

At Gulf, we're working on a way to light lights, cook meals, and heat houses with the energy stored in water?

"You probably remember from grade school science that water is two parts hydrogen and one part oxygen," says Dr. John Norman.

Here at General Atomic Company, a subsidiary 50% owned by Gulf Oil, a project is under way to

"There are 116 million cubic miles of water on earth, and hydrogen is more than 10% of that. It's a very abundant energy resource that we can use."



extract hydrogen from water for use as a fuel for heating, cooking, or anything that now uses petroleum or natural gas.

The extraction process is called thermochemical water-splitting. We know it works because we've done it. But it takes high temperatures—about 1500° F—so it's rather expensive.

"It may be the turn of the century before it becomes commercial. But it's an attractive idea. Hydrogen from a gallon of water has about half as much energy as there is in a gallon of gasoline."

Hydrogen can be made into a liquid or gaseous fuel. It can be transmitted long distances more cheaply than electricity. And when hydrogen burns, it's converted back into water. Very tidy!

At Gulf, our first priority is to get all the oil and natural gas we can out of resources right here in America. But we're working on a lot of other ideas, too. Thermochemical water-splitting is one of them. We are also working on underground coal gasification, solar research, liquefied coal and other synthetic fuels, geothermal energy, and other alternative energy sources.

Basically the business we see in is energy for tomorrow.



Gulf people:
energy for tomorrow.

Gulf Oil Corporation



SPLITTING WATER



The fuel of the future may be hydrogen gas, separated from water by artificial photosynthesis
by PAMELA WENTRUB

I believe that water will one day be employed as fuel, that hydrogen and oxygen which combine it, and simply re-together, and furnish us with heat the source of heat and light...
—Julius Verne, 1874
The Mysterious Island

Like so many other of Julius Verne's writings, this prophecy may become reality. If the hydrogen on earth were readily accessible, it could become a major and virtually unlimited source of energy. Passed through fuel cells, it could generate electricity. Cooled and liquefied, it could serve as fuel for modified internal combustion engines or liquid-fuel rockets. Two and a half times the energy of an equivalent weight of gasoline, and 100 times as great, environmental advantage as a fuel, the product of its combustion is water.

But most commercial hydrogen is looked up, bound with oxygen in the form of water. Electric current, passed through water in a process called electrolysis, can break that powerful bond, releasing hydrogen as

well as oxygen. But there is one real drawback: the amount of electricity to produce practical amounts of hydrogen is prohibitively expensive. Nature has a way. For hundreds of millions of years, plants have been splitting water in design and oxygen with chloroplast cellular factories energized only by sunlight.

Now man is copying nature. Nobel Prize laureate Melvin Calvin, a chemist at the University of California at Berkeley, has produced synthetic chloroplasts. Natural chloroplasts found in the cells of green plants, are stacked structures that manufacture the carbohydrates needed to sustain nearly a creature on earth. They produce the food photosynthesis, a chemical process that uses sunlight, water, and carbon dioxide. In green, sunlight striking a chloroplast is hydrogen from water, allowing the hydrogen to combine with carbon dioxide from the air, form the carbohydrates needed for the plant's growth. The oxygen released from the water molecule drifts away to become part of the atmosphere.

Calvin's artificial chloroplasts—the spheres of oil floating in water in an Berkeley laboratory—are different from the natural thing in one essential way: they are designed to help hydrogen combine with carbon dioxide to form raw plant material. Instead, as the diagram on the opposite page shows, they release hydrogen in the form of a gas.

When Calvin completed mapping the pathways of carbohydrates, the feat for which he won his Nobel in 1961, some scientists believed that the day was not far off when ample quantities of hydrogen could be produced economically. Although that goal, however, turned out to be enormously difficult, it required learning about the hundreds of chemical reactions that take place during the first phase of photosynthesis. Calvin and others have spent the past 20 years trying to decipher those reactions.

What they finally succeeded with was a very directly complex process. The membranes surrounding a natural chloroplast are bound inside and out, with molecules of chlorophyll, the green pigment that gives a plant its color. Whenever a photon, a unit of light energy, strikes a chloroplast, energy is transferred to an electron in a chlorophyll molecule. The energized electron leaps from the molecule, leaving with a "hole" that would ordinarily pull the electron back. But the electron path through the chloroplast membrane, which traps it and allows it to be captured by a second molecule of chlorophyll located inside the membrane.

At this point water, brought up through the roots and present in the plant tissue, is