American National Biography

Mayer, Maria Gertrude Goeppert (28 June 1906-20 Feb. 1972), physicist, was born in Kattowitz, Germany (now Katowice, Poland), the daughter of Frederich Goeppert, a pediatrician, and Maria Wolff. Maria Goeppert grew up in the university town of Gottingen, Germany, where her father became a professor of pediatrics at the University of Gottingen in 1910. With his encouragement, she became interested in science and mathematics at an early age and enrolled in the same university in 1924 to study mathematics.

Gottingen in the 1920s was one of the world's best universities, boasting of such great mathematicians and physicists as David Hilbert, Max Born, and James Franck. In 1927 Maria Goeppert switched from mathematics to theoretical physics after attending Born's seminars. With Born she studied the exciting new quantum mechanics that was being developed by Werner Heisenberg and Born himself. She spent one term in 1928 in England at Cambridge University, where she not only improved her English but also attended lectures by the great experimental physicist Ernest Rutherford. In 1930 she completed her dissertation under Born on a theory of the double photon process--the probability of the emission of two light quanta in a single atomic transition--and received her Ph.D. from Gottingen. The same year she married Joseph E. Mayer, an American chemical physicist who had come to work with Franck, and together they moved to Baltimore, where he accepted an appointment in chemistry at the Johns Hopkins University. She became a U.S. citizen in 1933 and gave birth to two children.

Because of nepotism rules and the traditional emphasis on experimental physics at American universities, Maria Mayer, a theoretician, received only a nominal appointment as a "volunteer associate" at Johns Hopkins. Nevertheless, with support from her husband and other faculty members, especially theoretical physicist Karl mechanics to chemical physics, the solid state, and other subjects. For several summers she also went back to Gottingen to work with Born. Later when Franck joined Johns Hopkins, and Edward Teller, another friend from the Gottingen days, came to George Washington University in nearby Washington, D.C. she renewed collaboration with them, too. At Johns Hopkins, she also had her first graduate student, Robert G. Sachs, with whom she studied the new nuclear physics and published a joint paper on the subject in 1938. She impressed her students with both her ability to use mathematics to solve physical problems quickly and her "well organized, very technical, and highly condensed" (Sachs, pp. 316-17) occasional graduate lectures.

In 1940 the Mayers went to Columbia University, where Joseph Mayer became associate professor of chemistry. The same year they completed a book, Statistical Mechanics. Maria Mayer received no offer from Columbia, although Harold Urey, head of the chemistry department, asked her to give some classes as a lecturer. Mayer continued her research in physics, now with the support and guidance of Enrico Fermi, a pioneer in modern physics who was then at Columbia. At Fermi's suggestion, Mayer fruitfully investigated the chemical properties of several transuranium elements through the use of quantum mechanics.

Like many other American women, Mayer was employed in a real job for the first time during World War II. In December 1941 she began to teach, part time, a science course at Sarah Lawrence College in Bronxville, near New York. Then in the spring of 1942 she took another part-time job in Urey's Substitute Alloy Materials Laboratory at Columbia, which, as part of the Manhattan Project, was aimed at separating uranium 235 from natural uranium for the making of the atomic bomb. In this work she made ample use of her expertise in chemical physics. She first explored, with a team of scientists, the possibility of separating isotopes such as U-235 by photochemical reactions, which proved not very promising (at least not until the invention of the laser in the 1960s). She then studied the thermodynamic properties of uranium hexafluoride for the gaseous diffusion and photochemical separation

Teller on problems related to the development of the thermonuclear weapon, entailing a stay of several months in Los Alamos, New Mexico.

In February 1946 the Mayers moved again, to the University of Chicago, where Joseph Mayer assumed professorships in both the chemistry department and the new Institute for Nuclear Studies. Nepotism rules once again prevented a regular position for Maria Mayer; she became a voluntary associate professor of physics in the institute. The position allowed her to participate in all university activities, including lecturing to classes and supervising graduate students. With the arrival of Fermi, Franck, Urey, Teller, Willard Libby, the Mayers, and other prominent scientists, Chicago soon became a center of nuclear physics and chemistry in the world. During this period, Maria Mayer continued to work with Teller on the thermonuclear project, first at the Metallurgical Laboratory of the Manhattan Project, and then at its successor, the Argonne National Laboratory, which the University of Chicago managed for the new Atomic Energy Commission. When Sachs came to head Argonne's theoretical physics division in 1946, he offered his former professor a regular, albeit half-time, paid job as a senior physicist. In this especially stimulating environment, Maria Mayer began to study nuclear physics seriously and soon made her own major contribution, the nuclear shell model.

Mayer first became interested in the shell structure of nuclei when she collaborated with Teller on a cosmological model of the origin of the chemical elements. The project involved compiling a list of available isotopes--atoms with the same number of protons but differing numbers of neutrons in their nuclei--of the elements and their "abundances." A higher abundance of an isotope indicated that it had a more stable nuclear structure than others. In collecting and analyzing the data, Mayer found a pattern in that nuclei with "magic numbers" of 2, 8, 20, 28, 50, 82, or 126 neutrons or protons were unusually stable. It immediately led her to think of a shell structure of the nucleus analogous to the shell structure of the atom itself.

The shell model of the atom portrays it as a planetary system, more electrons, negatively charged and spinning around the nucleus and on their own axes, like the planets around the sun. According to quantum mechanics, there are only certain discrete energy levels (shells or orbits) for an electron to occupy, and only certain numbers of electrons can occupy each level. If an atom fills each of its shells with the maximum number of electrons, it becomes stable. This is the case with the inert gases, whose atomic numbers (numbers of electrons) are 2, 10, 18, 36, 54, and 86. In studying the nuclei, several other physicists before Mayer had also speculated about a shell structure on similar but less firm evidence. Most nuclear physicists, however, discounted the shell model on the ground that the interactions among protons and neutrons within the small nucleus are so strong that the internal structure of the nucleus must be radically different from that of the atom. The prevailing liquid-drop model of the nucleus treated it as a homogeneous mass of materials, rather than a collection of discrete particles.

A near novice in nuclear physics, Mayer nevertheless persisted in constructing a shell model, through the use of quantum mechanics, to make sense of her magic numbers. In this, she was aided by her husband and, above all, Fermi. Her various calculations failed to yield the desired results, however, until one legendary moment when Fermi, leaving Mayer's office after a long discussion on the subject to take a phone call, asked her the crucial question, "Is there any indication of spin-orbit coupling?" "When he said it," Mayer later recalled, "it all fell into place." Familiar with electrons' spin-orbit coupling in her earlier research and proficient in the mathematics of quantum mechanics, Mayer proceeded to calculate how protons or neutrons spinning and orbiting in different directions could have different energy levels and thereby allow, in a manner analogous to the atomic structure, only the magic numbers of them to occupy each level.

Mayer's spin-orbit-coupling shell model of nuclear structure soon gained acceptance by the scientific community, partly because it was independently and simultaneously discovered by a team led by Hans D. Jensen at the University of Heidelberg in Germany.

Theory of Nuclear Shell Structure (1955), to explain their work. In 1963 Mayer and Jensen were awarded the Nobel Prize in physics (shared with Eugene P. Wigner) for their theory. (Wigner earlier had worked on the nuclear structure, but he won the prize mainly for his application of group theory in particle physics.) She was the second woman in history, after Marie Curie in 1903, to win that prize.

In 1960 Maria and Joseph Mayer made their last move, this time to the University of California at San Diego, where she became, for the first time, a full-time professor in physics and he a professor in chemistry. Unfortunately, she suffered a stroke shortly after arriving in San Diego and had health problems thereafter, although she continued to teach and conduct research until her death. She died in San Diego.

Maria Goeppert Mayer, through her scientific research, especially her shell model of nuclear structure, made a great contribution to human understanding of nature and, by her example, served to inspire many women in science.

Bibliography

Maria Goeppert Mayer's papers are deposited in the Special Collections of the Library of the University of California, San Diego. Robert G. Sachs, "Maria Goeppert Mayer," National Academy of Sciences of the United States of America Biographical Memoirs 50 (1979): 311-28, provides useful biographical information and a bibliography. Joan Dash, A Life of One's Own: Three Gifted Women and the Men They Married (1973), accounts Mayer's personal and family life based on interviews with Maria and Joseph Mayer. Karen E. Johnson, "Maria Goeppert Mayer: Atoms, Molecules and Nuclear Shells," Physics Today 39 (Sept. 1986): 44-49, traces Mayer's scientific contributions and her route to the nuclear shell model. An obituary is in the New York Times, 22 Feb. 1972.

Zuoyue Wang

Online Resources

The Nobel Prize in Physics 1963
http://www.nobel.se/physics/laureates/1963/
From the Nobel e-Museum, the Official Web Site of The Nobel Foundation.

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