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Determination of the Rydberg Constant in the Study of the Balmer Series of the Hydrogen Atom

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ABSTRACT
The work is devoted to the study of the Rydberg constant - a fundamental physical quantity that determines the quantum structure of the hydrogen atom. The discovery of the Rydberg formula, which describes the wavelengths of the spectral lines of the hydrogen atom, as well as experimental methods for accurately measuring the value of the Rydberg constant are considered. The role of this constant in the formation and development of the quantum theory of atomic structure in the late 19th - early 20th centuries is analyzed. Particular attention is paid to the importance of accurate knowledge of the value of the Rydberg constant for many areas of physics, chemistry and technology. In conclusion, it is emphasized that the experimental determination of the Rydberg constant is a key method for testing the quantum theory of the structure of the hydrogen Atom.

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The Rydberg constant is one of the fundamental physical quantities that plays an important role in describing the structure of the hydrogen atom and the patterns of its spectrum. It was introduced by Swedish physicist Johann Jakob Rydberg in 1888.

Rydberg discovered that the wavelengths of spectral lines in the Balmer series of the hydrogen atom obey a simple mathematical pattern, which can be expressed by the formula:

$$\frac{1}{\lambda} = R_H * (\frac{1}{2^2} - \frac{1}{n^2})$$

Where:

- λ- wavelength of the spectral line
- R_H- Rydberg constant
- n- an integer defining the energy level to which the electron goes

The Rydberg constant $R_H$has the dimension of the inverse length and is numerically equal to $1.097 * 10^7 \text{м}^{-1}$. It is a dimensionless quantity, since its dimension can be reduced to the form $^1/_\text{м}$.

Rydberg's discovery of this simple mathematical pattern was an important step towards the development of the quantum theory of atomic structure. It showed that the energy levels of the hydrogen atom are quantized and can be described by integers. The Rydberg constant reflects the fundamental properties of the hydrogen atom and relates its spectral characteristics to its internal structure.

The essence of the method is as follows:

1. The wavelengths of several bright spectral lines in the Balmer series of the hydrogen atom are measured experimentally.
2. For each measured wavelength, the value is calculated $^{1}/_{\lambda}$.
3. A graph is constructed depending $^{1}/_{\lambda}$on the value ($^{1}/_{2^2} - ^{1}/_{n^2}$), where n −are integers corresponding to transitions between levels.
4. The slope of a straight line drawn through the experimental points on the graph gives the value of the Rydberg constant R_H.

Thus, by analyzing experimental data on the spectral lines of hydrogen and using the theoretical Rydberg formula, it is possible to determine with high accuracy the value of this fundamental physical constant. Millikan and other physicists obtained values of the Rydberg constant with an error of less than 0.001%.

A spectral series is a set of transitions with a common lower level. For example, the Lyman series of the hydrogen atom and hydrogen-like ions consists of transitions to the first level: $n \rightarrow 1$, where the main quantum number of the upper level, or its number n, takes values 2, 3, 4, 5, etc., and the Balmer series - transitions $n \rightarrow 2$ for $n > 2$. Table 1 shows the names of the first few series of the hydrogen atom.

Series	Episode title
$n \rightarrow 1$	Lymana (Ly)
$n \rightarrow 2$	Balmera (H)
$n \rightarrow 3$	Pashena (P)
$n \rightarrow 4$	Bracket (B)
$n \rightarrow 5$	Pfunda (Pf)
$n \rightarrow 6$	Humphrey
$n \rightarrow 7$	Hansen – Strong

Table.1 Spectral series of the hydrogen atom

The Lyman series of the hydrogen atom falls entirely within the vacuum ultraviolet region. In the optical range is the Balmer series , and in the near infrared region is the Paschen series . The first few transitions of any series are numbered with letters of the Greek alphabet according to the scheme in Table 2:

Δn	1	2	3	4	5	6	7	8
Index	α	β	γ	σ	ε	ζ	η	θ

Table 2 Designations of the first lines of the spectral series

As a result of a spontaneous transition from the upper level i to the lower j, the atom emits a quantum whose energy E_{ij} is equal to the difference

$$E_{ij} = E_i - E_j (1)$$

During a radiative transition from j to i, a quantum with the same energy is absorbed. In the planetary model of the hydrogen atom, the energy levels are calculated using the formula

$$E_n = \frac{me^4Z^2}{2\hbar^2n^2} = -R_y\frac{Z^2}{n^2} (2)$$

and the nuclear charge is equal to unity:

$$E_{ij} = R_y\left(\frac{1}{j^2} - \frac{1}{i^2}\right) \ (3)$$

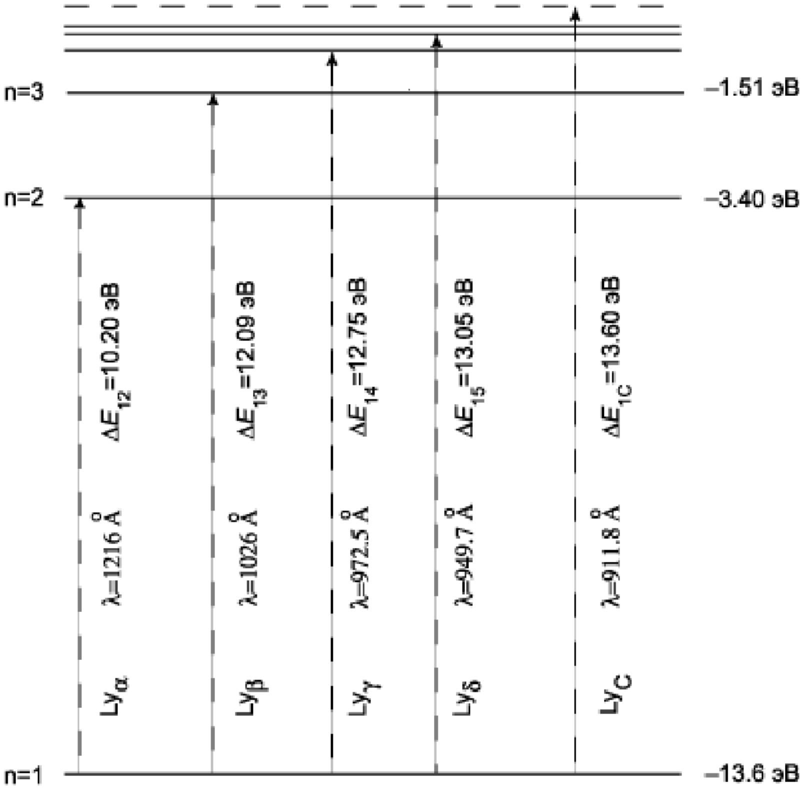
Dividing this formula by hc, we obtain the transition wave number:

$$k_{ij} = R_H\left(\frac{1}{j^2} - \frac{1}{i^2}\right) \ (4)$$

The wavelength in vacuum is equal to the reciprocal of the wave number:

$$\lambda_{ij} = \frac{1}{k_{ij}} \ (5)$$

As the top level number *i increases* the transition wavelength decreases monotonically. In this case, the lines move closer together without limit. There is a lower limit to the wavelength of the series, corresponding to the ionization limit. It is usually indicated by the suffix "C" next to the series symbol. Figure 1 shows schematically



In conclusion, we can say that the experimental determination of the Rydberg constant is a key method for verifying the correctness of the quantum theory of the structure of the hydrogen atom and further progress in understanding the fundamental principles of the structure of matter.

It should be noted that accurate knowledge of the Rydberg constant is of great importance not only for understanding the quantum structure of the atom, but also for many areas of science and technology related to atomic and molecular systems. Thus, the study of the Rydberg constant and the Rydberg formula became an important milestone in the development of quantum physics in the late 19th and early 20th centuries, deepening our understanding of the basic structure of the atom.

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