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Nobel Prize in Physics 1939

Ernest Orlando Lawrence

The Nobel Prize in Physics 1939 was awarded to Ernest Lawrence *"for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements"*.

RESEARCH INFORMATION:

In 1919 Lord Rutherford discovered that nitrogen can be brought to emit protons by bombardment with alpha particles, according to the nuclearreaction equation:

$$^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{17}_{8}O + ^{1}_{1}H$$

This discovery meant the initiation of a new era in natural sciences. However, as long as one was limited to the use of alpha radiation of naturally radioactive substances for carrying out nuclear reactions, very strict limits were set to further development both with regard to the substances which could produce these reactions, as well as to the quantitative yield of the reactions.

How then would it be possible, by some method other than the use of radioactive substances, to make available projectiles with sufficient energies to bring about nuclear reactions in an artificial way? Fortunately, the quantum-mechanical treatment of this problem, developed in the meantime, implied that the energy of the particles need not be as

high as might be expected from classical theories. Among all the proposals and experiments carried out in different quarters to produce sufficiently fast particles for nuclear experiments, those carried out at the Cavendish Laboratory on Rutherford's initiative were the first to yield a positive result (1932). In this case use was made of a high electrical voltage, up to about 600 kV, to accelerate protons which, upon bombarding lithium, caused a nuclear reaction:

$$^{7}_{3}\mathrm{Li} + ^{1}_{1}\mathrm{H} \longrightarrow 2 + ^{4}_{2}\mathrm{He}$$

Two years earlier (September, 1930), however, Lawrence had indicated an entirely new method to obtain fast particles, i.e. the so-called magnetic resonance acceleration. This method is based on a brilliant combination of a constant homogeneous magnetic field and an oscillating electrical field with constant frequency, whereby the ions move about in circular orbits with ever-increasing radii, through stepwise acceleration. The communication on the first simple experimental model of the "*cyclotron*" was published in the same year as the aforementioned experiment with artificially produced nuclear reactions at the Cavendish Laboratory. Under Lawrence's guidance and with the assistance of a large number of skilled collaborators the cyclotron method soon proved suitable for rapid development towards an exceptionally effective tool for research in this field. The energies of the particles, successively obtained by the further development of the cyclotron method, surpassed significantly that which had been obtained by other means. The maximum energy of the particles accelerated in the cyclotron even considerably exceeded the energy values present in alpha rays of naturally radioactive substances. While the latter energy is of the order of magnitude of 7 to 8 MeV, the energy of alpha particles supplied by the cyclotron is, according to latest reports (November, 1939), up to 38 MeV.

Experiments with heavy hydrogen nuclei as projectiles, with which Lawrence and his collaborators could produce nuclear reactions with practically all elements, proved to be particularly successful.

With regard to the intensities of the radiation produced in the cyclotron, it can be mentioned that a current of over 150 microamperes has been attained, corresponding to

the alpha radiation of *30 kg radium*. As a comparison it may be mentioned that the entire world stock of purified radium can be estimated at 1 kg.

With the powerful means given to nuclear research by the cyclotron, an explosive development took place in this field. Nowadays, cyclotron installations are built or planned in a large number of laboratories throughout the world. The number of publications on the results obtained with the use of cyclotrons has grown with the speed of an avalanche.

The greatest significance the cyclotron has had is in the production of artificially radioactive substances. True, the discovery of active isotopes was made by the Curie-Joliots in 1933 with the use of alpha particles from naturally radioactive substances, but only with the cyclotron was it possible to produce active isotopes in large quantities. This was, among other things, an essential condition for the use of active elements for biological and medical purposes. On this terrain, where such splendid achievements had already been made, a new field for research and practical applications has been opened, thanks to the cyclotron. To appreciate the strength of the radioactive sources produced for the last-mentioned purposes, the following data may be given. Using deuterium in his cyclotron Lawrence was able, already in 1936, to produce daily quantities of *active sodium*, which, with regard to gamma radiation, were equivalent to 200 mg radium. The later cyclotrons of larger dimensions (1939) have a production capacity of about 10 times this value. Finally, it may be mentioned that the cyclotron offers possibilities of producing neutron

of great intensity, as a result of which quantitative research on the physical and biological effects of this radiation has been carried out. With regard to therapeutic applications, these preliminary investigations are rather encouraging.

Within the history of the development of experimental physics, the cyclotron takes an exceptional position. It is, without comparison, the most extensive and complicated apparatus construction carried out so far. As to the scientific results achieved, we can scarcely find anything similar among the other experimental tools in physics. It is also evident that the operation and testing of an apparatus of this type, with such a multitude of details, cannot be the merit of one man alone. As promotor and leader of this almost

gigantic work, Lawrence has shown such merits in the field of physics that the Royal Swedish Academy of Sciences has considered him as having fulfilled to the highest degree the requirements implied in the award of the Nobel Prize*.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1939/press.html