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