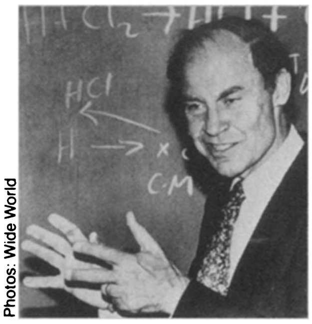
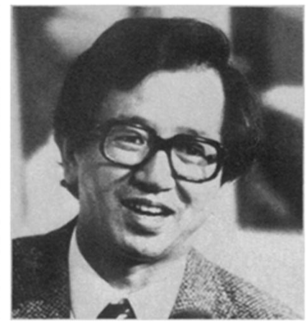
Nobels

Chemistry: Probing reaction dynamics





Photos: Wide World

Herschbach *Polanyi* *Lee*

Three chemists whose research involves the details of how chemical reactions occur are this year's winners of the Nobel Prize in chemistry. The Royal Swedish Academy of Sciences awarded the prize last week to Dudley R. Herschbach of Harvard University, Yuan T. Lee of the University of California at Berkeley and John C. Polanyi of the University of Toronto.

The award honors the development of two important techniques for probing what happens during the fractions of a second when different molecules collide and atoms rearrange themselves to form new molecules. Herschbach and Lee worked with molecular beams, studying the results of crossing two streams of fast-moving particles so that molecules collide under carefully controlled conditions. The spray of products provides clues about what goes on during the collisions. Polanyi measured and analyzed the extremely weak infrared radiation emitted by newly formed molecules. This allowed him to monitor the energy flow at the molecular level during a chemical reaction.

The crossed molecular beam technique is "one of the most important advances within the field of reaction dynamics," according to the award citation. Herschbach was one of the pioneers in developing this method and used it to define the dynamics of basic reaction types.

In the reaction between potassium atoms and methyl iodide molecules, for instance, Herschbach and his colleagues showed that the product potassium iodide is formed only if a potassium atom strikes the iodide end of a methyl iodide molecule at just the right angle. This result showed for the first time that molecular orientation strongly influences how readily a chemical reaction occurs. Molecular beam experiments also led to the discovery that intermediate "reaction complexes," temporarily created during a collision, sometimes survive for a surprisingly long time before they decay to form stable molecules.

Lee, who initially worked with Herschbach, extended molecular beam experiments to include larger and more complex molecules. He studied, for example, reactions between organic molecules and fluorine or oxygen atoms. Recent work has focused on basic reactions related to those that occur in the atmosphere or during combustion.

Lee's group at the Lawrence Berkeley Laboratory is now looking into photochemical processes. The researchers use a laser to excite molecules or atoms after they have been accelerated but before they collide. In this way, they have some control over the type of chemical reaction that occurs. They are also studying the use of laser excitation during molecular beam experiments to promote the removal of one or more specific atoms from larger molecules — a selective type of photodissociation.

Polanyi's complementary infrared-chemiluminescence technique, developed at the same time as the molecular beam method, provides information about how a product molecule gets rid of its excess energy after the high-speed collision that creates it. Spectroscopic analysis of the emitted infrared light reveals the quantum states occupied by the molecules. This gives indirect information about the system's potential energy at various stages during a reaction.

Polanyi's method, the Nobel award states, "can be considered as a first step towards the present, more sophisticated but also more complicated, laser-based methods for the study of chemical reaction dynamics." *—I. Peterson*

Nobels

Physics: Tiny world garners grand laurels


Photos: Wide World

Above: Heinrich Rohrer (left) and Gerd Binnig. At right: Ernst Ruska.

Modern microscopy has brought scientists within sight of the very bonds that hold together the atoms of matter. For their innovations in this field, three Europeans have won the 1986 Nobel Prize in physics.

Cited for designing, between 1931 and 1933, the first electron microscope and for doing "fundamental work in electron optics," West German scientist Ernst Ruska of the Fritz-Haber Institute of the Max Planck Society in West Berlin will receive half of the $290,000 prize. Sharing the other half for their 1981 design of the scanning tunneling microscope are Gerd Binnig of West Germany and Heinrich Rohrer of Switzerland. Both work at IBM Corp.'s research laboratory in Zurich, Switzerland.

Before the 1930s, the resolution or "defining power" of microscopes was limited by the wavelength of light, which is roughly 2,000 times the diameter of a typical atom. "Trying to probe atomic structures with visible light is like trying to find hairline cracks on a tennis court by bouncing tennis balls off its surface," wrote Binnig and Rohrer in the August 1985 SCIENTIFIC AMERICAN.

By switching from visible light to a beam of high-energy electrons, whose wavelengths can be roughly 100 times smaller than an atom, Ruska was tossing the tennis balls away in favor of balls smaller than a grain of sand. In 1931, Ruska used two simple magnetic coils to focus this electron beam, and the electron microscope was born.

Modern electron microscopes can resolve down to about 1 angstrom or 10^{-10} meters, which is smaller than the typical atomic diameter.

Unlike the electron microscopes and their visible-light predecessors, the scanning tunneling microscope does not produce an image by focusing beams of wave/particles. Instead, it works like the stylus of a record player, albeit on a much smaller scale.

With a tip so fine it consists of a single atom, the microscope's stylus moves across the surface of a sample and traces its topography. To prevent the stylus from scratching the surface, Binnig and Rohrer kept the two apart by 5 to 10 angstroms. A potential difference across the gap induces electrons to flow from the stylus to the sample, and the stylus rides along on this blanket layer of electrons.

The key to the sensitivity of the scanning tunneling microscope is a quantum mechanical effect known as tunneling (SN: 4/6/85, p.215). To allow the stylus to ride within 2 atomic diameters of the surface, the voltage across the gap between