A. W. Overhauser

Albert W. Overhauser (1925–2011)

Albert W. Overhauser, one of the best-known and beloved pioneers in the development of magnetic resonance, passed away peacefully on December 10, 2011.

Born August 17, 1925 in San Diego, California, he attended high school in San Francisco. In 1942, he entered the University of California in Berkeley as a physics and mathematics major. He left college from 1942–1944 to serve in the United States Naval Reserve, training to be a radar repair specialist. Returning to college after the war, he graduated in 1948 and promptly entered Berkeley graduate school, also in physics. His thesis advisor, Charles Kittel, who was in the process of moving from Bell Labs to Berkeley, proposed as a thesis topic developing the theory of the spin lattice relaxation time of the conduction electrons in metals. When Kittel finally arrived permanently at Berkeley in 1951, Overhauser presented him with the completed thesis. Kittel immediately placed a phone call to Frederick Seitz at the University of Illinois who offered Overhauser a postdoctoral appointment doing experimental studies of radiation damage in solids working with Professor James Koehler. At this point Overhauser asked his fiancée Margaret Mary Casey whether she could imagine leaving Berkeley to move to Illinois, a subtle but successful way to propose marriage.

At that time, Illinois was a hotbed of NMR research. Erwin Hahn had received his PhD at Illinois in 1949, and stayed on for a year as a postdoc after discovering spin echoes. Herbert Gutowsky had joined the Chemistry Department in 1948, a fresh PhD from Harvard where he had begun NMR research with Purcell's student George Pake. I obtained my PhD in 1949 with Purcell, and joined the Physics Department that year. When Overhauser arrived, my first student, Dick Norberg, was just finishing his PhD thesis studying the ^{1}H NMR of hydrogen adsorbed in Pd metal. Overhauser got to know the resonance groups and learned about their studies of relaxation times in the alkali metals. In January 1952 he attended a talk by Norberg about his thesis. Overhauser reminisced to me: "*What Norberg said in his seminar was: the free induction decay contains information. I believed that, during the decay, the system is out of equilibrium (of course). So what I did in the next two days was to find out what happens when the system is held (steadily) out of equilibrium. (The discovery followed quickly)*".

The discovery, now known as the Overhauser effect and also as dynamic nuclear polarization, was that one could increase the nuclear polarization in a metal one thousand fold if the resonance of the conduction electron spins is excited sufficiently strongly. My students and I were amazed at this prediction and were eager to test it. As yet, no one had observed the magnetic resonance from conduction electrons in metals. In his thesis, Overhauser predicted a very narrow (0.1 G wide), intense electron spin resonance (ESR) signal. So they immediately started searching various metals looking for such a narrow ESR signal using an NMR apparatus at 10 MHz and a correspondingly low magnetic field. In late 1952, Griswold, Kip, and Kittel discovered the resonance, which was much broader than predicted, in metallic Na using 3 cm microwaves. Immediately thereafter, Carver and I found the ESR signal (5 G wide) in powdered Li metal, and quickly embarked on an effort to verify Overhauser's predicted effect.

Overhauser pointed out that at low temperatures and in strong magnetic fields, large nuclear polarizations would shift the frequency of the ESR signal. He proposed looking for this frequency shift to verify his prediction. However, my group lacked the microwave and low-temperature equipment needed to carry out this method. Instead, they proposed a double-resonance experiment in which they observed the effect on the ^{7}Li nuclear magnetic resonance (NMR) of powdered Li metal produced by exciting the conduction electron ESR. This experiment could be carried out at room temperature and without microwave equipment. They required that the diameter of the metal particles be smaller than the electromagnetic skin depth for both electrons and nuclei, limiting the maximum frequency of ESR to approximately 100 Mhz, and requiring that the static magnetic field be about 30 G and the NMR frequency near 50 kHz.

Overhauser presented his idea in a ten-minute talk at the April 1953 meeting of the American Physical Society to an audience containing Bloch, Purcell, Bloembergen, Rabi, Ramsey, and Abragam. They were highly skeptical, perhaps suspecting that his idea violated the second law of thermodynamics. In June, Overhauser left Illinois to become assistant professor of physics at Cornell. He submitted a manuscript to Physical Review in late June. On August 12, Carver and I first observed the enhancement (100-fold) of the ^{7}Li NMR signal. They sent a telegram to Overhauser telling the happy news and quickly submitted a paper. It was received at Physical Review on August 17, Overhauser's 27th birthday.

Carver and I realized that the Overhauser effect required two elements: that the relaxation time involve matrix elements of the spin–spin interaction between nucleus and electrons in which both spins were simultaneously flipped in going from the initial to the final spin states, and that there were degrees of freedom that could absorb the Zeeman energy difference between the intial and final spin states. Thus the Overhauser effect might be possible in a nonmetallic liquid. In 1954, they demonstrated this, achieving a 100-fold enhancement of the polarization of protons in liquid ammonia in which they provided unpaired electron spins from dissolved Na atoms. Much of the present day dynamic polarization uses these principles. In 1955, Solomon demonstrated an Overhauser effect for a system whose spins consisting solely of nuclei (^{19}F and ^{1}H in the molecule HF). The nuclear Overhauser effect became very important in determining the structure of large biomolecules, as is evident in the Nobel Prize lecture of Kurt Wüthrich.[1]

At Cornell University, Overhauser was promoted to associate professor in 1956, but in 1958 he was lured by the physicist Jack Goldman to leave Cornell to join the research laboratory at Ford Motor Company. After Goldman left Ford to join Xerox in 1969 (and founded the Xerox Palo Alto Research Laboratory), Overhauser remained at Ford just until 1973 when he became Professor of Physics at Purdue, a position he held until his death.

Overhauser's many important contributions were honored by election both to the American Academy of Arts and Sciences and the National Academy of Sciences. He received the Oliver E. Buckley Solid State Physics Prize in 1975, the Alexander von Humboldt Senior Scientist Award (1979–1980), an Honorary Doctor of Science from the University of Chicago (1979), and an Honorary Doctor of Laws from Simon Fraser University in 1998. In 2009 he received the Russell Varian Prize, and in 1994, President William Clinton awarded him the United States National Medal of Science.

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[1] K. Wüthrich, *Angew. Chem.*, **2003**, *115*, 3462–3486; *Angew. Chem. Int. Ed.*, *42*, 3340–3363.

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