Niels Henrik David Bohr

Born: 7 Oct 1885 in Copenhagen, Denmark
Died: 18 Nov 1962 in Copenhagen, Denmark

Niels Bohr's father was Christian Bohr and his mother was Ellen Adler. Christian Bohr was awarded a doctorate in physiology from the University of Copenhagen in 1880 and in 1881 he became a Privatdozent at the university. Late in the same year he married Ellen, who was the daughter of David Adler, a Jewish politician with a high standing in Danish political and commercial life. Christian and Ellen had three children. The eldest was Jenny born in 1883 in the mansion which David Adler had owned opposite Christiansborg Castle where the Danish Parliament sat. Ellen's mother had continued to live in this house after her husband David Adler died in 1878 and Ellen had gone back to her mother's home to have her child. Two years later Niels was born on his mother's 25th birthday in the same stately home, Ellen again having returned to her mother's house for the birth of her child. The third child of the family, who went on to become a famous mathematician, was Harald Bohr who was two years younger than Niels.

When Niels was only a few months old his father Christian had been appointed as a lecturer to fill a post left vacant by the death of Peter Panum, the professor of physiology at the University of Copenhagen, and a short while later the family moved into the Panum's professorial house in Copenhagen.

Kennedy writes in [5]:-

Niels, Harald, and their older sister, Jenny, grew up in a cultured and stimulating home. From their earliest days they were exposed to a world of ideas and discussion, of conflicting views rationally and good-temperedly examined, and they developed a respect for all who seek deeper knowledge and understanding.

In October 1891 Niels entered the Grammelholms school. He attended this school, as did his brother Harald, for his complete secondary education taking his Studenterexamen in 1903. He did well at school without ever being brilliant, usually coming third or fourth in a class of about 20 students. If he really excelled at a subject it was, perhaps surprisingly, physical education. He was an excellent soccer player, yet not as good as his brother Harald who won a silver medal playing soccer for Denmark. Niels made some good friends while at school but his best friend throughout his life was his brother Harald.

During his last two years at school Niels specialised in mathematics and physics. There is certainly some evidence that he soon realised that the mathematics teacher did not have as good a grasp of the topic as he should have had, and that he became somewhat frightened of his exceptional pupil Bohr. In physics too Bohr studied texts ahead of the class finding errors in them. It was his father, more than his school teachers, who inspired him in his studies of mathematics and physics. He wrote in 1922:-

My interest in the study of physics was awakened while I was still in school, largely owing to the influence of my father.

Bohr studied at the University of Copenhagen which he entered in 1903. He studied physics as his main subject but took mathematics, astronomy and chemistry as minor subjects. He was taught physics by Christian Christiansen and philosophy by Harald Hoffding. He had known both of them for many years since they were close friends with his father and had met as part of a regular discussion group, with both brothers Niels and Harald Bohr taking part as soon as they were old enough to contribute. Bohr was taught mathematics at university by Thorvald Thiele.

At university Bohr could not carry out physics experiments since there was no physics laboratory. However his father had a physiology laboratory and his first paper describes experimental work in physics which he carried out in that laboratory. He dictated the paper to his brother Harald. A fellow student wrote of Niels and Harald:-

The two are inseparable. I have never known people to be as close as they are.

This paper is the only one that Bohr wrote describing experiments which he had carried out. With it he won the Gold Medal for 1906 from the Royal Danish Academy of Sciences for his analysis of vibrations of water jets as a means of determining surface tension. He received his Master's degree from the University of Copenhagen in 1909 and his doctorate in May 1911 for a thesis entitled *Studies on the electron theory of metals.* It was a thesis based on classical physics and as such necessarily failed to explain certain effects. Bohr wrote in this work:-

It does not seem possible at the present stage of the development of the electron theory to explain the magnetic properties of bodies from this theory.

Bohr dedicated his thesis to the memory of his father who had died from a heart attack a few months earlier in February 1911. By this time Bohr was engaged to Margrethe Norlund. The pair married on 1 August 1912 and Richard Courant, speaking after Bohr's death, had this to say of their marriage:-

Some people have speculated about the lucky circumstances which combined to make Niels so successful. I think the ingredients of his life were by no means matters of chance but deeply ingrained in the structure of his personality ... It was not luck, rather deep insight, which led him to find in young years his wife, who, as we all know, had such a decisive role in making his whole scientific and personal activity possible and harmonious.

Bohr applied to the Carlsberg Foundation for a travel grant in May 1911 and, after the award was made, went to England in September 1911 to study with Sir J J Thomson at Cambridge. He had intended to spend his entire study period in Cambridge but he did not get on well with Thomson so, after a meeting with Ernest Rutherford in Cambridge in December 1911, Bohr moved to the Victoria University, Manchester (now the University of Manchester) in March 1912. The timing was very fortuitous since shortly before Bohr and Rutherford met, Rutherford had published a major work showing that the bulk of the mass of an atom resided in the nucleus.

In Manchester Bohr worked with Rutherford's group on the structure of the atom. Rutherford became Bohr's role model both for his personal and scientific qualities. Using quantum ideas due to Planck and Einstein, Bohr conjectured that an atom could exist only in a discrete set of stable energy states. Remarkable evidence exists today of Bohr's scientific progress since he corresponded frequently with his brother Harald. He wrote to Harald on 12 June 1912:-

You can imagine it is fine to be here, where there are so many people to talk with ... and this with those who know most about these things; and Professor Rutherford takes such a lively interest in all that he believes there is something in. In the last years he has worked out a theory of the structure of atoms, which seems to be quite a bit more firmly founded than anything which has existed up to now.

A week after writing this letter, on 19 June, Bohr was reporting progress to Harald:-

Perhaps I have found out a little about the structure of atoms. Don't talk about it to anyone, for otherwise I couldn't write to you about it so soon. ... You understand that I may yet be wrong; for it hasn't been worked out fully yet (*but I don't think its wrong*). *... Believe me, I am eager to finish it in a hurry, and to do so I have taken a couple of days off from the laboratory* (*this is also a secret*).

By the 13 July he wrote:-

Things are going rather well, for I believe I have found out a few things; but, to be sure, I have not been so quick to work them out as I was stupid to think. I hope to have a little paper ready and to show it to Rutherford before I leave, and I therefore am so busy, so busy.

Although Rutherford and Bohr had completely different personalities, they shared an enormous enthusiasm for physics and they also liked each other personally. However the relationship was never quite that of close friends since Bohr always saw Rutherford as his teacher. They corresponded from the time they met in 1911 until 1937, the year of Rutherford's death.

On 24 July 1912, with his paper still unfinished, Bohr left Rutherford's group in Manchester and returned to Copenhagen to continue to develop his new theory of the atom, completing the work in 1913. The same year he published three papers of fundamental importance on the theory of atomic structure. The first paper was on the hydrogen atom, the next two on the structure of atoms heavier than hydrogen. In these papers Bohr [5]:-

... set out his startling attempt to combine aspects of classical physics with the concept of Planck's quantum of action. ... The three famous papers ... formed the foundation of Bohr's early reputation. His work, although not immediately accepted by everyone, intrigued his contemporaries and made them aware of the need for a new way of describing events at atomic level. The Bohr atom, although it has been superseded scientifically, persists even today in the minds of many people as a vivid image of what atoms look like and a symbol of physics.

In July 1913 Bohr was appointed as a docent in Copenhagen. However it was not a situation which pleased him since he could not pursue the style of mathematical physics which he was developing. On 10 March 1914 he wrote to the Department of Educational Affairs:-

The undersigned takes the liberty of petitioning the department to bring about the founding of a professorship in theoretical physics at the university and in addition to possibly entrust me with that position.

It was a bold move but Bohr's already high reputation meant that he would be taken seriously. The Faculty of the University recommended him for a chair of theoretical physics but the Department of Educational Affairs decided to delay confirming the post. Of course in 1914 times were uncertain and Bohr realised that no quick decision was likely. He therefore was delighted to accept an offer by Rutherford to join his Manchester group as Schuster Reader. He expected to be in Manchester for a year, anticipating that his chair of theoretical physics in Copenhagen would be confirmed by then. The outbreak of World War I while he was on holiday in the Tyrol before travelling to Manchester made his journey extremely difficult, but he and his wife arrived in Manchester in October 1914 having sailed round the north of Scotland through severe storms on their way.

Bohr was in Manchester longer than he expected since his chair was not confirmed until April 1916. However, it was a very productive and happy period. Pais writes in [13]:-

In the early summer of 1916 *the Bohrs returned to Denmark. Four years earlier Bohr had left Manchester full of exciting but undigested ideas about the atom. Now he departed as the master of that field, professor in Copenhagen, his wife who was expecting their first child at his side.*

In 1917 Bohr was elected to the Royal Danish Academy of Sciences and he began to plan for an Institute of Theoretical Physics in Copenhagen. This was created for him and, from its opening in 1921, he became its director, a position he held for the rest of his life [3]:-

That Institute soon became a Mecca for theoretical physicists from all over the world, and after 1933 *a refuge for a good many scientists who had fled from Hitler's Germany. Their social centre was the mansion "Gamle Carlsberg", given to the nation by the founder of the well-known brewery and placed at Niels Bohr's disposal in* 1932. *Here, under the motherly care of Bohr's beautiful wife, Margrethe ... students and scholars of all nations gathered to eat and talk and listen to music, and often to sit quite literally at the feet of Bohr, trying to catch his challenging remarks, subtle comments and gentle jokes, spoken in his soft Danish voice.*

Bohr is best known for the investigations of atomic structure referred to above and also for work on radiation, which won him the 1922 Nobel Prize for physics. He gave a lecture on the work for which he was awarded the Prize on 11 December 1922 in Stockholm. He talked of atomic stability and electrodynamic theory giving an account of the origins of quantum theory, the hydrogen spectrum, explaining the relationships between the elements. His explanation covered the absorption and excitation of spectral lines and the correspondence principle which he had set out in three papers *On the quantum theory of spectra* between 1918 and 1922.

In 1923 Bohr summed up the ideas:-

Notwithstanding the fundamental departure from the ideas of the classical theories of mechanics and electrodynamics involved in these postulates, it has been possible to trace a connection between the radiation emitted by the atom and the motion of the particles which exhibits a far-reaching analogy to that claimed by the classical ideas of the origin of radiation.

Quantum mechanics may be said to have arrived in 1925 and two years later Heisenberg stated his uncertainty principle. In a meeting at Como in north Italy in September 1927 Bohr put forward his principle of complementarity which gave a physical interpretation of Heisenberg's uncertainty relations. He proposed complementarity of perceptions and pictures, particle-wave, conjugate variables, quantum evolution - classical measurements etc. as a fundamentally new interpretation of the foundations of quantum theory. Bohr's ideas on complementarity are fully explored in [30].

Bohr thought that his idea of complementarity could play an important role in fields other than quantum physics and he worked on these ideas throughout the rest of his life. He considered applications to biology, psychology and epistemology. It has been suggested that the idea of complementarity came from outside physics, some arguing that the roots of the idea came from the discussions with his father, Christiansen and the philosopher Hoffding when he was still at school. Others, such as Pais in [13], give convincing arguments to show that Bohr was not knowingly influenced by Hoffding's philosophy.

It was Bohr's view of quantum theory which was eventually to become accepted. Einstein expressed grave doubts about Bohr's interpretation and Bohr, Einstein and Ehrenfest spent many hours in deep discussion, but Bohr's view prevailed. Bohr expressed this view saying:-

Evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary in the sense that only the totality of the phenomena exhausts the possible information about the objects.

H B G Casimir wrote describing what it was like working with Bohr in his Institute:-

Even Bohr who concentrated more intensely and had more staying power than any of us, looked for relaxation in crossword puzzles, in sports, and in facetious discussions.

Bohr's other major contributions, in addition to quantum theory, include his theoretical description of the periodic table of elements around 1920, his theory of the atomic nucleus being a compound structure in 1936, and his understanding of uranium fission in terms of the isotope 235 in 1939.

In 1937 Bohr, his wife and their son Hans, made a world tour. They travelled to the United States, Japan, China, and the USSR. In the same year he attended Rutherford's funeral in Westminster Abbey in London, giving a moving speech:-

When I first had the privilege of working under his personal inspiration he was already a physicist of the greatest renown, but nevertheless he was then, and always remained, open to listen to what a young man had on his mind. ... The thought of him will always be to us an invaluable source of encouragement and fortitude.

Bohr, although he had been christened in the Christian Church, had Jewish origins on his mother's side and so, when the Nazis occupied Denmark in 1940, his life became exceeding difficult. He had to escape in 1943 by being taken to Sweden by fishing boat. From there he was flown to England where he began to work on the project to make a nuclear fission bomb. After a few months he went with the British research team to Los Alamos in the United States where they continued work on the project.

However Bohr was deeply concerned about the control of nuclear weapons and from 1944 he tried to persuade Churchill and Roosevelt for the need to have international cooperation. He wrote a public letter to the United Nations in 1950 arguing for rational, peaceful atomic policies:-

Humanity will be confronted with dangers of unprecedented character unless, in due time, measures can be taken to forestall a disastrous competition in such formidable armaments and to establish an international control of the manufacture and use of powerful materials.

Bohr's son Aage also became a physicist and shared the Nobel prize for Physics in 1975. (This is just one instance of famous scientists in the same family. Others are the Van Vlecks as well as the Braggs and Madame Curie and her daughter Irene Joliot.)

Bohr received the first U.S. Atoms for Peace Award in 1957. He died from a heart attack in his home in 1962 and following this scientists and leading figures world-wide joined in paying tributes to him. President Kennedy wrote (see for example [53]):-

American scientists, indeed all American citizens who knew Doctor Bohr's name and his great contributions, have respected and venerated him for more than two generations ...

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