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Nobel Prize in Physics 1923

Robert Andrews Millikan

The Nobel Prize in Physics 1923 was awarded to Robert A. Millikan *"for his work on the elementary charge of electricity and on the photoelectric effect"*.

RESEARCH INFORMATION:

The Royal Academy of Sciences has awarded this year's Nobel Prize for Physics to Doctor Robert Andrews Millikan for his work on the elementary charge of electricity and on the photoelectric effect.

We speak of an electric charge when electricity is accumulated on a body, and of an electric current when it spreads along a metallic wire. But when electricity passes through water or water solutions there is no current in the same sense of the word; there is a convection of charges combined with chemical decomposition - electrolysis. Thus water is decomposed into its constituents, hydrogen and oxygen, and metallic silver is deposited from solutions of silver salts. If one and the same current is used to cause these decompositions, the weight of hydrogen liberated in a certain time bears the same ratio to the weight of silver deposited as the atomic weight of hydrogen to the atomic weight of silver, and a current of a given strength in a given time always causes the appearance of a constant quantity of hydrogen and the depositing of a corresponding quantity of silver. As

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the strength of the current indicates the quantity of electricity passing through the fluids in a given time, it follows that the hydrogen atom and the silver atom carry the same charge, and this charge is what is meant by the unit of electric charge. The same laws hold good for all electrolytic processes, different atoms carrying as many units as are indicated by their valency. The charged atoms are called ions, but this word is used also in a wider signification.

It follows from these laws of electrolysis that it was possible to calculate the unit of electric charge with the same degree of probability with which the number of atoms in a gram of hydrogen could be estimated, and as early as 1874 an approximate value of the unit was arrived at in this way, equalling about two thirds of the exact value now known through the researches of Millikan. The word electron was proposed later as a name for the unit of charge, but now that the discovery of cathode rays has brought to our knowledge free units of negative electricity, an electron means an amount of negative electricity equalling the unit of charge.

Electricity does not pass through gases under normal conditions, but when a gas is exposed to X-rays it acquires the power of transmitting a current. It was soon proved that under the influence of these rays, positive and negative ions are formed, conveying charges of electricity in the same way as in the case of electrolysis. The discovery of radioactive elements provided still more powerful means for such an ionization of gases.

With the methods that were now available it could be shown that the unit of charge of the gas ions was approximately the same as the unit known from electrolysis. Ionization was also observed in monatomic inert gases, which proves that the unit of electric charge is a constituent of the atom that is liberated from it by ionization. Eager attempts were now made to obtain a more exact value for the unit of charge, but the results were not much better than before - until Millikan took up the problem.

Millikan's aim was to prove that electricity really has the atomic structure, which, on the base of theoretical evidence, it was supposed to have. To prove this it was necessary to ascertain, not only that electricity, from whatever source it may come, always appears as a unit of charge or as an exact multiple of units, but also that the unit is not a statistical mean, as, for instance, has of late been shown to be the case with atomic weights. In other words it was necessary to measure the charge of a single ion with such a degree of accuracy as would enable him to ascertain that this charge is always the same, and it was necessary to furnish the same proofs in the case of free electrons. By a brilliant method of investigation and by extraordinarily exact experimental technique Millikan reached his goal.

In his fundamental experiments he had two horizontal metal plates, one a short distance above the other, and by means of a switch he could join them with the poles of a source of high-tension current or short-circuit them. The air between the plates was ionized by radium that could be screened off. There was a minute pin-hole in the middle of the top plate, and over it he had arranged a spray of oil droplets with a radius of about one thousandth of a millimeter. Sooner or later such an oil droplet must fall through the pin-hole and enter the space between the plates, where it was illuminated in such a way that Millikan could see it in a telescope like a bright star on a black background. In the eyepiece of this telescope were placed three cross-hairs, and Millikan measured the time which the droplet required to pass between them. In this way he measured the velocity of fall, which for such small droplets is only a fraction of a millimeter a second. The droplet had been charged with electricity by the frictional process involved in blowing the spray, and when it had fallen down, Millikan switched on the source of current so as to cause the drop to be pulled up by the attraction of the upper plate. The droplet rose, and its velocity was measured during its rise; then the plates were short-circuited, and the drop turned again and began to fall. In this way he kept the drop travelling up and down, many times during several hours, and measured its velocity again and again by means of a stopwatch or, later, a chronoscope. The velocity of fall was constant, but on the way up the velocity varied, which means that the drop had captured one or more of the ions spread in the air between the plates. Now in this experiment the difference of velocity is proportional to the charge captured, and the results showed that the difference of velocity always had the same value or an exact multiple of that value. In other words: the drop had caught one or more units of

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electrical charge, all exactly equal, however the experiments were varied. In this way the charge of a single ion could be measured in a very large number of cases, and it was determined with an exactitude of one in a thousand.

When the source of current is switched on, the positive ions are driven with a high speed towards the negative plate, and vice versa. Thus Millikan only needed to have the droplet near one of the plates at the moment when he switched on the source of current, if he wished to expose it to a shower of positive or negative ions and in this way alter its charge. By this method he proved that the electric charge which the drop had acquired by friction was an exact multiple of the unit.

To give unimpeachable proof Millikan was obliged to make similar experiments with cathode rays and with alpha- and beta-rays and, moreover, to investigate the law of fall of small bodies through gases and the law of their Brownian movements.

Even leaving out of consideration the fact that Millikan has proved by these researches that electricity consists of equal units, his exact evaluation of the unit has done physics an inestimable service, as it enables us to calculate with a higher degree of exactitude a large number of the most important physical constants.

In justifying the reward of Millikan the Academy has not omitted to refer also to his investigations of photoelectric effect. Without going into details I will only state that, if these researches of Millikan had given a different result, the law of Einstein would have been without value, and the theory of Bohr without support. After Millikan's results both were awarded a Nobel Prize for Physics last year.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1923/press.html