SLAC Science
Harnessing the Power of Chemistry

Scientists at SLAC observe chemical reactions in unprecedented detail and find ways to make them more efficient, with the goal of using chemistry to help solve the nation's energy challenges.

Chemical to the Core

Everything we do and everything we see around us has chemistry at its core – from the way living things function to the fuels that give us light, heat and mobility and the consumer goods that make life comfortable.

SLAC gives researchers an unrivaled set of tools for following chemical reactions step by step, at quadrillionths-of-a-second timescales, and improving catalysts that make reactions more efficient. The results feed efforts to improve batteries, fuel cells and solar power, make industrial processes greener and find entirely new ways to make fuels from sunlight.

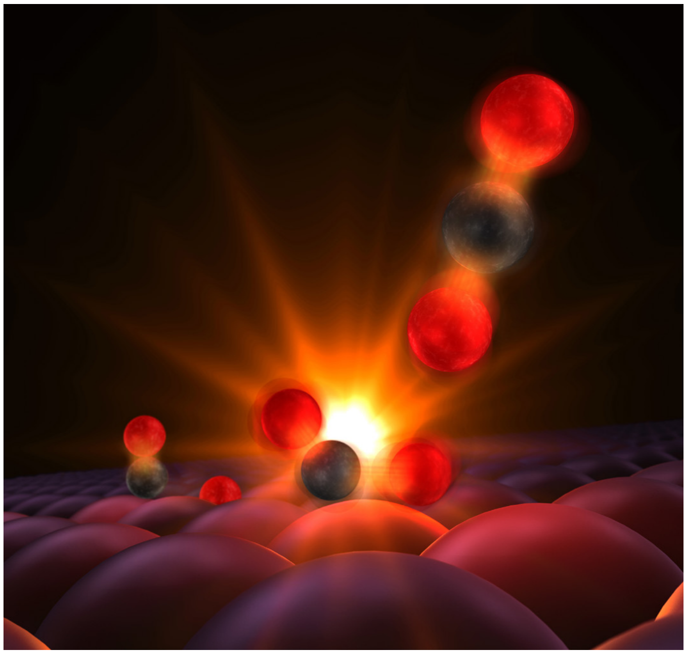
Two Joint Institutes

SLAC and Stanford work together on these problems through two joint institutes.

At the Stanford PULSE Institute, researchers use SLAC's revolutionary X-ray laser, the Linac Coherent Light Source, to watch and analyze chemical reactions in much more detail than ever before. For instance, they want to understand exactly what happens when a single photon of sunlight hits a leaf, setting off a chain of photosynthetic reactions that create sugar and oxygen – insights that could help researchers develop new ways to generate and store energy.

At the SUNCAT Center for Interface Science and Catalysis, the focus is on improving catalysts, which are widely used to promote reactions for making fuels, fertilizers and other products. The more sensitive and efficient the catalyst, the less energy it uses and the less waste it leaves behind. Scientists want to reach such a deep understanding of how catalysts work that they can deliberately design them for particular jobs from scratch, and use them to generate and store energy in novel ways.

Above: A SLAC researcher at an LCLS instrument where chemical science experiments are performed. Below: Illustration of an LCLS experiment that gave scientists their first glimpse of a chemical bond being born.



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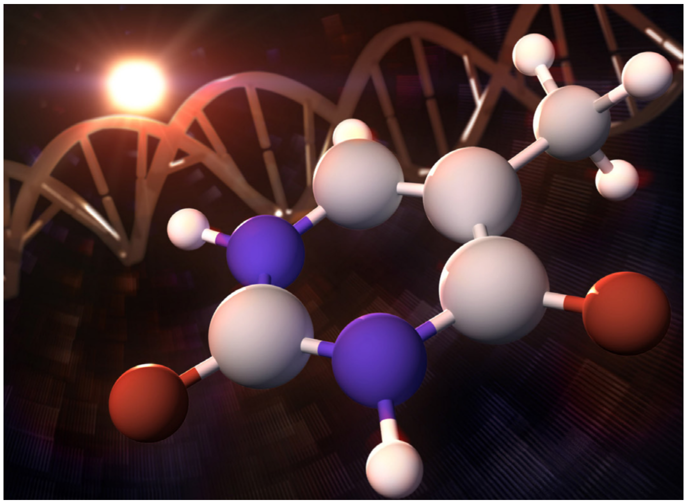
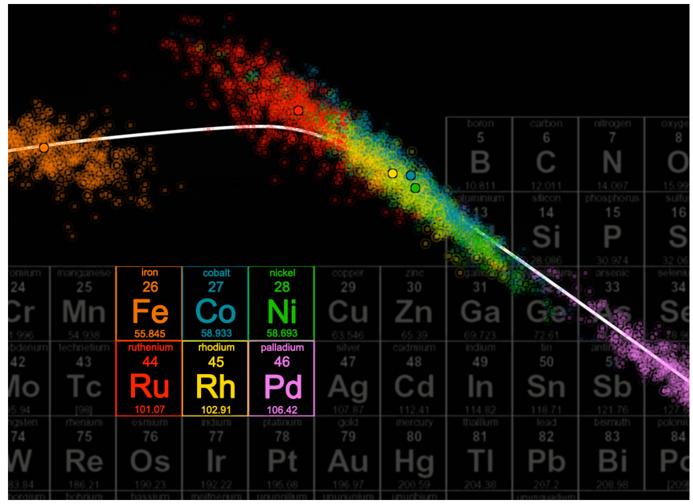




Watching a Catalyst at Work

The best-known example of a catalyst at work is a car's catalytic converter, which breaks down exhaust gases so they won't form smog.

SLAC's X-ray laser gave scientists their closest look yet at how one of those exhaust gases – toxic carbon monoxide – hooks up with oxygen from the air to form carbon dioxide. They attached carbon monoxide molecules and oxygen atoms to the surface of a catalyst, applied heat to get things going and watched the chemicals vibrate, knock into each other and bond. The finished CO2 molecules detached and drifted away.

Fine-tuning Fuel Cells

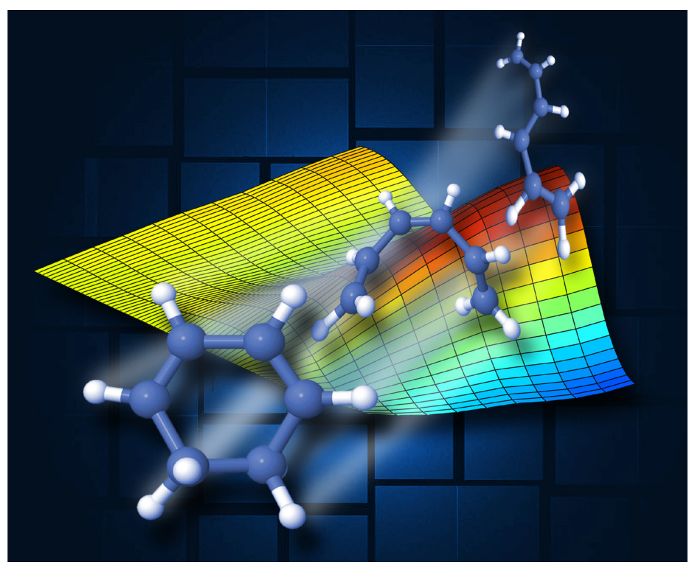
Theory plays an important part in finding better catalysts. For example, a SUNCAT researcher used theory and computer simulations to predict that an unlikely combination of two metals, platinum and yttrium, would make a good catalyst in fuel cells, which are a promising, non-polluting way to power cars. X-ray studies at SLAC's Stanford Synchrotron Radiation Lightsource found that the combo worked as predicted – and because it contains much less pricey platinum, it should be a lot cheaper than current technology.

Making Molecular Movies

In another recent milestone, scientists at SLAC made a "molecular movie" of a ring-shaped molecule unraveling after one of its chemical bonds snapped. To make the movie, they scattered X-ray laser pulses off the molecules to reveal the precise positions of the atoms inside, repeated at incredibly short intervals and strung those snapshots together. Each movie frame represented 25 quadrillionths of a second – about 1.3 trillion times faster than the 30-frames-per-second rate used to display TV shows.

A New Tool: The "Electron Camera"

A new instrument at SLAC uses ultrafast electron diffraction, or UED, to capture some of nature's speediest processes. It can reveal motions of electrons and atomic nuclei that take place in less than a tenth of a trillionth of a second. This new "electron camera" will complement ultrafast studies at the LCLS X-ray laser and allow groundbreaking research in chemistry, materials science and biology.



Top left: A SLAC experiment showed how this DNA building block protects itself from sun damage by stretching a single chemical bond, setting off vibrations that dissipated harmful energy. Top right: SUNCAT theorists calculated-which of six chemical elements would make the best catalyst for promoting an ammonia synthesis reaction; the winner was ruthenium, depicted as the red-streak at top (SUNCAT, Callie Cullum). Above: This illustration shows a "molecular movie" of a molecule changing shape in quadrillionths-of-a-second intervals after being broken open by light.

SLAC is operated by Stanford University for the U.S. Department of Energy Office of Science

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