THE NOBEL PRIZE CENTENARY IN PHYSICS

A.N. Dovbnya, V.A. Shendrik, A.A. Shendrik[1]
Scientific-Production Complex "Accelerator"
National Science Center "Kharkov Institute of Physics and Technology"
1, Akademicheskaya St., 61108 Kharkov, Ukraine
[1] Secondary School, Valki, Kharkov Region, Ukraine

The report is dedicated to the discovery of X-rays and their revolutionary effect on the formation and development of modern physics.

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On the 10th of 1901, in the Large Hall of the Academy of Music in Stockholm the Nobel Prize Committee awarded Roentgen with the first Nobel Prize in physics as a mark of gratitude of scientists and the mankind.

Wilhelm Konrad Roentgen was born in a small German town of Lennepe not far off from the Germany-Netherlands frontier. He devoted all his life to physics. Having become Professor of Physics, Roentgen gave lectures on physics at a number of institutes in Germany.

The physical experiment was in his element. Hardly anybody could be compared with him in thinking out the experiment, in the accuracy of measurements and in thoroughness of analyzing possible mistakes. Roentgen had already become famous among physicists of that time for his investigations in various areas. Thus, for example, in 1890, he was the first to prove by direct experiment that moving charges generate a magnetic field. At the end of the 19th century, W. Roentgen, Professor of the Wurzburg University in Germany, conducted experiments with electric discharge in gases. He used a glass tube having two electrodes soldered in it and pumped down to a pressure of about 10^{-5} of atmospheric pressure. When a high voltage was applied to the electrodes, the glass about the anode started glowing with a yellow-green light. This glow was attributed by physicists to the action of the so-called cathode rays, the flux of which was emitted by the cathode, and was incident on the anode and, partially, on the tube walls.

One November evening of 1895, when working in the laboratory, Roentgen hit upon an unusual phenomenon. For experiments, he wrapped the discharged tube with a black light-proof paper. It was dark in the room, and this allowed the scientist to notice that the barium salt crystals lying not far from the tube radiated a faint light. He deenergized the tube and the luminescence disappeared. Then Roentgen placed a barium salt-coated screen not far from the tube, and the screen started glowing. The scientist began placing different objects between the tube and the screen. Cardboard, paper, ebonite plates exerted no effect on the brightness of the glow. Metal subjects cast a shadow on the screen. Evidently, the tube was a source of unknown penetrating rays, X rays, as Roentgen called them, or Roentgen rays as we now call them.

The researcher put his hand in the path of X-rays, and a dark image of the hand skeleton appeared on the screen - soft tissues were transparent to the radiation, while the bones were nearly opaque to it.

A unique talent of physicist-experimenter, exceptional powers of observation, and a firm rule to attain clarity in everything permitted Roentgen to discover the phenomenon which had been for many years close by the scientists who made experiments using the same devices.

However, the character of this new radiation remained enigmatic. Only one thing was clear, i.e., the radiation could not be identified with the cathode rays. Similarly to the cathode rays, it gave rise to fluorescence, had a chemical action, propagated in straight lines, formed shadows. However, the X-rays did not have the characteristic properties of the cathode rays - they were not deflected by the magnetic field. Maybe they were of the same nature as the ultraviolet radiation was? But in that case they should be appreciably reflected, refracted, polarized.

Those were the questions (repeating an attempt to explain the nature of the rays), with which Roentgen finished his first work on X-rays, reported at the Physics Institute of the Wurzburg University in December, 1895.

The first article of the scientist "About a new kind of rays", where he described the properties of the radiation discovered by him, aroused an enormous interest throughout the world and was then published as a separate brochure in all European languages.

The second work reported on 5 March, 1896, comprised two new essential facts. The first was that under the action of X-rays the electrified bodies get discharged. It is not the X-rays themselves but the air penetrated by them that acquires the property to discharge the electrified bodies. The second important fact mentioned even in the first Roentgen′s work was that X-rays were produced with the cathode rays hitting not only the glass of discharge tubes, but also any substance, not excluding liquids and gases. Depending on the character of substance struck by the cathode rays, the intensity of the resulting X-radiation turned out to be different. Those observations brought Roentgen as early as in February, 1896, to the development of the "focus" tube, where a concave aluminum mirror served as a cathode and a platinum plate placed at the centre of curvature of the mirror and inclined at 45° to the mirror axis served as an anode. Before the advent of thermionic devices, the "focus tubes were the only setups to produce X-rays for medical and physical investigations. Roentgen did much to quickly promote his discovery, having rejected with his characteristic disinterestedness any possibility of making a profit from it. The general interest much contributed to a rapid progress of X-ray engineering. It will suffice to give only one example to illustrate the path covered: in 1896 the radiography of a hand took a 20 min exposure, while now an instant is sufficient for the purpose.

The physicists who held the viewpoint that X-rays were the electromagnetic radiation naturally tried to detect not the reflection but the diffraction on extremely narrow slits, as dictated by the supposed small value of X-ray wavelength. However, the man-made slits, no matter how narrow they were, appeared to be too rough. Besides, it was clear that it was difficult, if possible, to find the mechanical way of scribing rulings being well off at a distance of about a molecular size. In 1912, the German physicist M. Laue put forward a bold idea to use crystals as diffraction gratings for X-rays. In the same year, the theory was corroborated by experiments. In 1914, for the discovery of X-ray diffraction by crystals M. Laue was awarded the Nobel Prize in physics.

And yet, Roentgen could not explain the nature of enigmatic rays. He did not know about the existence of electrons, and it was their slowing down in the tube glass that was the reason for the appearance of X-rays and a greenish visible light. When a charged particle comes flying into the substance, it slows down, loses its velocity and emits electromagnetic waves. The X-radiation wavelengths range from $5 \cdot 10^{-8}$ to $5 \cdot 10^{-12}$ m. On the scale of electromagnetic waves they take the place between ultraviolet radiation and gamma-radiation. The beam of slowing down electrons emits waves of a wide diversity of wavelengths. These waves form a continuous X-ray spectrum. The wavelength which accounts for the maximum intensity of radiation should decrease as the electron velocity increases, i.e., as the tube voltage increases. Experiments have established the short wavelength boundary of the continuous X-ray spectrum $\lambda_{min} = 12390/U$, where λ_{min} is expressed in angstroms, and U - in volts.

The existence of the short wavelength boundary directly follows from the quantum nature of the radiation. Really, if the radiation arises at the expense of energy lost by the electron in its slowing down, then the quantum value $\hbar\omega$ cannot exceed the electron energy eU: $\hbar\omega \leq eU$. Hence it turns out that the radiation frequency cannot exceed $\omega_{max} = eU/\hbar$, and therefore, the wavelength cannot be smaller than $\lambda_{min} = 2\pi c/\omega_{max} = = 2\pi\hbar c/eU$. Thus we have arrived at the empirical relation given above. The $\hbar$ value found from these relations for the Planck constant is in good agreement with the values calculated in other ways. Of all the methods of determining $\hbar$ the method based on the measurement of the sort wavelength boundary of the continuous X-ray spectrum is believed to be most exact.

At a rather high electron velocity, apart from the continuous X-ray radiation (i.e., the radiation due to electron deceleration), the characteristic radiation is also excited (generated by excitation of inner electron shells of anticathode atoms). While the continuous X-radiation is independent of the anticathode material and is determined only by the energy of electrons bombarding the anticathode, the characteristic radiation is specified by the nature of substance, from which the anticathode is made. As long as the electron energy is insufficient to excite the characteristic radiation, only continuous X-ray radiation arises. At a sufficiently high energy of bombarding electrons, sharp lines of the characteristic spectrum appear against the background of the continuous X-ray spectrum, the intensity of these lines being many times higher than that of the background.

The characteristic X-rays were discovered in 1906 by the English physicist Ch. Barkla, and in 1917 he was also awarded with the Nobel prize in physics. In 1913, another English physicist H. Moseley established a simple law relating the frequency of spectral lines from the characteristic X-ray radiation to the ordinal number of the emitting element (Moseley law). The dependence established by Moseley allows one to determine exactly the atomic number of the given element from the measured wavelength of X-ray lines; it has played a great role in the arrangement of elements in the periodic system.

W. Roentgen devoted his life to classical physics. But it was his discovery of “a new type of rays” that was the starting point for the development of new physics - physics of atom and atomic nucleus. In less than half a year after the discovery of X-rays, in an attempt to puzzle out their nature the radioactivity was discovered, and a year later the electron was found with their use.

The discovery of X-rays had extremely important consequences for both scientific investigations and practical applications in medicine and industry. It will not be an exaggeration to say that from this discovery new present-day physics begins.