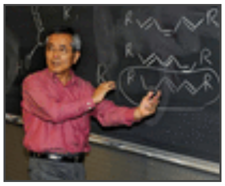
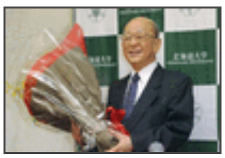
Prize for Chemistry

The Nobel Prize for Chemistry for 2010 went to three organic chemists, Richard F. Heck of the University of Delaware, Ei-ichi Negishi of Purdue University, West Lafayette, Ind., and Akira Suzuki of Hokkaido University, Sapporo, Japan, for finding and developing an ingenious way to link carbon atoms. The key to their discovery is the capability of palladium atoms, a relatively unreactive metal in bulk form, to join carbon atoms together.



The process that brought them the award is known as palladium-catalyzed cross coupling. A palladium atom is attached to one of the two carbon atoms that one wants to bind together. With the host atom holding its palladium atom, the two carbons find each other and join, leaving the palladium atom behind. Heck, Negishi, and Suzuki each found different but related ways—which now bear their names—to accomplish the process. In the Heck reaction the carbon to be attached carries no activating atom or group. The Negishi reaction uses a zinc atom “tag” to transfer a carbon atom to the palladium atom. The Suzuki reaction uses boron, usually attached to a ring of eight carbons. This class of catalyzed reactions has become one of the most important ways to synthesize natural products and molecules with complex structures and is widely used in nanotechnology and medicine.



Richard F. Heck was born on Aug. 15, 1931, in Springfield, Mass. He received a doctoral degree (1954) from the University of California, Los Angeles, and in 1957 he joined the American chemical company Hercules Powder in Wilmington, Del. In 1968 Heck reported that palladium could catalyze formation of new carbon-carbon bonds, but at that time the starting materials, organic compounds of mercury, lead, or tin, were toxic, were difficult to prepare, and required problematic conditions for carrying out the reactions. Three years later three Japanese chemists—Tsutomu Mizoroki, Kunio Mori, and Atsumu Ozaki—carried out palladium-catalyzed attachment of benzenelike compounds containing iodine atoms (aryl iodides) to ethylene-like molecules under somewhat more practical but still difficult conditions. In 1972 Heck and J.P. Nolley published the paper that truly triggered the breakthrough, building on the work of Mizoroki and his colleagues, opening the possibilities to carry out a wide range of specific carbon-carbon couplings under relatively mild conditions. Their approach provided a very efficient way to bind benzenelike molecules, so-called aromatics, to molecules with a double carbon-carbon bond, compounds known as alkenes, and in 1975 to molecules with a triple carbon-carbon bond, such as acetylene.

Ei-ichi Negishi was born on July 14, 1935, in Xinjing, Manchukuo (now Changchun, China). He received a doctorate from the University of Pennsylvania in 1963. Negishi and co-workers in 1977 showed how a catalytic process similar to that of Heck enabled coupling of two different alkenes. Negishi’s version of palladium-catalyzed cross coupling made possible the synthesis of discodermolide, a substance that protects a Caribbean marine sponge from its predators but may have great potential as a treatment for cancer. Only an efficient synthesis using the Negishi reaction can produce enough discodermolide to provide real treatment.

Akira Suzuki was born on Sept. 12, 1930, in Mukawa-cho, Japan. He earned a Ph.D. from Hokkaido University in 1959. The Suzuki reaction links carbons of alkanes, molecules that have only single bonds. In the Heck, Negishi, and Suzuki reactions, the palladium atom slips between the hosting carbon and an iodine or bromine atom; at this stage this carbon is ready to react. The other carbon may just be one of two held by a double bond, or it may be activated by something special attached to it. The special advantage of the Suzuki reaction is the stability of its starting materials; they can be prepared and stored indefinitely, in contrast to the starting materials for the Heck and Negishi reactions, which must be prepared specifically for each reaction. Furthermore, boron is less toxic than the zinc tag of the Negishi reaction and thus is safer for large-scale operations. Consequently, the Suzuki reaction is usually the choice for industrial processes.

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