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Nobel Prize in Physics 1922

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The Nobel Prize in Physics 1922 was awarded to Niels Bohr *"for his services in the investigation of the structure of atoms and of the radiation emanating from them"*.

RESEARCH INFORMATION:

Ever since Kirchhoff and Bunsen (1860) introduced spectral analysis, that extremely important aid to investigation has produced the finest results. To begin with, material was collected and spectra were investigated not only from terrestrial objects but also from the heavenly bodies. There was a splendid harvest. Then came the second stage of research. Attempts were made to find regularities in the structure of the spectra. To begin with, it was natural to try to compare the different spectral lines which are emitted by a glowing gas with the different notes that could be produced by a vibrating solid. The vibrating bodies in a glowing gas would in that case be its atoms and molecules. But little progress could be made on this track. It was necessary to fall back on another method, namely to try by calculation to establish the connection between the various vibrations which could be emitted by a gas. Hydrogen ought to be the simplest of all gases. The Swiss Balmer in 1885 found a simple formula for the connection mentioned between the lines of hydrogen as then known. There followed a large number of investigators, such as Kayser and Runge, Ritz, Deslandres, and especially our compatriot Rydberg, who sought for similar regularities in the spectra of the other chemical elements. Rydberg succeeded in representing their light vibrations by means of formulae which exhibited a certain resemblance to Balmer's formula. These formulae contain a constant which has afterwards acquired extremely great importance and has been recorded amongst the universal and fundamental values of physics under the name of the Rydberg constant.

Now, if it were possible to obtain an idea of the structure of the atom, of course, that would form a good starting-point to create a conception of the possible light vibrations that can be emitted by an atom of hydrogen. Rutherford, who has to such an extraordinary degree wrung their secrets from the atoms, had constructed such "atom models". According to his conception, the atom of hydrogen should consist of a positive nucleus, with a unit charge, of extremely small dimensions, and about this a negatively charged electron should describe an orbit. As probably only electric forces are at work between the nucleus and the electron, and as these electric forces follow the same law as the attraction of gravity between two masses, the path of the electron ought to be elliptical or circular, and the nucleus to be situated either in one of the foci of the ellipse or in the centre of the circle. The nucleus would be comparable to the sun and the electron to a planet. In accordance with the classical theory of Maxwell, therefore, these orbit movements should emit rays and consequently cause a loss of energy, and the electron would describe smaller and smaller tracks with a declining period of revolution and finally rush in towards the positive nucleus. Thus the track would be a spiral, and the rays of light emitted, which will require a steadily declining period of vibration, would correspond to a continuous spectrum, which, of course, is characteristic of a glowing solid or liquid body, but not at all of a glowing gas. Consequently, either the atom model must be false, or else the classical theory of Maxwell must be incorrect in this case. Ten years or so previously there would have been no hesitation in the choice between these alternatives, but the atom model would have been declared to be inapplicable. But in 1913, when Bohr began to work at this problem, the great physicist Planck of Berlin had traced his law of radiation, which could be explained only on the assumption, which was in conflict with all preceding notions, that the energy of heat is given offin the form of "quanta", that is to say small portions of heat, just as matter consists of small portions, i.e. the atoms. With the help of this assumption Planck succeeded, in complete accordance with experience, in calculating the distribution of energy in radiation from a hypothetically completely black body. Afterwards (in 1905 and 1907) Einstein had perfected the quantum theory and deduced therefrom several laws, such as the diminution of the specific heat of solid bodies with declining temperature and the photoelectric effect, for which discovery he has this day been awarded the Nobel Prize.

Accordingly, Bohr had no need to hesitate in his choice: he assumed that Maxwell's theory does not hold good in the present case, but that the atom model of Rutherford is correct. Thus the electrons do not emit light when they move in their tracks round the positive nucleus, tracks which we begin by assuming to be circular. The emission of light would take place when the electron jumps from one track to another. The quantity of energy which is thus radiated is a quantum. As, according to Planck, the quantum of energy is the product of the number of light vibrations with the Planckian constant, which is denoted by the letter h, it is possible to calculate the number of vibrations which corresponds to a given passing from one orbit to another. The regularity which Balmer found for the spectrum of hydrogen requires that the radii of the different orbits should be proportional to the squares of the whole numbers, that is to say as 1 to 4 to 9, and so on. And indeed Bohr succeeded, in his first treatise on this question, in calculating the Rydberg constant from other known magnitudes, namely the weight of an atom of hydrogen, the Planckian constant, and the value of the electric unit of charge. The difference between the value found by observation and the calculated value of the Rydberg constant amounted to only 1 percent; and this has been diminished by more recent measurements.

This circumstance at once attracted the admiring attention of the scientific world to Bohr's work and made it possible to foresee that he would to a great extent solve the problem before him. Sommerfeld showed that what is known as the fine structure of the hydrogen lines, by which is meant that the lines observed with a strongly dispergent spectroscope are divided up into several closely adjacent lines, can be explained in accordance with Bohr's theory in the following way. The various stationary tracks for the movement of the electrons - if we leave out of account the innermost one, which is the ordinary one, and is called the "orbit of rest" - may be not only circular but also elliptical, with a major axis equal to the diameter of the corresponding circular orbit. When an electron passes from an elliptical orbit to another track, the change in the energy, and consequently the number of vibrations for the corresponding spectral lines, is somewhat different from what it is when it passes from the corresponding circular orbit to the other track. Consequently we get two different spectral lines, which nevertheless lie very close to one another. Yet we observe only a smaller number of lines than we should expect according to this view of things.

The difficulties thus revealed, however, Bohr succeeded in removing by the introduction of what is known as the principle of correspondence, which opened up entirely new prospects of great importance. This principle to some extent brings the new theory nearer to the old classical theory. According to this principle, a certain number of transitions are impossible. The principle in question is of great importance in the determination of the tracks of electrons which are possible within atoms that are heavier than the atom of hydrogen. The nuclear charge of the atom of helium is twice as great as that of the atom of hydrogen: in a neutral condition it is encircled by two electrons. It is the lightest atom next that of hydrogen. It occurs in two different modifications: one is called parhelium, and is the more stable, and the other is called orthohelium - these were supposed at first to be two different substances. The principle of correspondence states that the two electrons in parhelium in their tracks of rest run along two circles, which form an angle of 60° to one another. In orthohelium, on the other hand, the tracks of the two electrons lie in the same plane, the one being circular, while the other is elliptical. The following element with an atomic weight which is next in magnitude to helium is lithium, with three electrons in a neutral state. According to the principle of correspondence, the tracks of the two innermost electrons lie in the same way as the tracks of the two electrons in parhelium, while the track of the third is elliptical and is of far greater dimensions than the inner tracks.

In a similar manner Bohr is able, with the help of the principle of correspondence, to establish, in the most important points, the situation of the various tracks of electrons in other atoms. It is on the positions of the outermost electron tracks that the chemical properties of the atoms depend, and it is on this ground that their chemical valency has partly been determined. We may entertain the best hopes of the future development of this great work.

Professor Bohr. You have carried to a successful solution the problems that have presented themselves to investigators of spectra. In doing so you have been compelled to make use of theoretical ideas which substantially diverge from those which are based on the classical doctrines of Maxwell. Your great success has shown that you have found the right roads to fundamental truths, and in so doing you have laid down principles which have led to the most splendid advances, and promise abundant fruit for the work of the future. May it be vouchsafed to you to cultivate for yet a long time to come, to the advantage of research, the wide field of work that you have opened up to Science.

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