds for all atoms, and Sommerfeld's picture of the circular and elliptical rings is applied to the shape of the ring electron.

The discussion following the symposium was of necessity brief. Emphasis was given to the clear advantage of preferring a theory of atomic structure that gives correct quantitative results.

G. W. Stewart,
Secretary Section B

SCIENTIFIC EVENTS

PUBLICATIONS AND MEMBERSHIP OF THE NATIONAL ACADEMY OF SCIENCES

At the recent meeting of the academy the home secretary presented the following report:

The President of the National Academy of Sciences.

Sir: I have the honor to present the following report on the publications and membership of the National Academy of Sciences for the year ending April 26, 1920.

Two parts of Volume 14 of the Memoirs of the National Academy of Sciences have been completed and distributed: the second memoir, "Complete Classification of Triad Systems," by H. S. White, F. N. Cole and L. D. Cummings, and the fourth memoir, "Minor Constituents of Meteorites," by G. P. Merrill.

The third memoir, "Tables of Minor Planets," by A. O. Leuschner, A. E. Glancy, and S. H. Levy, and the fifth and final memoir of Volume 14, "Tables of the Exponential Function," by C. E. Van Orstrand, are now in page proof and will be issued shortly, as will also Volume 15, "Psychological Examining in the United States Army," by Robert M. Yerkes.

Volume 16, first memoir, "Lower California and its Natural Resources," by E. W. Nelson, and the second memoir, "Studies upon the Life Cycles of Bacteria," by F. Löhnis, are now in galley proof. The third memoir, "A Recalculation of Atomic Weights," by F. W. Clarke, is now in the hands of the printer.

Volume VIII. of the Biographical Memoirs has been completed with the publication of the biog-