# AMAZING SCIENCE

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# Fuel-Cell Finish

Well, we're back to finish the series on fuel cells. Let's get right to it and construct a derivative of the fuel cell made famous by NASA.

### Hydrogen-Oxygen Fuel Cell

This fuel cell, see Fig. 1, would more properly be called an *open-air fuel cell*, because leaving one side of the cell open to the atmosphere provides the oxygen. Using pure $O_2$ at the oxygen electrode *provides superior performance.* However, the additional work required for construction and subsequent operation doesn't merit the performance increase.

Gather together the items listed in the sidebar. While you're out shopping, pick up some galvanized nails (a good source of zinc) and some *hydrochloric* acid—muriatic acid (found in home-improvement stores for cleaning brick and stone); you'll need those items to produce hydrogen—the fuel cell's fuel.

The fuel cell is make from ¼-inch *thick plastic. The plastic is fashioned* into three 2½-inch squares. Two of the plastic squares have an internal 1¾-inch square cut out from the center, see Fig. 2. Two gaskets are cut to the same dimensions as the two internal plastic pieces. The nickel screen is cut to fit inside the cell and overlap the internal cutout. A tab is placed on each electrode that extends outside the fuel cell to make electrical connections easy. The outer plastic piece has two additional center holes for gas vents.

Make a solution by mixing one gram of platinic chloride in 100 milliliters of distilled water. Clean the nickel screens in the alcohol to remove any grease or dirt. Then plate the two nickel screens with platinum *by soaking them in the* platinic chloride solution until they turn black.

To activate the fuel cell, soak some filter paper in a solution of potassium hydroxide. You can use the same solu*tion from last month's* alcohol fuel cell.

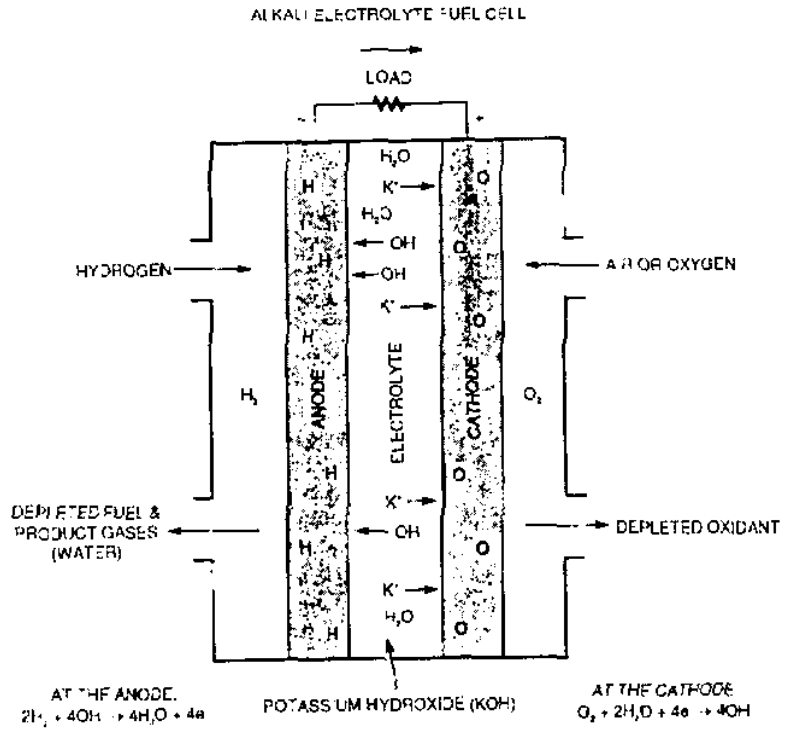


*Fig. 1. An alkali-electrolyte hydrogen/oxygen fuel cell, in the process of combining hydrogen and oxygen, strips a few extra electrons during the chemical reaction to create an electromotive force electricity.*

After the filter paper has absorbed the electrolyte, blot the excess liquid from the paper with a blotter, leaving the filter paper damp.

Next, assemble the fuel cell. Place a gasket on the outside case, followed by a nickel screen, *filter paper, nickel screen,* second gasket, and finally the open plastic piece. Make sure during assembly that the two nickel screens don't touch one another: if they do touch, they will short the output of the fuel cell.

Use the plastic machine screws and nuts to keep the assembly together.

### Hydrogen Gas Production

Many experimenters generate hydrogen gas from the electrolysis of water. I did not want to set up the apparatus to *do this; I wanted* a fast and simple method of $H_2$ production. Zinc and magnesium react with hydrochloric acid to generate hydrogen gas. I assume that you've already picked up the muriatic acid (a solution of hydrochloric acid) and galvanized nails—zinc is the "galvanizing" coating that protects iron and steel from the elements when used outside. Roofing nails are a good example. Although I've probably already said it until I'm "blue in the face," always wear gloves and eye protection when handling acid.

Prepare a gas-generating vessel using a jar with a metal screw-on lid, see Fig. 3. First, drill a ¼-inch hole in the cover of the jar. Next, pass an inch or two of ¼-inch rubber or silicone tubing through

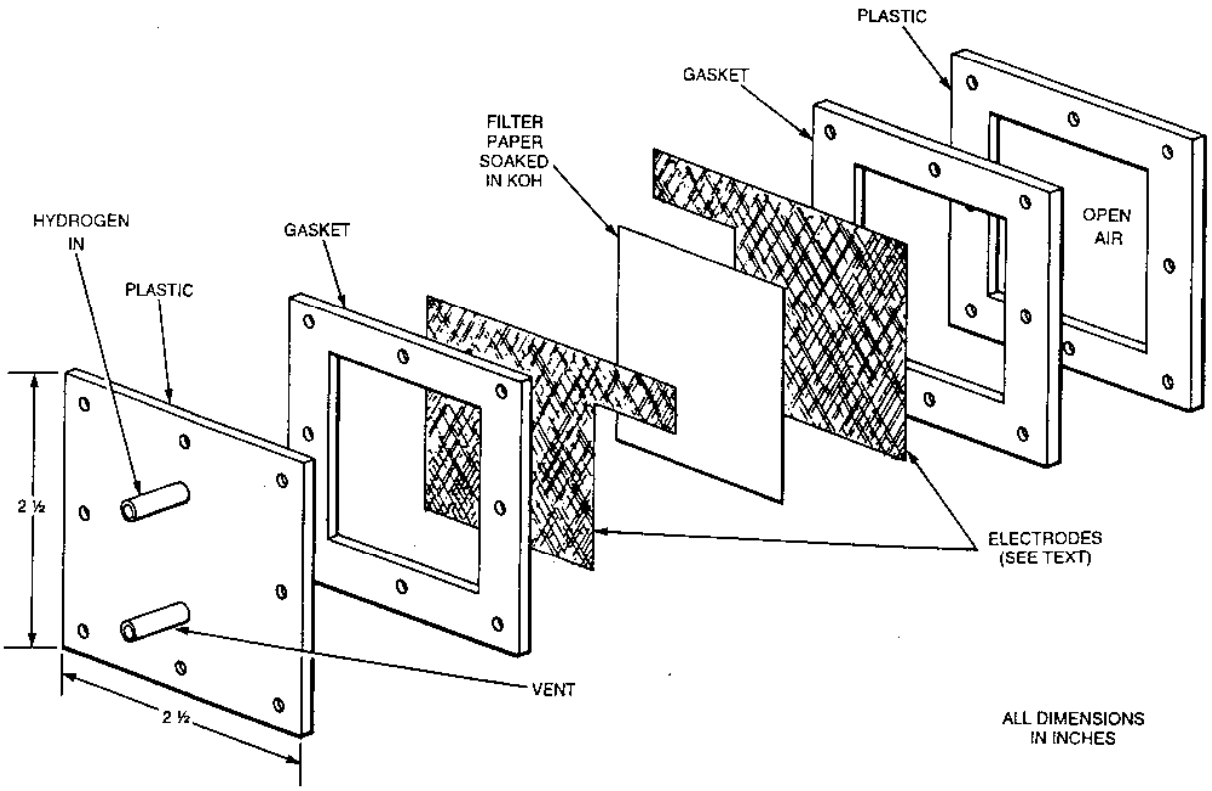


*Fig. 2. The construction cross section of the hydrogen/oxygen fuel cell is a sandwich of electrodes, electrolyte-soaked paper, and gaskets surrounded by a pair of flat plastic end pieces.*

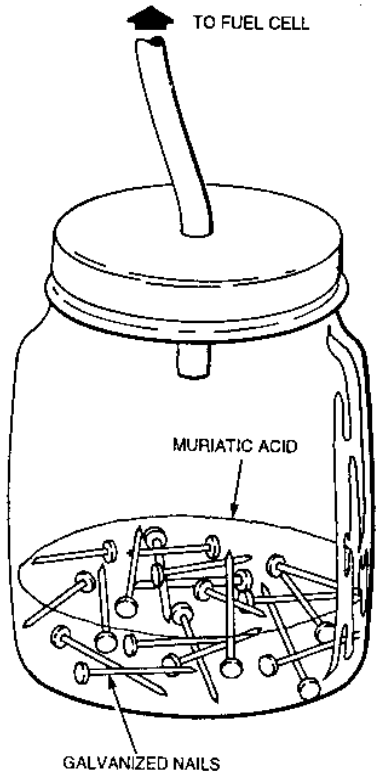


*Fig. 3. A "quick and dirty" hydrogen-gas generator uses galvanized nails and hydrochloric acid to produce hydrogen gas.*

the hole. Make the junction between the jar lid and tube airtight by coating the seam—both on the top and bottom of the lid—with aquarium silicone sealant. Allow the sealant to dry (about 24 hours).

To generate hydrogen gas, cover the bottom of the jar with galvanized nails. Pour in enough muriatic acid to cover the nails. Screw the lid of the jar in place. Let the hydrogen gas vent for a minute through the rubber tube and then attach the open end of the tube to the fuel cell.

Remember, muriatic acid is corrosive; take proper precautions when handling this chemical. Hydrogen gas is explosive. Do not operate the hydrogen-gas generator near open flames or sparks (remember the Hindenburg!). The hydrogen-gas generator, when generating gas, must always remain open to the atmosphere, allowing the hydrogen gas to vent. This will prevent any gas pressure from building that could cause the jar to explode.

The finished fuel cell, see Fig. 4, generated between 0.8 and 1.0 volt. You should expect similar results with your fuel cell.

Now that we've taken that "small step for [a] man" in building NASA-style fuel cells, let's move on to...

### Microbial Fuel Cell

The "bug battery," as it's affectionately known, uses yeast to generate electric power. Originally, I believed that the yeast cells metabolized sugar to produce alcohol and that the alcohol became the fuel to power the fuel cell. While that secondary type of fuel cell has been built many times, it is not the principle behind this fuel cell. The actual process is more complex and elegant. Essentially, current is generated by cellular respiration and digestion!

I was surprised to find out that bug batteries aren't new technology. In fact, they date back to 1910, when Michael

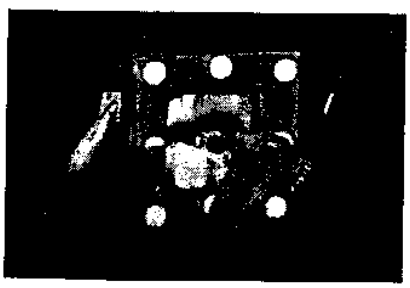

*Fig. 4. The finished hydrogen/oxygen fuel cell might not be as pretty as some of NASA's best space-faring designs, but it works the same.*

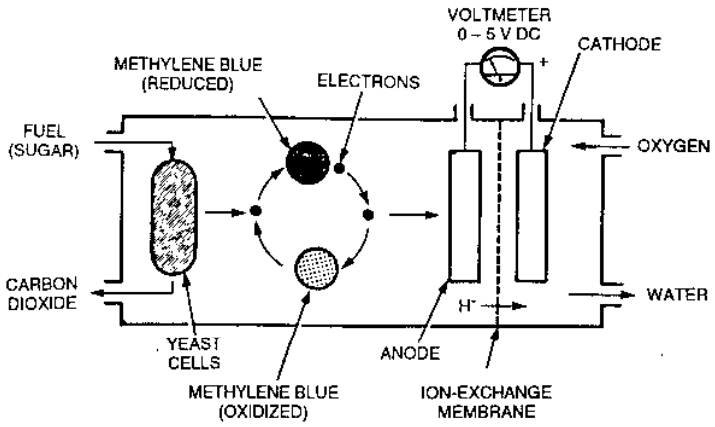


*Fig. 5. A microbial fuel cell uses yeast as the active element, with methylene blue as a mediator.*

Potter placed a platinum electrode into a solution of yeast and another in an organism-free solution and measured a current. In 1931, Barnett Cohen, a biochemist at Cambridge University, put together a 35-volt microbe-powered battery.

The basic bio-chemical mechanics of microbe-powered fuel cells follows the process of digestion and respiration. Carbohydrates, such as sugars, starches, and cellulose, are basic food nutrients. When a carbohydrate is broken down, electrons in the molecule are released (oxidized). Those electrons are used (reduced) in intermediate compounds before they finally react with oxygen in respiration:

$$6O_2 + 24H^+ + 24e^- \rightarrow 12\ H_2O$$

Electrons may be stolen from the respiration cycle by a *mediator*. The mediator ferries the electrons to an electrode. To complete the circuit, a second (positive) electrode is needed in the solution, usually separated by an ion-exchange membrane.

A basic microbial fuel cell is illustrated in Fig. 5. On the left side of the illustration, we have sugar being fed to a yeast culture. The yeast cells digest the sugar, producing carbon dioxide. The electrons in the digestion cycle are stolen by the mediator—in this case, methylene blue—and delivered to the electrode. Hydrogen ions are able to pass through the ion-exchange membrane to combine with the electrons on the cathode side with oxygen gas to form water.

In the demonstration bug battery and microbial fuel cell, a solid oxidizing reagent (potassium ferricyanide) is used in place of oxygen gas.

## Bug Battery Design

A basic bug battery is shown in Fig. 6. The electrodes are carbon rods salvaged from old dry-cell batteries. The electrodes, once removed from the batteries, should be cleaned first with alcohol to remove as much chemical compound as possible and then washed in distilled water and allowed to dry.

Standard metal electrodes should be avoided when constructing a bug battery because the metal could cause spurious electric current from its electrochemical dissolution.

First, one needs a standard phosphate buffer with a pH of 7.0 made by dissolving 4.08 grams $Na_2HPO_4$ and 3.29 grams $NaH_2PO_42H2O$ in 500 milliliters of distilled water.

The oxidizing solution (catholyte) is a 0.01-0.10 Mole solution of potassium ferricyanide in the standard phosphate buffer. (See the warning on potassium ferricyanide.)

The anode and cathode of this cell are separated by a length of tubular dialysis membrane that's made into a bag by tying a knot in one end. The bag is filled with the second electrode—the microorganisms (yeast or E.coli) suspended in the pH 7.0-buffered solution and a mediator (methylene blue 5-10 mM or

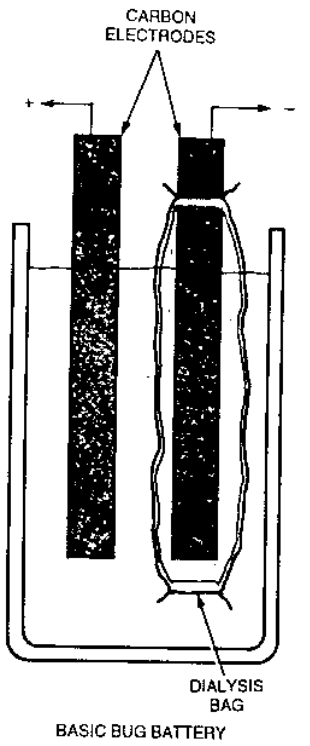


*Fig. 6. A simple "bug battery" contains the living portion of the fuel cell in a dialysis membrane. Carbon electrodes collect the electrical energy.*

milliMole in water). The top of the dialysis bag is tied with string. The bag/electrode assembly is placed in the vessel with the potassium ferricyanide solution.

The current and voltage generated by this bug battery is measured in millivolts and microamps. The dialysis bag is permeable to ions, including the potassium ferricyanide oxidant. However, the dialysis membrane will only last for about 30 minutes—more than enough time for a demonstration.

**FUEL-CELL COMPONENTS**

| | | |
|---|---|---|
| Nickel Screen | 150-200 mesh | 2.5 × 5 inches long |
| Platinic Chloride | | 1 gram |
| Isopropyl Alcohol (rubbing alcohol) | | 1 pint |
| Potassium Hydroxide | | 500 grams |
| Distilled Water | | 2 liters |
| ¼-inch thick plastic acrylic plastic | | |
| Filter Paper | | |
| 1/16-inch rubber gasket material | | |
| 6-32 plastic machine screws and nuts | | Eight |

## Microbe Cell Recipe

One may also purchase a microbial fuel cell in kit form, see Fig. 7. However, be aware that the kit does not include

*(Continued on page 53)*

I welcome feedback on this and all previous "Service Clinic" columns. I recognize that the series on VCRs probably dragged on about 50 percent too long and won't make that mistake again.

What would you like to see in this column? How about the format? Would you like to have specific questions addressed? Please send your comments to me at the e-mail address at the top of this column.

See you next time! P

## AMAZING SCIENCE

*(continued from page 49)*

any of the chemistry or microbes to make it work. To make the kit work, you need:

- Dried baker's yeast
- 50 milliliters of methylene blue solution (10 mM)
- 50 milliliters of glucose solution (1M)
- Potassium ferricyanide

In addition, you will also need 0.1 Mole solution of phosphate buffer with a pH of 7.0 made by dissolving 4.08 grams of $Na_2HPO_4$ and 3.29 grams of $NaH_2PO_42H_2$ in 500 milliliters of distilled water.

If you do not have the means to obtain or make the above-mentioned chemistry, do *not* purchase the microbial fuel-cell kit.

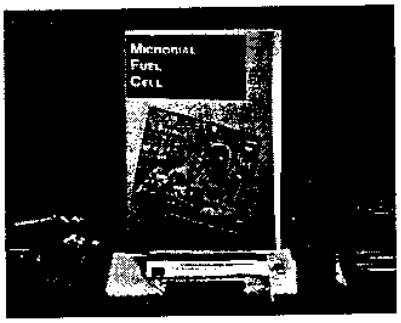


*Fig. 7. Here's an experimenter's microbial fuel-cell kit. You add the chemistry and microbe portion of the formula.*

### Toward The Future

While microbial fuel cells are just starting to peek out of the laboratories, two key microbial fuel-cell researchers—Peter Bennetto and John Stirling—see a bright future for bug batteries. Looking ahead, they anticipate electric cars getting eight miles per pound of sugar. Bug batteries can theoretically provide energy densities comparable to lithium. P

### CHEMICAL WARNING

Potassium ferricyanide is poisonous. Eye protection should be worn when handling this chemical. If the solution comes into contact with the eyes, flood them with tap water and seek medical attention. If swallowed, give plenty of water to drink and seek medical attention.

### SOURCE INFORMATION

The microbial fuel-cell kit in this month's text is available for $100. NY residents must add appropriate sales tax.

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