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EDITORIAL

Nanophase Chemistry

Most research in chemistry deals with atoms and molecules, but a field is emerging that focuses on assemblages of components in structures having nanometer-scale dimensions. Some of these structures are created by experimenters moving individual atoms, but others are self-assembled and may contain more than a million molecules. Their study holds promise of relevance to important questions in biology and the possibility of ultimate major technological applications.

Progress in nanophase chemistry was reviewed by international leaders in the field at a Welch Foundation conference held in Houston, Texas, on 23 and 24 October 1995. The event, attended by about 500 chemists, stirred unusually vibrant enthusiasm. I present below the highlights of three talks, followed by mention of the role of the Welch Foundation in fostering basic research.

George Whitesides of Harvard University reviewed some of the many experiments on self-assembled structures that he and his associates have conducted. They have used as basic components a gold surface and alkanethiols. When gold is exposed to hexadecanethiol—$CH_3(CH_2)_{15}SH$—the thiol group reacts with the gold. The result is a self-organized, 2-nanometer-thick, semicrystalline, upright layer of organic molecules covering the surface of the gold. Other, related thiols having substituted top terminal groups such as CF_3 and COOH also have been formed; thus, the self-organized structures may present hydrophobic or hydrophilic surfaces. Complex surfaces have been created by using patterned stamps to transfer substituted thiols to the gold. When coated by self-adsorption with different proteins, the structures may adsorb particular mammalian cells. Whitesides has also demonstrated high-resolution microlithography by bombarding 1.5-nanometer-thick, self-assembled monolayers with neutral, metastable argon beams.

Charles Kresge of Mobil Oil Research spoke of ordered mesoporous molecular sieves. When a complex mixture of a quaternary ammonium surfactant, aluminosilicate, or precipitated silica is incubated at 150°C for 48 hours, self-organization leads to a regular hexagonal array. Heating this product to 540°C yields a product with an internal surface area of more than 1000 square meters per gram. In one typical experiment the interplanar spacing was 4 nanometers. By varying the composition of the synthesis mixture, arrays of hexagonal pores of different dimensions have been obtained, which have excellent adsorption capabilities for benzene, *n*-hexane, and cyclohexane. Mobil had great success with porous zeolites as catalysts and sorption media. The new structures extend that capability.

Richard Smalley of Rice University spoke of another example of self-assembly of interesting structures. He has been a leader in the synthesis and study of the properties of fullerenes. When a carbon arc is established, temperatures in the arc may exceed 3500°C, and carbon atoms are released. Some of the atoms combine, yielding modest amounts of 60-carbon fullerenes. Recently, carbon has been heated and vaporized by intense laser light. Fullerenes form in a region maintained at about 1200°C. When the carbon that is irradiated contains one atom percent of nickel plus cobalt, the resultant structures take the form of tubes about 0.1 millimeter long that contain millions of carbon atoms. As much as 60 percent of the vaporized carbon is found in these tubes, and the nickel and cobalt are easily removed by leaching. The tubes tend to form ropes that are stronger than carbon fibers, and they can also serve as support for catalytic processes.

As for the conference's sponsor, the Welch Foundation was formed in 1954 and now has assets of about $400 million. Robert A. Welch, the donor, stipulated that proceeds from the corpus be used to support basic chemical research in Texas. As the frontiers of chemistry have changed, Welch trustees have implemented the counsel of a distinguished scientific advisory board. Chemistry in Texas has benefited greatly from Welch Foundation support, and the nation and the world have benefited from annual Welch conferences on chemical research. Each conference has been arranged in turn by a member of the advisory board, who has often identified important research fields to highlight. The conference on nanophase chemistry was organized by William O. Baker with the help of Robert A. Laudise of the AT&T Bell Laboratories.

Philip H. Abelson