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(*b*. Halmstad, Sweden, 8 November 1854; *d*. Lund, Sweden. 28 December 1919)

mathematics, physics.

Rydberg was the son of Sven R. and Maria Anderson Rydberg. After completing the Gymnasium at Halmstad in 1873, he entered the University of Lund, from which he received a bachelor's degree in philosophy in 1875. He continued his studies at Lund and was granted a doctorate in mathematics in 1879 after defending a dissertation on the construction of conic sections. In 1880 Rydberg was appointed a lecturer in mathematics. After some work on frictional electricity, he was named lecturer in physics in 1882 and was promoted to assistant at the Physics Institute in 1892. Rydberg married Lydia E.M. Carlsson in 1886: they had two daughters and a son. After provisionally occupying the professorship in physics at Lund from 1897, he was granted the appointment permanently in March 1901 and held it until November 1919. He was elected a foreign member of the Royal Society in 1919.

Rydberg's most significant scientific contributions were to spectroscopy: but his involvement with spectra had its origin in his interest in the periodic system of the elements, an interest that endured throughout his professional life. His earliest published papers in physics dealt with the periodic table. In the introduction to his major work on spectra (1890), he stated that he considered it only a part of a broader investigation, the goal of which was to achieve amore exact knowledge of the nature and constitution of the chemical and physical properties of the elements. He held that the effective force between atoms must be a periodic function of their atomic weights and that the periodic motions of the atoms, which presumably gave rise to the spectral lines and were dependment on the effective force, thus might be a fruitful study leading to a better knowledge of the mechanics, nature, and structure of atoms and molecules and to a deeper understanding of the periodic system of the other physical and chemical properties of the elements. In line with contemporary conceptions, Rydberg's view was that each individual line spectrum was the product of a single fundamental system of vibrations.

His major spectral work, "Recherches sur la constitution des spectres d'émission des éléments chimiques', published in 1890, mapped out Rydberg's total approach with remarkable clarity. He conceived of the spectrum of an element as composed of the superposition of three different types of series—one in which the lines were comparatively sharp, one in which the lines were more diffuse, and a third that he called principal series even though they consisted mostly of lines in the ultraviolet. The first lines were located in the visible spectrum and were usually the most intense. The members of each series might be single, double, triple, or of higher multiplicity. Any particular elementary spectrum might contain any number (even zero) of series of each of the basic types.

While Rydberg observed and measured some spectral lines on his own, he was not particularly noted as an experimental physicist and did not publish any of his experimental investigations or spectroscopic measurements. Most of the data he needed were already available in the voluminous literature. While T. R. Thalén and Bernhard Hasselberg, Rydberg's major Swedish contemporaries in spectral studies, concentrated upon accurate measurements of the spectra of the elements, Rydberg's major spectral contributions were to theory and mathematical form, and those to form were the ones of enduring value.

Unlike most others, Rydberg used wave numbers (the number of waves per unit length) instead of a correlated reciprocal, the directly measured wavelengths. This enabled him to manipulate his final formula into a particularly useful form.

Rydberg concluded that each series could be expressed approximately by an equation of the form

where *n* was the wave number of a line; N_0= 109.721.6, a constant common to all series and to all elements; n_0 and μ constants peculiar to the series: and *m* any positive integer (the number of the term). The lines of a series were generated by allowing m to take on integer values sequentially; n_0 defined the limit of the series that the wave number *n* approached when *m* became very large.

Just when he became occupied with confirming this relationship, Rydberg learned about Balmer's formula, which represented the observed lines of the hydrogen spectrum with extraordinary accuracy. He arranged Balmer' formula into its wave number form and noted that, with appropriately selected constants, it was then a special form of his own more general formula. He felt that the success of Balmer's formula strengthened the justification of his own form. Thus encouraged, Rydberg proeeded to use the latter with sufficient success to propose it as the general formula for all series in all elementary line spectra, and to conclude that N_0 was indeed a universal constant, which has since become known as Rydberg's constant.

Spectroscopy had been a major developed field of physical study for several decades, but its most pressing need near the end of the nineteenth century was for the organization of its vast amount of data into some mathematically ordered form that theoreticians might find useful in their attempts to understand the underlying significance of spectra. Rydberg's general formula was the most important presentation of this type. Many others groped in the same general direction, mostly with ephemeral results. Rydberg's most significant competitors in this regard were Heinrich Kayser and Carl Runge, but their general formulas were of significantly different form.

The scope and structure of Rydberg's formula lowed him to note some important relationships. For example, he found not only that certain series with different values of μ exhibited the same value of n_0 but also that the value of the constant term n_0 in any series coincided with a member of the sequence of variable terms in some other series of the element. In particular, he discovered that the difference between the common limit of the diffuse and sharp series and the limit of the corresponding principal series gave the wave number of the common first-member term of the sharp and principal series, a relationship independently noted by Arthur Schuster and commonly known as the Rydberg-Schuster law.

Along this same line, Rydberg speculatively suggested as a comprehensive formula for every line of an element the relationship

with which he hoped to represent a series according to whether he assumed either m_1 or m_2 to be variable. Thus, he viewed every spectral series as a set of differences between two terms of the type $N_0(m+\mu)^2$ — is, every spectral line would be expressed as $n=T_1—T_2$where T_1 and T_2 are two members of a set of terms characteristic of the element. This aspect, little appreciated at the time, was stated independently in 1908 by Walther Ritz and is commonly known as the Ritz combination principle.

The combination principle revealed several significant features about spectra. First, the wave number of each line could be conveniently represented as the difference between two numbers, called terms, Second, the terms could be naturally grouped into ordered sequences— the terms of each sequence converging toward zero. Third, the terms could be combined in various ways to give the wave numbers of th spectral lines. Fourth, a series of lines all having similar character resulted from the combination of all terms of one sequence taken in succession with a fixed term of another sequence. Thus, fifth, a large number of spectral lines could be expressed as the differences of a much smaller number of terms that in some way were characteristic of the atom and therefore, form a theoretical perspective, were more important than the lines themselves when speculating on atomic structure. Now it was these terms, rather than the lines, for which a direct physical interpretation should be found. This last point was widely overlooked by most contemporary physicists, including Rydberg.

As deeply as the notion of the existence of some fundamental mechanism might be stimulated by them, all the regularities noted by Rydberg were in themselves only empirical generalizations. His own theoretical concepts on atomic structure were still based on an analogy to acoustics. Therefore, Rydberg did not reach the final goal he had set for his work; an adequate insight into the nature and structure of the atom. His work did, however, provide a basis for the later development of successful ideas on atomic structure.

Some radically new ideas concerning the structure of the atom resulted from the development of other lines of evidence. In 1913 Niels Bohr proposed his theory of atomic structure bases on Ernest Rutherford's nuclear atomic model and on Max Planck's quantum theory of radiation. These conceptions led to the first reasonably successful theoretical account of spectral data.

Bohr's view provided an immediate interpretation of the combination principle by identifying each Rydberg spectral term multiplied by *hc* (Planck's constant times the speed of light) with the energy of an allowable stationary state of the atom. The difference between two such states equaled the energy in the light quantum emitted in the transition from a higher allowable atomic-energy state to a lower one.

On this basis, spectral series were used to determine the excitation energies and ionization potentials of atoms. The further elaboration of these views led to a classification of the states of electron binding in a shell structure of the atoms that accounted for the periodic relationships of the properties of the elements, thereby fully justifying Rydberg's earlier faith that spectral studies could assist in attaining this goal. Rydberg played no role in this elaboration, however.

But earlier, along similar lines, Rydberg's study of the periodic properties of the elements led him in 1897 to suggest that certain characteristics of the elements could be more simply organized by using an atomic number instead of the atomic weights. This atomic number was to be identified with the ordinal index of the element in the periodic table. In 1906 Rydberg stated for the first time that 2, 8, and 18 (that is, $2n^2$, where n= 1,2,3) represented the number of elements in the early periods of the system. In 1913 he went further, correcting an earlier error about the number of rare earths from 36 to 32, thus allowing the $n = 4$ group to be included in the pattern.

Rydberg presented a spiral graph arrangement of the periodic table in which earlier holes in his system were corrected so that atomic numbers from helium on were two greater than at present. He maintained that there were two elements, nebulium and coronium, between hydrogen and helium in the system, supporting their existence by evidence from both spectra and graphical symmetry.

In 1913, H. G. J. Moseley published his paper based on researches on the characteristic X-ray spectra of the elements that strongly supported the fundamental importance of atomic numbers and Rydberg's basic expectations about the lengths of the periods of the periodic table. The physical reality that underlay Rydberg's atomic-number proposal was later interpreted as the positive charge on the atomic nucleus expressed in elementary units of charge.

Rydberg received a copy of Moseley's paper in manuscript form before publication. In a note written in 1914, he expressed satisfaction at the confirmation of his ideas on atomic numbers and the details of the periodic system, but he still maintained his conviction of the existence of the two elements between hydrogen and helium and the resulting difference of two in most atomic numbers. Later the nebulium spectrum was attributed to ionized oxygen and nitrogen, and the coronium lines to highly ionized iron.

Rydberg's health did not permit him to follow subsequent developments. In 1914 he became seriously ill. He went on an extended leave of absence that lasted until his formal retirement in 1919, a month before his death.

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II. Secondary Literature. A short biography of value in Manne Siegbahn, in *Swedish Men of Science 1650–1950*. Sten Lindroth, ed., Burnett Anderson, trans. (Stockholm, 1952), 214–218. Siegbahn was a student at the University of Lund from 1906 to 1911 and an assistant at the Physics Institute from 1911 to 1914 while Rydberg was there. In the autumn of 1915 Siegbahn was appointed to fulfill Rydberg's duties while the latter went on an extended leave. In early 1920 Siegbahn permanently succeeded Rydberg in the chair of physics at Lund.

On the centenary of Rydberg's birth, an important collection of papers was presented at Lund: "Proceedings of the Rydberg Centennial Conference on Atomic Spectroscopy," in *Acta Universitatis Lundensis*, Avd. 2, n.s. **50.** no. 21 (1954). Biographically, the two most significant articles are Niels Bohr, "Rydberg's Discovery of the Spectral Laws," 15–21; and Wolfgang Pauli, "Rydberg and the Periodic System of the Elements," 22–26.

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