Mimicking nature's chemistry to solve global environmental problems

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Theodore Betley, Ph.D., will present his pioneering work on catalysis today.
Credit: Harvard University

What many people might call the daily laboratory grind Theodore

Betley, Ph.D., calls play. As a student, he developed a passion for lab work that could now pay off for the rest of the world. Today, he will present pioneering work that could help turn greenhouse gases into useful products during "The Kavli Foundation Emerging Leader in Chemistry Lecture" at the 249th National Meeting & Exposition of the American Chemical Society (ACS).

"Our goal is to answer the questions: How do you take the sea of gases that makes up our atmosphere and convert that into liquid fuels?" Betley says. "Or how do you remediate greenhouse gases and turn them into something usable for the chemical industry?"

The key to answering these big-picture questions and others is getting a better grasp on how nature works, says Betley, who is a professor of inorganic chemistry at Harvard University.

"Nature has evolved over billions of years to convert nitrogen from the atmosphere into fertilizer or to harness solar energy to split water into oxygen and protons and electrons," he explains. "As chemists, we're trying to catch up in order to do those transformations ourselves."

Inorganic chemists design new catalysts that can spur such transformations along. But it's not an easy task. Betley says the field's top scientists in the 1960s started creating catalytic clusters that copy nature's strategy, relying on several underdog metals rather than just one heavy hitter to get a reaction going.

Betley's lab is now at the forefront of such efforts. They've developed novel materials that are extremely efficient at prompting reactions to take place in the lab. Harnessing the ability to drive and control these reactions could help provide new solutions for reducing levels of greenhouse gases that contribute to global warming. The reactions could remove those gases from the air and turn them into chemical products in

high demand that industry now gets in less sustainable ways.

Betley's path toward this potential turning point in the field started when he was an undergraduate student, he says. Through a series of internships in various labs, he developed a near-compulsive desire to understand chemical reactions on a fundamental level.

"What I discovered in my first interactions in the lab was just a passion for the minutiae," he says. "I didn't have one of those defining moments as a kid when I set my barn on fire and said, 'Holy smokes—I need to learn more about combustion.' To be honest, I think I entered undergraduate studies being very uncertain about what I wanted to do."

But by the time he completed his degree in chemical engineering, Betley knew there were provocative questions in inorganic chemistry that he wanted to answer, so he went to graduate school. Now, he's chipping away at those questions and turning them into novel solutions.

More information: Radical frontiers in catalysis, 249th National Meeting & Exposition of the American Chemical Society (ACS).

Abstract
The science of small molecule activation centers of the conversion of ubiquitous substrates (e.g. CO2 or N2) into useable chemical feedstocks or precursors for synthetic fuels. Therefore, small molecule activation catalysis could potentially play a central role in both emerging energy storage strategies, as well as mitigate the effects of accumulating greenhouse gases. State-of-the-art small molecule activation catalysts typically require strong oxidants or reductants to engage substrate, incurring large overpotential costs (or wasted energy) that limits their utility. We envisioned a new strategy wherein a multi-electron pathway could be accessed through the use of cluster?based catalysts. This strategy serves to delocalize the redox load over multiple redox-active

centers, making multi-electron redox behavior more accessible. Towards this end we developed simple, multidentate ligands to direct the formation of reactive metal clusters that feature proximally oriented transition metals that cooperatively act upon a single substrate. Embedding earth-abundant, first row transition metals within the weak-field ligand platforms allowed us to realize a new class of highly reactive clusters. Our research has led to new understanding of factors contributing to the promotion of productive small molecule activation processes, culminating in the development of new inorganic catalysts.

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