Iowa State, Ames Lab researcher hunts for green catalysts

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L. Keith Woo's hunt for green catalysts has led him to experiment with iron porphyrins. Here he's holding a model of an iron porphyrin compound in his Iowa State University research lab. Credit: Photo by Bob Elbert/Iowa State University

L. Keith Woo is searching for cleaner, greener chemical reactions. Woo, an Iowa State University professor of chemistry and an associate of the U.S. Department of Energy's Ames Laboratory, has studied catalysts and the chemical reactions they affect for more than 25 years. And these days, his focus is on green catalysis.

That, he said, is the search for catalysts that lead to more efficient chemical reactions. That could mean they promote reactions at lower pressures and temperatures. Or it could mean they promote reactions that create less waste. Or it could mean finding safer, cleaner alternatives to toxic or hazardous conditions, such as using water in place of organic solvents.

"We're trying to design, discover and optimize materials that will produce chemical reactions in a way that the energy barrier is lowered," Woo said. "We're doing fundamental, basic catalytic work."

And much of that work is inspired by biology.

In one project, Woo and his research group are studying how iron porphyrins (the heme in the hemoglobin of red blood cells) can be used for various catalytic applications. Iron porphyrins are the active sites in a variety of the enzymes that create reactions and processes within a cell. Most of the iron porphyrin reactions involve oxidation and electron transfer reactions.

Because the iron porphyrins of biology have evolved into highly specialized catalysts, Woo and his research group are studying how they can be used synthetically with the goal of developing catalysts that influence a broader range of reactions.

"We've found porphyrins are capable of doing many reactions – often as well, or better, or cheaper than other catalysts," Woo said.

Another project is using combinatorial techniques to accelerate the development, production and optimization of catalysts. Woo and his research group are using molecular biology to quickly screen a massive library of DNA molecules for catalyst identification and development. The goal is to create water-soluble catalysts for organic reactions.

"Combinatorial approaches such as these have been applied to drug design, but their use in transition metal catalyst development is in its infancy," Woo wrote in a summary of the project.

A third project is looking for catalysts that allow greener production of lactams, which are compounds used in the production of solvents, nylons and other polymers. Commercial lactam production traditionally uses harsh reagents and conditions, such as sulfuric acid and high temperatures, and also creates significant wastes.

Woo, in collaboration with Robert Angelici, a Distinguished Professor Emeritus of Chemistry, has found a gold-based catalyst that eliminates the need for the acid and high pressure and also eliminates the wastes. The Iowa State Research Foundation Inc. is seeking a patent on the technology.

And, in a fourth project, Woo is working to understand the chemistry behind the chemical reactions that create bio-oil from the fast pyrolysis of biomass. Fast pyrolysis quickly heats biomass (such as corn stalks and leaves) in the absence of oxygen to produce a liquid bio-oil that can be used to manufacture fuels and chemicals.

Woo's projects are supported by grants from the National Science Foundation, the U.S. Department of Energy, Iowa State's Institute for Physical Research and Technology, Iowa State's Bioeconomy Institute, and the National Science Foundation Engineering Research Center for Biorenewable Chemicals based at Iowa State. Woo's research team includes post-doctoral researcher Wenya Lu and doctoral students B.J. Anding, Taiwo Dairo, Erik Klobukowski and Gina Roberts.

Sit down with Woo and he'll call up slide after slide of the chemical equations that describe chemical reactions.

And before long he's describing how catalysts are discovered these days.

"The traditional way to develop catalysts was very Edisonian – one experiment at a time," Woo said. "It was all by trial and error."

Now, with high-throughput approaches, Woo said his research group is able to quickly test a reaction using one hundred trillion different catalysts.

And that, Woo said, is "helping us find less expensive and more environmentally friendly materials and conditions to perform these catalytic reactions."

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