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Abstract: Background information on twentieth century Danish physicist Neils Bohr is presented. The author reviews how Bohr received the Nobel Prize in Physics in 1922 for his work on creating a model of atomic structure. Bohr's theory that electrons orbit an atom's nucleus formed the foundation of quantum mechanics. Information of Bohr's birth and early life is presented.

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Niels Bohr

Background

Twentieth century Danish physicist Niels Bohr received the Nobel Prize in Physics in 1922 for his work on creating a model of atomic structure. His theory that electrons orbit an atom's nucleus formed the foundation of quantum mechanics. The chemical element bohrium is named for him.

Niels Henrik David Bohr was born in Copenhagen on October 7, 1885. Niels' father, Christian Bohr, was a doctor, scientist, and a Nobel Prize nominee. His mother was from a family of educators. Niels was a good student, and one of his boyhood projects won him a gold medal from Copenhagen's Academy of Sciences.

In 1903, Bohr entered Copenhagen University. He studied under physicist Christan Christansen, and received his Ph.D. in physics in 1911. While writing his thesis on the electron theory of metals, he first came across Max Planck's early quantum theory of radiation. The theory described energy as small parcels, or quanta.

Bohr went to England to work for J.J. Thompson, who had won the Nobel Prize in 1906 for his discovery of the electron. During his time there, Bohr met Lord James Rutherford, who had discovered the nucleus and developed a model of the atom. Under Rutherford, he studied the properties of atoms. Combining Rutherford's description of the nucleus and Planck's early ideas about quantum theory, Bohr explained what happens inside an atom and developed a picture of atomic structure.

In 1920, Bohr became the head of the Institute for Theoretical Physics at Copenhagen University. At the institute, he explored the structure of atomic nuclei and the changes that take place within them. Copenhagen became a world center for the study of quantum mechanics. The institute he headed is now named for him, and he helped found CERN, central Europe's particle physics research laboratory.

Beginning in the 1920s, Niels Bohr and Albert Einstein often discussed quantum theory. Einstein did not agree with Bohr, and attempted to disprove the new theory. Bohr and Einstein debated the meaning of quantum theory for the rest of their lives.

Through the early 1920s, Bohr concentrated his efforts on two interrelated sets of problems. He tried to develop a consistent quantum theory that would replace classical mechanics and electrodynamics at the atomic level. He also tried to explain the structure and properties of the atoms of all the chemical elements.

In 1939, Bohr visited the United States with the news that German scientists were working on splitting the atom. This prompted the United States to launch the Manhattan Project to develop the atomic bomb.

During World War II, Germany occupied Denmark. When Bohr learned in 1943 that he was to be arrested by the Nazis, he escaped. He lived in England and America for the remainder of the war; during this period, he contributed to the development of the first atomic bomb.

In 1912, Bohr married Margrethe Nørlund. One of their six sons, Aage, followed his father as director of the Institute for Theoretical Physics. He won a Nobel Prize in 1975, fifteen years after his father's death in Copenhagen on November 18, 1962.

The Atomic Model

The Bohr model shows the atom as a small, positively charged nucleus surrounded by orbiting electrons. Bohr discovered that electrons travel in separate orbits around the atom's nucleus, and that the number of electrons in the outer orbits determines the properties of the elements. He established that an electron could drop from a higher-energy orbit to a lower one, giving off energy in the process.

Bohr targeted the simplest atom of all, hydrogen. Hydrogen atoms radiate at certain frequencies, and Bohr looked for a formula to explain this. He found that an electron dropping from one energy level to another created the frequency. The difference between the electron's beginning and ending energies was released as quantum energy. His discovery accurately explained the physical and chemical properties of the elements.

Bohr based his work on that of Ernest Rutherford, who had suggested that the atom has a miniature, dense nucleus surrounded by electrons. If this were true, the electrons orbiting the nucleus would lose energy until they spiraled down into the center, collapsing the atom.

Bohr suggested adding Max Planck's new idea of quanta (small parcels of energy) to the model. Planck had found that the energy radiated from a heated body is exactly proportional to the wavelength of its radiation. The wavelength equals the energy times a number called Planck's constant.

According to Bohr's model, electrons existed at set levels of energy and fixed distances from the nucleus. If the atom absorbed energy, the electron jumped to a level further from the nucleus; if it gave off energy, it fell to a level closer to the nucleus.

This solution explained the series of lines observed in the spectrum of light emitted by atomic hydrogen. Bohr was able to predict the frequencies of these spectral lines using the charge and mass of the electron and Planck's constant. Bohr also proposed that an atom would not emit radiation while it was in one of its stable states, but only when it changed states. The frequency of the radiation given off would be equal to the difference in energy between those states divided by Planck's constant. This meant that the atom could neither absorb nor emit radiation continuously, but only in quantum jumps.

Liquid Droplet Theory and Complementarity

In 1936, Bohr developed the liquid droplet theory, which said that a liquid drop could give an accurate representation of an atom's nucleus. When other scientists split the uranium atom three years later, the droplet theory helped explain nuclear fission.

Bohr's liquid drop model treats the nucleus as a drop of nuclear "fluid." Because nuclei seem to have almost constant density, the nuclear radius can be calculated by using that density in the same way that one would if the nucleus were a drop of a uniform liquid. A liquid drop model of the nucleus explains why the force on the surface nucleons is different from the force on nucleons on the inside, by comparing the force to the surface tension of a drop of fluid. In this case, the fluid is made of nucleons and is held together by the strong nuclear force. Nucleons collide frequently with each other in the nuclear interior, and their activity resembles the movement of the molecules in a drop of liquid.

This model also explains the spherical shape of most nuclei, and helps predict the results of nuclear fission by comparing the energy necessary to change the shape of the drop to the energy added by a neutron joining the nucleon. If the energy is great enough, the drop breaks apart, resulting in fission. When uranium fission was discovered, the first interpretation of this new process was based on Bohr's liquid drop model.

Bohr's theory of complementarity says that an electron can be viewed two ways, either as a particle or as a wave, but never as both at the same time. In either case, according to Bohr, physics depends on measurement, and guesses beyond measurement cannot be proven. For example, the question "where was the particle before I measured its position?" cannot be answered.

Even while working on the first atomic bomb, Bohr worried about the danger of nuclear weapons after the war. He thought that sharing scientific information between countries would help control the threat of misuse of these weapons. He felt that if countries shared their research and avoided secrecy, many of the political and ethical problems associated with nuclear energy could be avoided.

Bohr, along with J. Robert Oppenheimer and other scientists, came to believe that a nuclear arms race was virtual suicide, and that there must be some kind of central regulation of nuclear power. In his letter to the United Nations in June 1950, Bohr stressed the importance of international cooperation in developing the potential of atomic energy for peaceful purposes.

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By Bob Crepeau

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