ISSN:2249-5347

IJSID

International Journal of Science Innovations and Discoveries

An International peer
Review Journal for Science

Nobel Prize in Physics 1924

Karl Manne Georg Siegbahn

The Nobel Prize in Physics 1924 was awarded to Manne Siegbahn *"for his discoveries and research in the field of X-ray spectroscopy"*.

RESEARCH INFORMATION:

The Royal Academy of Sciences has this year awarded the Nobel Prize for Physics for 1924 to Karl Manne Georg Siegbahn, Professor at the University of Uppsala, for his discoveries and researches in X-ray spectroscopy.

When the Prize for Physics was awarded to Röntgen at the First Nobel Festival, the conception of a spectrum of X-rays could not be set up, or at least could not be supported by experimental evidence. In fact, the domain of the work for which a prize has now been awarded did not yet exist. The assumption that X-radiation, like the radiation long known under the names of light and heat, consisted of transverse electric oscillations, it is true, was advanced by eminent scientists at a comparatively early date; but every attempt to demonstrate any of the phenomena characteristic of such oscillations - such as refraction, polarization or diffraction and interference - yielded results that were negative, or at least not free from ambiguity. The only means of distinguishing different kinds of X-rays was, and remained until later, the penetrative power or what is known as the degree of hardness, which was accessible for physical measurement.

But in the hands of a skilful investigator even this means was sufficient for the discovery of the characteristic X-radiation of the elements. Barkla in Edinburgh found that a series of elements, independently of the chemical composition in which they were used, emitted, in a certain experiment, X-rays of a degree of hardness which was characteristic of the element in question. As he proceeded from element to element with increasing atomic weight, the penetrative power of the characteristic radiation became greater, in other words the X-rays became harder and harder. If the atomic weight was sufficiently high, there appeared a new and much softer characteristic radiation, which in the same way became more and more penetrating the higher the atomic weight possessed by the element investigated. Barkla called these two radiations, by means of which the different elements could thus be distinguished from one another, their K- and L-radiation. These fundamental discoveries, as was soon to be seen, belong already to the domain of X-ray spectroscopy.

After Barkla had also found a kind of polarization of X-rays, it became more and more probable - though this phenomenon did not appear in the same way as the polarization of light - that the two forms of radiation were after all of the same nature, and enough progress had been made to render it possible to estimate the order of magnitude of the wavelength of the X-radiation, if that radiation really were a wave motion.

A spectrum in which every place corresponds to a definite wavelength is obtained by decomposing composite light. If all wavelengths are represented in this light, the spectrum is continuous; if not, the spectrum consists of lines or bands. The decomposition into a spectrum is effected either by refraction in a prism or by diffraction and interference in a grating. As gratings, there are generally used parallel grooves, very close together in a reflecting metal surface, but also gratings that let the light through, decompose it, in which case a spectrum may result both by the passage of the light and by its reflection. The closer together the grooves lie, the more effective is the decomposition and the shorter are the wavelengths that can be investigated. Metal gratings have been employed with great success for the investigation of wavelengths of that order of magnitude that occurs in light; but there seemed to be no prospect of measuring by such means the wavelengths, several thousand times smaller, which, it was estimated, should characterize X-radiation. If, on the other hand, as was assumed in crystallography, a regular arrangement of the atoms or the molecules in a space lattice was the basis of the shapes of the natural crystals, then, according to estimates, the distances of the points of the lattice ought to be exactly of that order of magnitude that was required for the decomposition of X-radiation in a spectrum. If this radiation were essentially a wave motion, therefore, a crystal ought to be a suitable grating for the spectral decomposition of the radiation, whether the X-rays had passed through the crystal or had been reflected in it. But it was only von Laue who drew from this the conclusion that an inquiry ought to be made as to whether such a diffraction and interference could be shown photographically when the X-rays passed through crystals. The experiment showed that this was the case. This epoch-making discovery, which not only bore upon the nature of X-radiation and the reality of the space lattice assumed in crystallography, but also placed a new means of research into the hands of Science, was rewarded with the Nobel Prize for 1914, though its distribution was postponed till the following year.

The new phenomenon could be employed for two different purposes, both for investigations of the crystal lattices and for spectral investigation of the X-radiation itself. It was only natural that precedence was given to the investigations first named, as a fruitful spectroscopical investigation of X-rays presupposed a certain knowledge of the lattice used. Inasmuch as this is a three-dimensional grating, its effect is in essential respects unlike the effect of the previously known line and cross gratings. It was by a stroke, brilliant in its simplicity, that the Englishman W.L. Bragg succeeded in replacing von Laue's comparatively complicated theory of the effect of the crystal lattice by an extremely manageable formula, which could not only be employed to interpret von Laue's photographs obtained by X-rays passing through the crystals, but also enabled his father, W.H. Bragg, to design a real X-ray spectrometer, which was based, like the majority of subsequent designs, on the reflection of radiation. With these means father and son cooperated in investigating the often very complicated structure of the lattices in a number of crystals; and their services were rewarded with the Nobel Prize for Physics of 1915.

The second path through the newly discovered region of X-ray spectroscopy, namely the investigation of X-radiation in the different elements, was trodden with the greatest success by the young scientist Moseley, who was also an Englishman. As the penetrative power of X-radiation increases with the decrease of the wavelength, it was now evident that Barkla's K- and L-rays must represent more or less limited X-ray spectra, which in passing over to elements with a higher atomic weight are displaced in the direction of shorter wavelengths. Now, Moseley investigated these rays by a photographic method and found the former to consist of two, the latter of four, spectral lines. He further discovered the simple mathematical law by means of which the frequencies determined by the position of the lines - and consequently the corresponding wavelengths - can be obtained by what is known as the atomic number, i.e. the number of the element in a series in which all the elements are arranged with a generally increasing atomic weight. As the atomic number has proved to distinguish the elements better than the atomic weight, it has now attained the very greatest importance for atomic physics of the present day. Moseley fell at the Dardanelles before he could be awarded the prize, but his researches had directed attention to the merits of Barkla, who consequently in 1918 was proposed for the Nobel Prize, which was awarded to him without delay.

Siegbahn has won his place in this noble row of eminent investigators by the work for which the Prize has now been awarded to him. It had already become clear that the X-radiation must arise in the inner parts of the atoms, and that consequently exact X-ray spectroscopical investigations form the only means for an experimental research of those parts. Clearly perceiving this fact, Siegbahn has in the course of ten years' assiduous and systematic labour devised a series of improvements and new designs dealing with almost every detail of the various apparatus and so constantly increased the exactitude of his measurements. The method has generally been photographical, and the crystal lattices have been used not only for reflection but also, in the case of shorter wavelengths, for diffraction of rays passing through the crystals. The high level to which he has brought X-ray spectroscopy can perhaps best be defined by the statement that the exactitude with which wavelengths can now be measured by his methods is a thousand times greater than that attained by Moseley. It was only to be expected that these much more accurate means would in his hand be used for a series of new discoveries. Thus to begin with, he has found a large number of new lines in the K- and L-series. Moreover he has made the experimental discovery of a new characteristic X-radiation, the M-series; and another such radiation, the N-series, has been discovered under his guidance. The fact that the existence of these radiations had already been surmised by Barkla in no wise diminishes the scientific value of their discovery and exact measurement.

In order to obtain an idea as to what has been gained by the researches of Siegbahn and his collaborators, it is sufficient to compare Moseley's results, two K-lines and four L-lines, with Siegbahn's statement ten years later. The K-series has been recently subjected to a fresh investigation for 42 elements. For 27 of these all the four main lines have been determined. For the lighter elements there are also special tables of eight fainter lines. The L-series has 28 lines and has been investigated for some 50 elements. The new M-series with 24 lines has been examined for 16 elements, and the N- series, which is also new, has been demonstrated for three of the heaviest elements, whereby five lines belonging to that series have been measured for uranium and thorium.

Siegbahn's work attains the character that is required for the award of the Nobel Prize not only because his methods of measurement provide an implement of hitherto undreamt-of exactitude, apt to further new scientific advances, or because he himself has used them to make a number of new discoveries, but above all owing to the importance for atomic physics that his methods of measurement and discoveries have.

It is obvious to everybody that it will always remain one of the chief goals of physics to gain knowledge of the laws that regulate the energy relations within the atom and the exchange of energy between the atoms and the various forms of radiations. But that goal lay far away as long as no other radiations were known than the electromagnetic oscillations that appear in the form of light, dark heat radiation, or ultraviolet rays, and the analogous oscillations with wavelengths of a higher order of magnitude which are brought about directly by electricity, and which play such a great part in our days. So long as science was restricted to these means of research, there was no such thing as atomic physics. Scientists worked on the assumption that the oscillations were emitted by what are known as dipoles, consisting of two points, one charged with positive electricity and the other with negative electricity, which were bound to one another by an attractive force.

Then came the discovery of the corpuscular radiations, first the cathode rays which, in a sufficiently strong vacuum, proceed from the negative pole of a suitable source of electric current to the positive pole, and which consist of free negative electric units of charge, known as electrons, and then the discovery of radioactive radiation, which, together with an electron radiation and an X-radiation of very short wavelength, contains positively charged corpuscles, known as alpha particles. With these means of research, it soon became evident that the notion of oscillating dipoles could not give a satisfactory picture of the structure of the atom.

Planck, however, even before a better picture had been obtained, had come to the conclusion that, if the electromagnetic theory is correct, it is impossible to obtain a theory of heat radiation agreeing with the facts without introducing the assumption that each dipole can exist only in a discontinuous series of different states of oscillation. The product of the frequency and a hitherto unknown constant, forms a value of energy, known as a quantum, and the dipoles can have no other values of energy than those which consist of an integral number of such quanta. The great importance due to this famous Planck's constant was only made clear through the later development of atomic physics.

A logical consequence of Planck's theory is that a transition from one state to another can only take place in such a way that an integral number of energy quanta is emitted or absorbed. An exchange of energy between matter and radiation, therefore - that is to say an emission or absorption of radiation - can be effected only by the transmission of an integral number of energy quanta. It was not Planck, however, but Einstein, that drew this conclusion, which involves the law of the photoelectric effect - a law that now, especially thanks to Millikan's work, has been verified in a brilliant manner. It is through Einstein's law that the Planck's constant and the whole-quanta theory have attained their greatest importance.

After the electrons had been discovered, and after it had been found that their mass is in round numbers only a two-thousandth part of that of an atom of hydrogen - while the positive unit charge never appears with a mass of such a small order of magnitude - atom models were devised in accordance with this fact. An observation that Rutherford made in the investigation of the paths of alpha particles shot out from radioactive substances, showed that the positively charged parts of an atom must be very small in proportion to the whole atom. According to his view, therefore, the atom consisted of a positive nucleus, surrounded by electrons moving in orbits, in the same way as the sun is surrounded by its planets. Rutherfords' atom model is the prototype of the one we now have, both in the matter of the distribution of electric charges and also in a much more important respect: it is in conflict with the electromagnetic theory of light.

The fact that this contradiction already existed and apparently could not be removed, provides perhaps a psychological explanation of the fact that someone hit upon the idea of propounding a theory like the one now accepted. It was the young Dane Bohr who carried things to a conclusion and laid down amongst his fundamental postulates that the electrons - in conflict with the current theory - do not radiate energy through their orbital motion. The electrons can only move in so-called stationary orbits, and energy is emitted or absorbed by the passing of an electron from one orbit to another. In accordance with Einstein's law, the exchange of energy between atom and radiation in such cases is always a quantum, forming the product of the frequency of the radiation with the Planck's constant, and the various stationary qualities that the atoms may possess are thus distinguished from one another by amounts of energy that form an integral number of Planck's quanta. This theory, which in the course of its development and accomplishment in the hands of a large number of investigators has attained a high degree of perfection, is supported experimentally by the fact that it is in accordance with important evidence concerning line spectra and the decomposition of spectral lines under the influence of magnetic and electric forces. For the merits thus indicated, both Planck and Einstein on the one hand, and also Bohr on the other, have been awarded the Nobel Prize for Physics.

As the chemical properties of the elements vary periodically with increasing atomic weight, while the characteristic X-radiation shifts continuously from element to element throughout the whole series, regardless of the chemical composition in which the element is used in exciting the radiation, it can be concluded already from Barkla's researches that the X-radiation must arise in the inner parts of the atom. Moseley's researches show again that the atomic number discovered by him in Bohr's atomic theory must give the number of free positive unit charges in the nucleus of the atom, that is to say also the number of electrons that move in the orbits when the atom is electrically neutral. In an element that can emit both K- and L-rays, the former radiation has much shorter wavelengths and consequently greater frequencies than the latter. As the energy quanta are proportional to the frequencies, therefore, the K radiation involves a larger change in the energy of the atom than the L radiation; and in the atomic theory this is as much as to say that an orbit into which an electron falls on emission of a K-line must lie nearer the nucleus than an orbit to which an electron falls on emission of an L-line. In this way it was inferred that there is a K-level nearest the nucleus, outside that an L-level, and after that an M-level and an N-level, all these four being experimentally determined. Further out hypothetical O- and P-levels have been assumed in the atomic scheme.

It is only through a consideration of these results that the importance of the discovery of the M- and N-series is fully realized. The value of Siegbahn's exact measurements and discoveries of new lines is best illustrated by the fact that they have formed the foundation of the work of a number of investigators, through which it has become evident that there are three different L-levels of energy, five M-levels, seven N-levels, and so on. The results of his measurements, in fact, form an immense material which is as yet far from being fully worked out, and which for a long time to come will probably remain the touchstone for future modifications or revolutions in atomic physics.

To this account of the most outstanding features of Siegbahn's work it will suffice to add that, partly alone and partly in collaboration with his pupils, he has made a number of other discoveries in the same subject. These include, for instance, an apparatus with which it is possible, by means of two X-ray exposures each lasting two hours, to make a qualitative analysis of an unknown substance and thereby find out all the elements in the substance extending from sodium with the atomic number 11 to uranium with the atomic number 92. And finally, also the refraction of X-rays in a prism, hitherto sought for with no less zeal than futility, has been demonstrated in his laboratory.Professor Siegbahn. Once before, a Swede, to the honour of his country, has won world-wide fame through exact determinations of wavelengths. It was Anders Jonas Ångstrom, who investigated the spectrum of light, and whose name survives as the denomination of the unit with which wavelengths are measured in this range of radiation. I now give expression to the pride of the Academy of Sciences in the fact, that once again a Swede, to the honour of his country, has gained a similar world-wide fame, and to her conviction that your work will always be inscribed in the history of the microcosm of the atom. It is a profound joy to us all that you have won this prize, which I now invite you to receive from the hands of His Majesty the King.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1924/press.html