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Nobel Prize in Physics 1936


Victor Franz Hess **Carl David Anderson**

The Nobel Prize in Physics 1936 was divided equally between Victor Franz Hess *"for his discovery of cosmic radiation"* and Carl David Anderson *"for his discovery of the positron"*.

RESEARCH INFORMATION:

The year 1895 is a turning-point in the history of physics: Röntgen discovered the rays that were to be called after him, and this was rapidly followed by Becquerel's discovery of radioactive radiation, and by the discovery of the negative electron - one of the fundamental elements of atomic structure.

Many research workers have made the radioactive rays discovered by Becquerel the subject of their investigations, starting with the Curies, husband and wife, who discovered the substance radium; these investigations have now come to a natural termination in the discovery by the Joliot-Curies, that normal atoms can be made radioactive by external influences.

The existence of a new, peculiar type of radiation, i.e. cosmic radiation, for the discovery of which Professor Victor Hess will today receive the Nobel Prize for Physics, became manifest during the search for sources of radioactive radiation. A few words on the nature of radioactive radiation may not come amiss. This radiation occurs during the explosion within the atomic nuclei of certain substances of instable structure. As is general knowledge, the rays derive their name from one of these substances, i.e. radium. In the event of an explosion in the atom, parts of the atom are ejected in all directions. The resulting rays are therefore bound to contain heavy, positively charged parts of the nucleus of the atom, and extremely light, negatively charged electrons on the periphery of the atom. When the energy in the atom is liberated, there occurs, apart from these two types of rays, a strong radiation, the so-called gamma rays, which are of the same nature as X-rays. During this explosion of the atom, other elements are formed by it. One element is therefore changed into another. The presence of radioactive rays can be detected from the circumstance that the emitted rays split the molecules of the air into positive and negative components and render the circumambient air electrically conductive, i.e. ionize it. An instrument that is electrically charged, e.g. an electroscope, will therefore lose its electrical charge when it is surrounded by air exposed to radioactive radiation. The instrument can on the other hand be protected against such radiation by being encased in lead plates of sufficient thickness.

During the years that followed the discovery of radioactive rays a search was made throughout nature for radioactive substances: in the crust of the earth, in the seas, and in the atmosphere; and the instrument just mentioned - the electroscope - was applied. Radioactive rays were found everywhere, whether investigations were made into the waters of deep lakes, or into high mountains. The most surprising discovery that was made was that it was impossible to eliminate the influence of the rays, no matter how thick were the lead plates that encased the instrument. This was inexplicable if the rays were to emanate from radioactive substance in the earth or from the atmosphere, and research workers were therefore compelled to the assumption that there exists another source of radiation unknown to us, with rays of immense powers of penetration.

In searching for this new source of radiation, it was obvious to investigate whether radiation decreased at high levels above the earth's surface. Such experiments were done by various research workers, including some on the Eiffel Tower. The experiments showed

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some decrease of radiation with increasing distance from the earth's surface, but not at the rate to be expected if radiation emanated from the earth. Observations were extended to greater heights by balloon ascents. In ascents to a height of 4,500 m a slight decrease with height was observed in some cases, but in other cases, ionization remained practically unchanged.

Although no definite results were gained from these investigations, they did show that the omnipresent radiation could not be attributed to radiation of radioactive substances in the earth's crust.

The mystery of the origin of this radiation remained unsolved until Prof. Hess made it his problem. Hess who was from the start of the opinion that the radiation was due to very powerful gamma rays, first investigated in detail the manner in which such rays are weakened on passing through dense layers of air. The sources of error in the instruments used were also investigated. With superb experimental skill Hess perfected the instrumental equipment used and eliminated its sources of error. With these preparations completed, Hess made a number of balloon ascents to heights up to 5,300 m, in 1911 and 1912. His systematic measurements showed that a decrease in ionization did occur up to 1,000 m, but that it increased considerably thereafter, so that at 5,000 m radiation was twice as intensive as on the earth's surface. Later ascents and investigations made by successors of Hess in free balloons equipped with recording instruments showed that at a height of 9,300 m radiation is about 40 times as intensive as on the earth's surface. From these investigations Hess drew the conclusion that there exists an extremely penetrating radiation coming from space which enters the earth's atmosphere. This radiation which has been found to come from all sides in space has been called cosmic radiation. Hess's investigations naturally aroused much interest and were received with much scepticism by many. No regular investigations into cosmic rays were carried out during the World War, but once war was over, investigations were resumed with enthusiasm both in Europe and in the USA, and before long the existence of cosmic radiation was generally accepted.

The new rays surpass in intensity and penetrating power everything previously known. They are capable of penetrating lead plates one metre thick and they have been detected on the floor of lakes with a depth of 500 m. The big question is: where does this radiation come from? During his first balloon ascents Hess observed that there was no particular difference between night and day, and no special influence either was detected in a balloon ascent during a solar eclipse. Cosmic radiation could not therefore originate in the sun.

At a later date Hess made extremely sensitive systematic measurements of the rays and found that they varied in one and the same place during the daily rotation of the earth with the position of the place relative to the fixed stars. The variation is small, only 0,1%. Meanwhile, Compton has shown theoretically that this change may be due to the motion of the sun and therefore of the earth in space. Being part of the galaxy, the solar system participates in the rotation of the galaxy, which imparts to the earth a velocity of about 300 km per second. The earth's motion results in an apparent increase in cosmic radiation, from the side towards which the earth moves, and in an apparent attenuation on the other side. Compton's calculations give the correct figure, from which the conclusion has been drawn that cosmic radiation does not come from our galaxy either, but from stellar systems far beyond it.

We still do not know what processes out in the deep fastnesses of space give rise to this radiation. Many theories have been put forward, but no one has yet been able to provide any detailed explanation of how these rays - over a thousand times more powerful than the strongest radioactivity - come into being. When in the years to come the mysteries thus posed by cosmic radiation have been completely or partially solved, this will surely shed new light on the interaction between energy and matter, and on the origin and disintegration of matter.

Professor Hess. By virtue of your purposeful researches into the effects of radioactive radiation carried out with exceptional experimental skill you discovered the surprising presence of radiation coming from the depths of space, i.e. cosmic radiation. As you have proved, this new radiation possesses a penetrating power and an intensity of

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previously unknown magnitude; it has become a powerful tool of research in physics, and has already given us important new results with respect to matter and its composition. The presence of this cosmic radiation has offered us new, important problems on the formation and destruction of matter, problems which open up new fields for research. We congratulate you on your fine achievements

For your discovery of cosmic radiation, the Royal Academy of Sciences has awarded you the Nobel Prize for Physics, and I now call upon you, Professor Hess, to receive the award from the hands of His Majesty the King.

The experimental discovery of the positive electron, for which discovery Dr. Anderson receives today the Nobel Prize, has such an intimate relation to the cosmic radiation that I must take the liberty to touch once more upon this subject. After the existence of cosmic radiation had been clearly stated there arose the question of the nature of this radiation. On an earlier occasion this day I have had the opportunity of mentioning the various kinds of rays emanating from an atom of a radioactive substance, when this atom explodes. It has been stated that these rays consist partly of heavy, positively charged particles from the nucleus of the atom, partly of light, negative electrons, and finally of so-called gamma rays, which are of the same nature as X-rays and light rays although with an exceedingly short wavelength, and for this reason possessing great penetrating power. The two first kinds of rays, which consist of charged particles, have come to be called corpuscular rays. The question now arose, whether the cosmic radiation was a corpuscular radiation or whether it consisted of gamma rays. It was obvious, in order to settle this question, to examine the rays when passing between the poles of a powerful magnet. In the case that the rays consisted of charged particles, their paths would be changed by the magnetic field in different directions for various kinds of charge. If, on the other hand, they consisted of gamma rays, they would experience no influence from the magnetic field. An excellent instrument for the investigation of the nature of the rays is the Wilson chamber, which consists of a closed vessel filled with supersaturated steam. On account of the condensation caused by the passage of a ray, the path of the ray becomes visible to the eye and can be photographed. The first experiments carried out by means of a magnetic field showed, however, no deviation of the rays. But the high energy which the rays possess requires very strong magnetic fields to produce visible effects. Meanwhile investigations carried out along quite other lines had indicated the probability of the cosmic rays being corpuscular rays. The earth itself is a magnet and above all a big one. It has long been known that a corpuscular radiation consisting of negative electrons emanates from the sun. As Störmer has shown the rays are caused to deviate from the earth by its magnetic field. It is only at the magnetic poles, where the rays have the same direction as the magnetic force, that the rays can penetrate into the atmosphere of the earth, where they give rise to the phenomena called polar lights. On the other hand, the cosmic rays have a much greater penetrating power than the rays from the sun and therefore everywhere make their way down to the surface of the earth. It ought then to be expected that, owing to the influence of the magnetic field of the earth, a certain difference of the intensity of the radiation at the poles and at the equator should be noticeable. To demonstrate this Professor Clay in Amsterdam had, already in 1929, carried out comparative measurements of the cosmic radiation in Holland and Java, and these measurements have shown a distinct latitude effect. It might be mentioned, incidentally, that according to later investigation this effect increases considerably with increasing height above the earth. In order to be able to study more in detail the nature of cosmic radiation Millikan decided to set up, in his institute at Pasadena, an installation for experiments on a large scale containing, among other things, a Wilson chamber equipped with very strong magnets. The planning and direction of the experiments Millikan entrusted to Dr. Anderson. When some years later the installation was ready, the cosmic radiation was recorded day and night every 15 seconds. The result of the rich material thus collected was published in 1931. Upon examination of the photographs there were found, besides the curved paths of negative electrons, also paths deviating in the opposite direction, which accordingly should be attributed to positively charged particles. These paths could as a rule be interpreted as being traces of heavy nuclear residues. On one of the photographs, however, Dr. Anderson found a path with positive deviation, to which this interpretation was not applicable. Owing to their greater weight the nuclei maintain their rectilinear path better than the light electron. The peculiarity is that the path found by Dr.Anderson showed the same deviation as the negative electrons, but in the opposite direction. The most plausible interpretation was to suppose that this was the path of a positive electron with the same mass as the negative one. Previously Dirac had found by theoretical investigation that the equations which determine the electromagnetic field require the existence of such light positively charged particles of the same size as the negative electrons. Since, however, no such particles had been found Dirac formulated the hypothesis that it might be that in other parts of the universe positive and negative charge were reversed. Dr. Anderson now pursued his investigations, introduced certain improvements of the equipment and after having carried out verifying experiments and new measurements he was able to furnish, in the summer of 1932, clear evidence of the existence of the positive electron. The positron Dirac had been searching for was thus found. Now the traces of ray paths appearing in the Wilson chamber could either be due to the cosmic radiation itself or to secondary rays in the chamber or the walls of the chamber caused by rays which, coming from outside, had collided with atoms which were thereby split up into their constituents. It was therefore not yet possible to come to the conclusion that the cosmic rays in part or entirely consisted of charged particles. Several scientists and among them also Dr. Anderson found that the gamma radiation from a radioactive substance containing thorium could release, by interaction, positive as well as negative electrons. The peculiar thing is that then there is often formed a twin pair of electrons consisting of one positive and one negative electron. In this case particles are thus created by the influence of pure radiation energy. It has likewise been found that a positive and a negative particle disappear when united, the only trace left being radiation passing away in every direction.

During these later years an intensive scientific research programme has been carried out concerning the nature and qualities of cosmic radiation. To this work Dr. Anderson has made important contributions. Thus it has been shown that the cosmic radiation consists to a large extent of corpuscles which with enormous energy and velocity enter the atmosphere from all parts of the universe. Positive and negative electrons exist in this radiation in about the same quantities, but the positive electrons soon disappear after having entered the atmosphere, because they coalesce with the atoms. Dr. Anderson has studied the distribution of energy in the cosmic radiation and the loss of energy sustained when it passes through matter

Doctor Anderson. In the course of your comprehensive studies on the nature and qualities of cosmic radiation you have made important and material contributions to the elucidation of the questions involved, and by utilizing ingenious devices you have succeeded in finding one of the buildingstones of the universe, the positive electron. We congratulate you on this great success attained in your young years and we wish to express the hope that your further investigations will bring to science many new and equally important results.

For your discovery of the positron the Royal Swedish Academy of Sciences has awarded you the Nobel Prize in Physics, and I now request you to receive the prize from the hands of His Majesty.

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