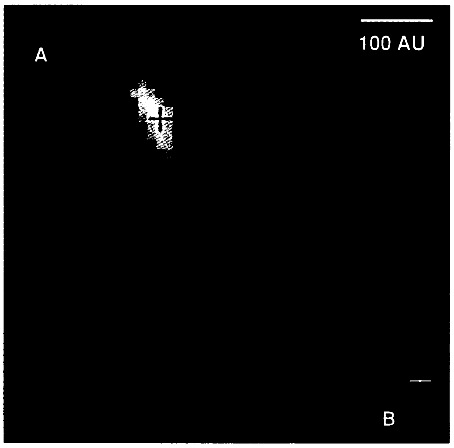
the Harvard-Smithsonian Center for Astrophysics and his colleagues from the University of Florida, Gainesville, spotted a flattened dust disk around the star. At a mere 10 million years old, the star is a "perfect [age] for planets to be forming in its disk," says Jayawardhana. A second team, from the California Institute of Technology and Franklin and Marshall College in Lancaster, Pennsylvania, independently photographed the disk with the 10-meter Keck II Telescope on Mauna Kea. Both groups announced their findings at a press briefing last Tuesday.

Earlier measurements by Michael Jura of UCLA had suggested that HR4796A has a dust shroud in which planets could be coalescing. Jura couldn't see the disk directly, but by measuring the infrared brightness of the star at various wavelengths, he calculated that it is surrounded by dust with an average temperature of about 110 kelvin. Because dust close to the star would be much warmer, Jura concluded that the dust must be sparse in the inner regions of the disk, perhaps because planets are forming there. Astronomers are also intrigued by the discovery because, like more than half of the stars in our galaxy, HR4796A is part of a binary star system. It has a faint companion star orbiting it at a distance of some 75 billion kilometers. Some theorists had thought that the gravitational effects of a companion might prevent a star from sprouting a protoplanetary disk.



R. JAYAWARDHANA ET AL.

Planetary nursery. The HR4796A dust disk. Crosses indicate the star and its companion.

The HR4796A disk implies that this restriction doesn't hold, at least for binaries as widely separated as this one. Together with the holes and bulges seen in the other stars' disks, it suggests that once a star has a dust disk, planets are likely to follow, says Rens Waters of the University of Amsterdam. "Apparently, it's not hard to make planets," he says. "As soon as a star is surrounded by a disk of gas and dust with the right density and composition, you end up with a solar system."

–Govert Schilling

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

GEOCHEMISTRY

Catalytic Explanation for Natural Gas

DALLAS—Frank Mango believes that the textbook version of how natural gas forms in Earth's crust is all wrong. As geology books tell the story, natural gas deposits occur at or near hot spots where high temperatures break down the long hydrocarbon chains in petroleum to the short hydrocarbons found in natural gas: methane, ethane, propane, and butane. But in recent years, Mango, a geochemist at Rice University in Houston, has argued that it's not heat that breaks down petroleum but catalytically active metals in the ground. At a meeting of the American Chemical Society here earlier this month, Mango offered new evidence to support this view: laboratory results showing that the catalytic breakdown of petroleum produces component gases with the exact same mixture of heavy and light carbon isotopes as is found in natural gas deposits.

"I think he's on to something," says Everett Shock, a geochemist at Washington University in St. Louis, of Mango's latest work. But not all geochemists are won over to Mango's ideas. Martin Schoell, a geochemist and natural gas expert with the Chevron oil company in La Habra, California, says he finds Mango's experiments "elegant and very interesting." But, he adds, "I feel his mechanism does not explain what we observe in nature." In particular, it has trouble explaining the relative amounts of the four component gases of natural gas in certain types of rock formations.

Ironically, it was the distribution of the component gases that first pushed Mango toward the notion that catalytic metals must be involved in the creation of natural gas. In most natural deposits, methane comprises at least 80% of the total gas present, with the other light hydrocarbons accounting for the rest. Yet, when elevated temperatures are used in the lab to break down petroleum into lighter hydrocarbons, the result is a very different mix, with methane making up between 10% and 60% of the total. Other lab studies suggest that at temperatures at which petroleum is thought to break down in the Earth—between 150 and 200 degrees Celsius—the heavy hydrocarbons are so stable that this mechanism cannot account for the formation of natural gas even over the eons of geologic time.

In 1992, Mango and his Rice University colleagues suggested that transition metals such as nickel and vanadium, which are invariably found in petroleum, may act as catalysts to speed the reactions along. Since then they've also shown that the types of rock where natural gas is commonly found carry transition-metal compounds that are catalytically active and that passing a stream of petroleum through these rocks liberates methane and other light hydrocarbons in the same proportions that are commonly found in natural gas reservoirs deep in the Earth.

At the Dallas meeting, Mango described new lab experiments that further bolster his hypothesis. He looked at the isotopic composition of the gases that were formed as petroleum was catalytically broken down into lighter hydrocarbons. In typical natural gas deposits, the components not only follow a standard distribution pattern, but each gas typically has a distinctive ratio of heavy to light carbon isotopes—carbon-13 to carbon-12. Methane, for example, is richer in carbon-12, while the heavier gases contain progressively more carbon-13. And when Mango catalytically broke down petroleum using nickel and cobalt catalysts, he found that the product gases came out with the most common isotope mixes found in natural deposits. This supports but doesn't nail down the theory, says Mango, as isotopic measurements from some heat-driven petroleum breakdown experiments produce similar results.

Schoell argues that the catalytic mechanism doesn't explain everything. Three years ago, for example, he and his colleagues published a study of a natural gas deposit in North Dakota, known as the Bakken formation. It is thought that most natural gas arises in source rocks that are rich in organic matter and then migrates through porous rocks to a reservoir where it's confined. In the Bakken formation, however, the natural gas did not filter to a new home but has remained locked in the source rock. And when Schoell and his colleagues looked at the distribution of component gases and their isotopic concentrations, they found that they closely matched the results of pyrolysis experiments, the lab tests which simply use high temperatures to transform petroleum to natural gas. "If we look into the kitchen of natural gas formation, we find that they are not methane-rich gases but the gases we see in pyrolysis experiments," says Schoell.

Schoell suggests that natural gas deposits found in reservoir rocks end up rich in methane because as the gases flow through the porous rocks, the higher hydrocarbons are filtered out. Regions like the Bakken formation, he adds, represent just the first step in this process, where the petroleum is originally broken down. But Mango doesn't buy this explanation, arguing that this extra filtering step that Schoell proposes should leave heavier hydrocarbons behind, which he says is not observed in nature.

For now, that leaves both sides with a little explaining to do, says Washington University's Shock. Mango needs to be able to explain why deposits such as the Bakken formation don't have elevated levels of methane like other deposits—especially as the oil there is rich in transition metals. And Schoell and his colleagues need to explain why the filtering mechanism hasn't been detected.

Whether one or both of these mechanisms turn out to rise to the top could have practical implications, says Shock. In particular, if the catalytic formation theory of natural gas proves correct, it may give oil companies new insight into where to find rich gas deposits. For now, says Shock, "I would say that [the debate] is still not resolved. Our whole society depends on fossil fuels. Yet we still understand so little about how they form. It's astonishing."

–Robert F. Service

CHEMISTRY

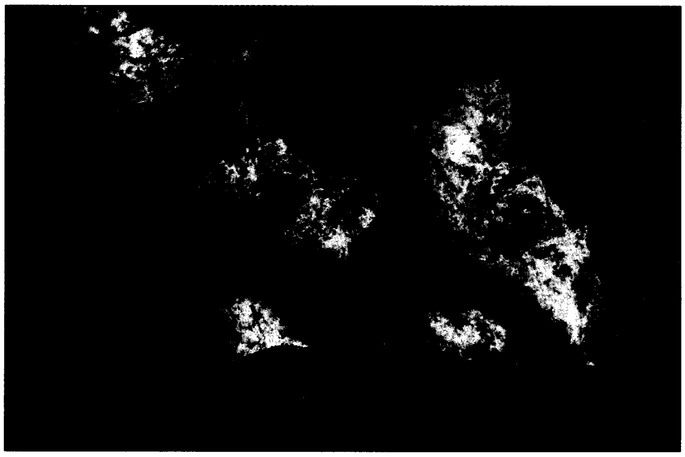
Will New Catalyst Finally Tame Methane?

The bright orange flares of natural gas burning near oil wells are a dramatic sight. But they illuminate a paradox: Natural gas is a vast and valuable natural resource, but it's often cheaper to burn than to use. Unless pipelines are already in place, carting natural gas from remote sites such as the north slope of Alaska or Siberia costs more than the gas is worth. As a result, the gas is either flared off or pumped back into the ground. Now, on page 560, a team of researchers in California reports developing a new catalyst that may change all that.

The compound efficiently converts methane, the primary component of natural gas, to a derivative of methanol, a liquid fuel that can easily be transported in trucks and tankers, much like petroleum. As such, if used in plants near remote wellheads, the new catalyst could make use of vast remote natural gas reserves around the world. "This is a major breakthrough in terms of doing something with methane," says Jay Labinger, a chemist at the California Institute of Technology in Pasadena who has worked on similar catalysts.

The oil industry has for years been grappling with the problem of methane. Occasionally, companies use energy-intensive schemes to either liquefy natural gas or convert methane to methanol with high-temperature steam. But in the mid-1980s, researchers first discovered that some metal-containing organic compounds could catalyze the conversion of methane to methanol without adding extra energy. The problem was that less than 2% of the methane was converted, making such catalysts commercially worthless. The new catalysts, developed by researchers at Catalytica Advanced Technologies in Mountain View, California, transform 70% of methane to a final compound known as methyl bisulfate, which itself is easily transformed to methanol. And that yield is "a big deal," says Labinger.

Converting methane to methanol is actually extremely easy: All it takes is a match. At about 625 degrees Celsius, molecules of methane, each made up of a carbon atom bound to four hydrogens (CH_4), begin to burn, with oxygen displacing the hydrogens. Methanol (CH_3OH) is one of the first byproducts. But the trouble is that once methane begins to burn, "you can't stop that reaction," says Roy Periana, who led the Catalytica team. In no time, oxygen atoms oust all the hydrogens, leaving only everyday carbon dioxide. The trick is to stop the process in midburn.


SUPERSTOCK

Up in smoke. Converting methane to methanol could end the wasteful flaring of natural gas.

Periana likens the challenge to rolling a ball down a hill and getting it to stop in the shallow valley at the bottom rather than continuing up and over the small incline on the other side and then off a cliff. What's needed, says Periana, is a way to lower the height of the first hill—the amount of energy needed to start methane burning—or raise the second hill—the barrier to methanol or any other product reacting. Periana and his colleagues have managed to do both.

They first accomplished these tasks in 1993 with a catalyst of mercury-based salts. In a bath of sulfuric acid, this catalyst converts 43% of methane to methanol in a single pass (*Science*, 15 January 1993, p. 340). But because mercury is toxic, the researchers kept searching for a better alternative. Now, Periana and his colleagues have developed a new catalyst based on platinum—an expensive but nontoxic metal—that also contains a small, nitrogen-rich organic group called a bipyrimidine, which helps control the metal's reactivity. When the catalyst is dissolved in a bath of sulfuric acid, it encourages methane to shake loose one hydrogen—transforming methane to methyl—and form a bond with the platinum. But it does so at just 200 degrees, which means that the ball in this case starts atop a much smaller hill. Next, the sulfuric acid solvent swipes a pair of electrons from the platinum. That frees the methyl to grab a bisulfate group (OSO_3H) from the surrounding solvent, creating the final methyl bisulfate (CH_3OSO_3H), which then drops off the catalyst.

The reaction stops at that point. "The catalyst doesn't like the bisulfate," says Periana, so rather than pulling another hydrogen off the methyl bisulfate, the catalyst grabs a fresh methane molecule and works on that. In effect the second hill—the barrier to the methyl bisulfate reacting—is pushed higher. The outcome is that more than two-thirds of the methane molecules that pass through the catalyst-loaded solution are converted to methyl bisulfate and then left alone.

The hitch is that the end product is methyl bisulfate rather than methanol. To finish the job, the researchers must separate out the sulfuric acid and add water to convert the methyl bisulfate to methanol. Those extra steps currently make it difficult to say whether the process will be economical on an industrial scale, says Labinger. Consequently, Periana and his Catalytica colleagues plan to continue their efforts to find catalysts capable of making methanol directly at high yields, as well as operating in more benign solvents than sulfuric acid. But even without these advances, the current catalyst may open the door to making use of some of the world's vast untapped reserves of natural gas.

–Robert F. Service