spouting like a fountain from a rift. Whatever form the eruptions take, the magma is like nothing seen on Earth for a long time, says planetary scientist Dennis Matson of JPL. The temperatures of basaltic magma top out at 1500 K, so Io's magmas are probably ultramafic—so rich in magnesium and iron that their melting points approach 2000 K, he says.

Because an ultramafic composition is the result of repeated cycling that concentrates magnesium and iron, this fits planetary scientists' latest view of Io as the scene of the most intense geological processing in the solar system. Jupiter has driven enough heat through the moon to melt every bit of it 40 times over, estimate Keszthelyi and McEwen. To find a time on Earth that was in any way comparable, "you're looking at a period before continents formed," says Matson, a time that is not preserved in Earth's geologic record. The Earth of more than 3.8 billion years ago would still have been hot from its formation and heated further by frequent comet and asteroid impacts. It may have been destroying and recycling its crust so rapidly—as Io appears to be doing now—that continents couldn't form.

Scientists using Io to understand the mysteries of the early Earth will get a windfall if Galileo makes its first really close pass by Io, scheduled for October 1999. Assuming Jupiter's fierce radiation belts haven't killed or crippled the spacecraft by then (*Science*, 13 March, p. 1628), planetary geologists will get a good look inside the gates of hell.

–Richard A. Kerr

RENEWABLE ENERGY

A Record in Converting Photons to Fuel

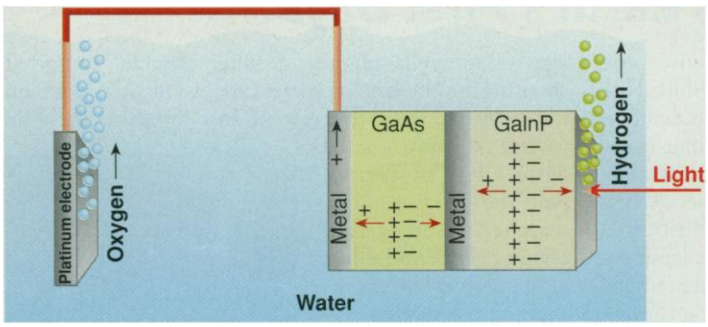
It's the ultimate in clean energy: Generate fuel from water using only the power of sunlight, and when the fuel burns, it gives off nothing but water. Outlandish as it sounds, the dream was accomplished decades ago by using solar energy to split water into its components, oxygen and hydrogen—a powerful fuel that can be used to run everything from power plants to cars. But as a commercial proposition, the process has been a nonstarter because it's so inefficient and expensive. The two steps involved—generating electricity from sunlight and using it to split water—normally take place in separate devices, and energy is lost in between.

Now on page 425, researchers at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, have come up with a single device that accomplishes both tasks and has set a world record in efficiency for converting photons to fuel. The new solar-powered water splitter, built by NREL chemists John Turner and Oscar Khaselev, converts about 12.5% of the energy in sunlight to gaseous fuel—nearly double the previous record achieved by a conventional two-step process.

Marye Anne Fox, a chemist at the University of Texas, Austin, calls this efficiency "impressive." Fox's UT colleague Adam Heller adds that the new device avoids one pitfall common to conventional solar water splitters: It doesn't require the additional external energy that others need to get the job done. The NREL device "is a stand-alone cell that is nicely efficient and no longer needs external energy," says Heller. "It's a nice milestone." Even so, it's not about to catalyze a wholesale switch from fossil fuels to hydrogen, because the semiconductors at the heart of the new devices are expensive; they are currently used only for specialized applications, such as powering satellites.

Splitting water to create gaseous hydrogen and oxygen is quite simple. Stick a pair of metal electrodes into water, apply a voltage across them, and presto, oxygen gas is liberated at one electrode and hydrogen gas at the other. The process, known as electrolysis, is commonly used to produce pure hydrogen for making everything from food oils to computer chips. But it's expensive and requires fossil fuels to generate the electricity that powers the process. So energy researchers have long dreamed of using solar energy to drive the electrolysis.

The basic principle of generating electricity from sunlight is, again, well known. When photons from sunlight strike normally static electrons in some semiconductor materials, they kick the electrons into a higher energy level, allowing them to roam about. Left behind are electron vacancies, or "holes," that act like positive charges that can also migrate through the material. Additional semiconductor layers on either side of the absorbing layer then channel the electrons and holes in opposite directions, creating an electric current that can perform work or be stored in a battery. But, unfortunately, combining this so-called photovoltaic effect with electrolysis in a single device isn't simple.



SOURCE: KHASELEV *ET AL.*

Solar water splitter. Two different semiconductors produce electrical charges with just the right energies to catalyze the split.

First, there's a compatibility problem. Solar cells must sit in water in order to split it into hydrogen and oxygen, but semiconductors that are efficient light absorbers are often unstable in water. Then there's the energy problem. A water molecule splits into hydrogen and oxygen atoms only if each atom absorbs electrical charges packing very precise—and different—amounts of energy. In conventional electrolysis, the metal electrodes carry electrical charges with a wide energy range, allowing those with just the right amount of energy to catalyze the split. But semiconductors are more finicky. Charges in these materials can exist only at well-defined energy levels, and "nature has not been kind to us in this instance," says Turner. The only semiconductor materials that produce electrical charges at just the right levels to generate both hydrogen and oxygen are very poor absorbers of sunlight.

To overcome these problems, Turner and Khaselev constructed a sandwichlike device that pairs the talents of two different semiconductor materials. One—made from gallium indium phosphide—absorbs ultraviolet and visible light and produces mobile electrons with the right energy to produce hydrogen. The other—made from gallium arsenide—absorbs infrared light and produces holes with the right amount of energy to produce oxygen. Gallium indium phosphide is stable in water, so it can be used directly as an electrode. But the unstable gallium arsenide layer is sealed with a transparent epoxy coating to protect it, and the holes are shuttled to a separate platinum electrode.

Although the new device appears to be efficient and stable, Turner estimates that it would produce hydrogen at three times the cost of the cheapest method for bulk production of hydrogen, in which hydrogen atoms are stripped from natural gas by superheated steam. Turner and his colleagues are now trying to engineer cheaper semiconductors to perform the water-splitting reaction. If they succeed, the energy of the future may finally find its way to the present.

–Robert F. Service