until the cumulative power of the intellectual and social ferment induced became so great as to be irresistible, and the whole mass was moved forward.

From the outset Welch was the central figure and guiding genius of the medical group. The pathological laboratory became an active center of research and teaching. Welch's life quickly became filled to overflowing. He conducted investigations of his own, launched others on productive themes, and saw to it that the invaluable pathological specimens from the surgeons and gynecologists were made use of to advance knowledge and train a generation of special pathologists in those important fields. He lectured on special and general subjects in pathology and bacteriology in a manner so learned and fascinating as to produce impressions not only immediately stimulating to his auditors in high degree but of enduring permanence. The suggestiveness of these lectures led frequently to new undertakings in research. Moreover, the autopsies he performed, his demonstrations of gross pathological specimens and his teachings at the microscope stand out as unsurpassable models. He entered also into the medical activities of Baltimore and of the state of Maryland, and became a great influence for betterment in private and public medicine. He was, of course, the first dean of the medical school and guided the policy of the new institution into the productive channels that have so eminently distinguished it. His many talents were therefore called into constant play, and heavily overtaxed as they must often have been there was never indication of exhaustion. When occasion arose he was always ready, eager and able for a new advance, as witness his leading part in the recent development of the full-time system, so-called, in the clinical branches of medical teaching, in establishing a model school of public health and hygiene, and in serving on scientific and philanthropic boards possessing great wealth, for promoting scientific discovery and for carrying the benefits of medical knowledge to the furthest parts of the world.

The achievements of Welch as an investigator, teacher and reformer in medicine are so many and varied that it is not possible to do justice to them in detail in a mere sketch. This is particularly true of that part of his career covered by the Baltimore and Johns Hopkins period. These three noble volumes of his collected papers and addresses are the best expression of his many-sided activities. And yet precious as they are, they afford no real insight into Welch's almost flawless personality, the depth of his friendship and wealth of his kindness, his faculty of intense application and devotion to the work in hand whether in laboratory or in public interest, his commanding influence and guiding spirit over the work of his associates and many pupils, the stimulating wholesomeness of his public activities, and his rarely unselfish and tolerant nature which led him to shower his great gifts prodigally and far and wide. The recipient of almost every honor in the gift of his colleagues, he fortunately, in time, saw the return of his labors, increased many-fold, enriching science through progress made in education, in deeds performed and discoveries by the men and institutions over whose destinies he had presided. And lastly these volumes fail to show us still another side of Welch's accomplishments as remarkable almost as those of the science we so love to laud in him. I refer to his culture outside the realm of medicine in the field of literature, in which he possesses an almost unerring taste for the best in poetry and prose, and in the domain of the fine arts. His mind is indeed stored with the beautiful creations of other men's minds from ancient times to our own day. It is to all these remarkable qualities, innate and acquired, united in one man, that we owe that thrice rare personality William Henry Welch, master in medicine and beloved of men.

Simon Flexner

THE STRUCTURES OF THE HYDROGEN MOLECULE AND THE HYDROGEN ION

In a letter to Science published June 18 I described a model for the helium atom which is in better accord with the chemical relationships of helium than is the model proposed by Bohr. It leads to a value 25.59 volts for the ionizing potential in agreement with experimental determinations while Bohr's theory gives too high a value. In the model which I proposed the two electrons move in separate orbits in a plane containing the nucleus. The electrons are always symmetrically located with respect to a second plane which passes through the nucleus and is perpendicular to the plane of the orbits. Each electron thus oscillates back and forth along an approximately semi-circular path.

We may conceive of the hydrogen molecule as having a similar structure except that there are two nuclei. The electrons may thus move in separate orbits in a plane which is perpendicular to and bisects the line connecting the nuclei. The positions of the electrons at any time are symmetrical with respect to another plane which passes through both nuclei. Starting from two points on opposite sides of the center of the molecule, we may imagine the electrons to revolve about the center in opposite directions. After something less than a quarter revolution the electrons come so close to one another that the repulsive forces between them bring them both to rest. These forces then cause them to return back along the same paths to the starting points. They then continue their motion and complete another quarter of a cycle before they again come to rest. Each electron thus oscillates along a nearly semicircular line.

On the basis of the classical mechanics, by a series of approximations, it is possible to calculate the size and shape of the orbits and the relative velocities of the electrons at any point in their paths in terms of the distance between the nuclei. If we let a be the distance from the center of the molecule to the mid-point of the nearly semicurcular orbit of the electron, then the distance between the nuclei is $0.619 \times a$ and the radius vector of the electron at the ends of the orbit (where the electron comes to rest) is $1.152 \times a$. The angle through which the electrons move is 71° 26′ each side of the mid-point as measured from the center of the molecule. The angular velocity of the electrons at the mid-points of their paths is such that if they continued to move with this velocity they would travel through 106° 00′ during the time that they actually take to move to the end of the orbits (*i. e.,* through 71° 26′). The total energy (W) of the molecule (kinetic plus potential) is found to be $1.604 \frac{W_0 a_0}{a}$ where W_0 is the corresponding energy for the hydrogen atom according to Bohr's theory and a_0 is the radius of the electron orbit in the hydrogen atom (0.530×10^{-8} cm.).

It should be possible by means of the quantum theory to determine a, and fix the absolute dimensions of this model. But, so far as I know, the quantum theory has not yet been formulated in such a way that it can be applied with certainty to the type of motion that we are here considering. The quantum condition $\int pdq = nh$ is only valid when the co-ordinates are chosen in a particular manner, and for a case like the one in hand I have not been able to find any general method for determining what system of coordinates should be used. It may be, however, that others having greater familiarity with the recent mathematical development of the quantum theory will be able to determine the value of a for the model under consideration.

I have therefore proceeded to calculate the value of a from the known heat of dissociation of molecular hydrogen into atoms, and then to test this result by calculating other properties of hydrogen. Taking q the heat of dissociation (at constant volume), as 84,000 calories per gram molecule we find that $W/W = 2.270$. Since q is proportional to $W - 2W_0$ it takes a relatively large change in q to have much effect on the value of W. Thus an error of eight per cent. in determining the heat of dissociation (which is greater than the probable error), would cause only a one per cent. error in W and in a. From the relation previously given, we thus find $a = 0.707a_0 = 0.375 \times 10^{-8}$ cm. When the electrons are at the ends of their orbits their distance from the center is 0.432×10^{-8} cm. In Bohr's model for the hydrogen molecule the radius of the orbit of the elctrons is 0.953 a_0 or 0.506×10^{-8} cm. In the new model the distance of the nuclei from the center is 0.232×10^{-8} cm. while in Bohr's model this distance is 0.292×10^{-8} cm. The moment of inertia of the molecule about its center is thus 1.78×10^{-41} g. cm.^{2} for the new model while Bohr's model gives $2.81 \times^{-41}$ g. cm.^{2} From the theory of band spectra which has recently been developed by Lenz, Heurlinger and others it is possible to calculate the moment of inertia of the hydrogen molecule from certain relationships between lines of the secondary spectrum of hydrogen which were found by Fulcher and Croze. Thus Sommerfeld[1] calculates that the moment of inertia of the hydrogen molecule is 1.85×10^{-41}. This value agrees within four per cent. with that calculated from the new model (1.78×10^{-41}) while Bohr's model gives a value 52 per cent. too high.

It is of interest to enquire if there are not other simple models for the hydrogen molecule which are consistent with the known chemical facts regarding the remarkable stability of a pair of electrons in molecules. Sommerfeld has modified Bohr's original theory of atomic structure by considering elliptical as well as circular orbits. A two-quantum orbit of an electron in an atom may have both quanta in the form of angular momentum (circular orbit), or there may be one quantum of angular and one of radical momentum (elliptical orbit). Both quanta can not be in the form of radial momentum, for the ellipse would then degenerate into a straight line which would pass through the nucleus and this would lead to infinite velocities for the electron. This reason for the exclusion of orbits having only radial quanta fails for the case of a molecule in which there is no nucleus at the center. We should therefore consider models for the hydrogen molecule in which the two electrons oscillate in and out along a straight line passing through the center of the molecule, and perpendicular to the line joining the two nuclei. The repulsion of the electrons for each other would prevent them from reaching the center. We assume of course that the two electrons are coupled together by some quantum relationship, in such a way that they are always at equal distances from the center. If the electrons are at their greatest distance from the center they are more strongly attracted by the two nuclei than they are repelled from each other and they therefore fall in towards the center. When they get close to the center the repulsion increases rapidly and finally causes the electrons to rebound to their original positions. When the electrons are far apart there is a net repulsive force between the nuclei, but when the electrons are close together the attractive force on the nuclei predominates. The length of the path traveled by the electrons must be so related to the distance between the nuclei that the time averages of the repulsive and attractive forces acting on the nuclei must be equal.

By a series of approximations, based wholly on the classical mechanics, the following results have been calculated. If we take b. the distance between the center of the molecule and the nuclei as unity, the maximum distance reached by the electrons (from the center) is 3.710, while the minimum distance within which they approach the center is 0.1644. The electrons attain their greatest velocity when they are at a distance of 0.5773 from the center, and if they continued to move with this velocity they would travel a distance 8.989 in the time that it actually takes to move from the position of nearest approach to the point in the orbit furthest from the center. The total energy W of the molecule according to this model is 0.8124 $W_0 a_0/b$ where W_0 and a_0 have the same meanings as before.

In the absence of definite knowledge as to how to apply the quantum theory to this model we may calculate the absolute dimensions from the heat of dissociation. Taking

[1] "Atombau und Spectrallinien," p. 561, 2d edition, soon to be published.

as before $W = 2.270\ W_0$ we find for b, the distance from the nuclei to the center of the molecule, the value 0.190×10^{-8} cm. The moment of inertia is thus 1.20×10^{-41} g. cm.[2] Since this value does not agree at all well with the value 1.85×10^{-41} calculated from the spectrum it is improbable that this model corresponds to the true structure of the hydrogen molecule in its normal state. It may be however that such a model with a different value for b may apply to a disturbed state of the molecule.

According to Bohr's theory in which the paths of electrons are circular, a hydrogen ion consisting of two hydrogen nuclei with one electron, should not be capable of existing, for the value of W for such a structure ($0.88\ W_0$) is less than that for the hydrogen atom and the ion should therefore break up into an electron and a hydrogen atom. There seems to be considerable experimental evidence[2] that the positive H_2 ion is stable and is formed from ordinary molecular hydrogen when an ionizing voltage of about 11 volts is applied.

Since the H_2^+ ion has two nuclei there is no obvious necessity for assuming a circular path for the electron. I have therefore considered a model in which the electron oscillates along a rectilinear path passing through the center of the ion and perpendicular to the line joining the nuclei. By the methods of the classical mechanics it can be shown that if we take b, the distance between the center of the ion and the nuclei, as unity, then the maximum displacement of the electron from the center (*i. e.*, at the end of its path) is 2.214. The velocity of the electron when it passes the center of the ion is such that if it should continue to move with this velocity it would travel a distance 5.148 during the time that it actually takes to move from the center to the point furthest from the center. The total energy W of the ion is $0.6468\ W_0 a_0/b$. As soon as b is known the ionizing potential of hydrogen corresponding to this model can be calculated.

I have tried to apply the quantum theory in two different ways, although without certainty that either way is correct. According to the first method I have assumed that the angular momentum (or the moment of momentum) of the electron about each of the nuclei is $h/2\pi$ when the electron passes through the center. Of course the angular momentum about one of the nuclei decreases as the electron moves further from the center but this is due to the fact that the momentum is imparted to the other nucleus. A consideration of Landé's models for the octet, as well as the model which I previously proposed for the helium atom, suggests that in structures having more than one electron and one nucleus, we are concerned not with the momentum possessed by any electron, but rather with the momentum which is *transferred* from one electron to another or from an electron to a nucleus. On the basis of this assumption, it can be readily calculated that the value of b, the distance of the nuclei from the center, is $0.4250\ a_0$ or 0.225×10^{-8} cm. The energy of the ion is then $1.522\ W_0$. Since this is larger than that for the hydrogen atom, this ion will be stable. The difference between this energy and that for the hydrogen molecule (*i. e.*, $0.748\ W_0$) corresponds to the energy required for ionization. Expressed in volts this is 10.15 volts, which is in fair agreement with the experimental values (11 to 11.5 volts).

In the second method of applying the quantum theory I have used the relation $\int p\,dq = h$ where I have taken q to be the distance measured from the center along the rectilinear path, and p is the momentum in the direction of this path. As far as I know there is no good reason for choosing this particular coordinate system except that it seems to be the simplest. These assumptions lead to the value $b = 0.5261\ a_0 = 0.279 \times 10^{-8}$ cm. The energy is then $1.229\ W_0$, which again corresponds to a stable hydrogen ion but the ionizing potential is 14.1 volts.

The evidence in favor for these models is far from conclusive but in view of the fact that Bohr's models for the hydrogen molecule and ion can not be correct it seems important

[2] See particularly Franck, Knipping and Krüger, *Deut. Phys. Ges. Verh.*, 21, 728 (1919).

to test out the new models in as many ways as possible. The mathematical calculations upon which these models are based will probably be published in the *Physical Review*.

Irving Langmuir
Research Laboratory,
General Electric Co.,
Schenectady, N. Y.,
October 13, 1920

SCIENTIFIC EVENTS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Edwin S. Carman, manufacturer, of Cleveland, Ohio, has been elected president of the American Society of Mechanical Engineers in a mail ballot covering a membership of 13,000 engineers, managers and technologists in every industrial center of the country. Mr. Carman succeeds Major Fred J. Miller, of this city. He will take office after the society's annual convention, which will be held in New York in December.

John L. Harrington, consulting engineer, of Kansas City; Leon P. Alford, editor, of New York, and Robert B. Wolf, president of the R. B. Wolf Company, of New York, were chosen vice-presidents for two years in succession to John A. Stevens, of Lowell, Mass; Henry B. Sargent, of New Haven, Conn, and Fred R. Low, of this city.

Three managers, each for a term of three years, were elected, as follows: Henry M. Norris, of Cincinnati; Carl C. Thomas, of Los Angeles; Louis C. Nordmeyer, of St. Louis. Major William H. Wiley, publisher, of New York, was re-elected treasurer. The secretary will be elected by the society's council in December. Calvin W. Rice has held this office since 1906.

Following a meeting of the society's council, composed of the president, vice-presidents, managers, past presidents, treasurer and secretary, representing engineering effort in many sections of the country, and with a membership of twenty-one, broad plans for promoting professional endeavor and public service, particularly as to industrial relations and rewarding engineering achievement, were announced. The finance committee recommended a budget for the ensuing year of over $500,000.

The meetings and progress committee detailed plans for the annual convention of the society in New York in December and also announced plans for a congress of mechanical engineers to be held in Chicago next spring.

THE AMERICAN ORNITHOLOGISTS' UNION

The thirty-eighth stated meeting of The American Ornithologists' Union will convene in Washington, D. C., November 9–11.

Headquarters will be at The Harrington, 11th and E Streets, N. W., four blocks from the U. S. National Museum. Owing to the crowded condition of hotels in Washington members intending to be present are urged to make reservations well in advance.

The public meetings will be held in the U. S. National Museum, from 10 A.M. until 4.30 P.M. each day.

The reading of papers will form a prominent feature of the meetings. All classes of members are earnestly requested to contribute, and to notify the secretary before November 1, as to the titles of their communications and the length of time required for their presentation, so that a program for each day may be prepared.

In addition to the usual social features there will be opportunities to visit various places of interest, including the National Zoological Park and the Library of Congress. Arrangements have been made for a special exhibit in the library, showing the development of zoological illustrations as applied to birds and original drawings and photographs of birds by American artists and photographers.

T. S. Palmer,
Secretary
1939 Biltmore St., N. W.,
Washington, D. C.

THE AMERICAN SOCIETY OF NATURALISTS

The American Society of Naturalists will hold its thirty-eighth annual meeting at Chicago, under the auspices of the University of Chicago, beginning on Thursday, December