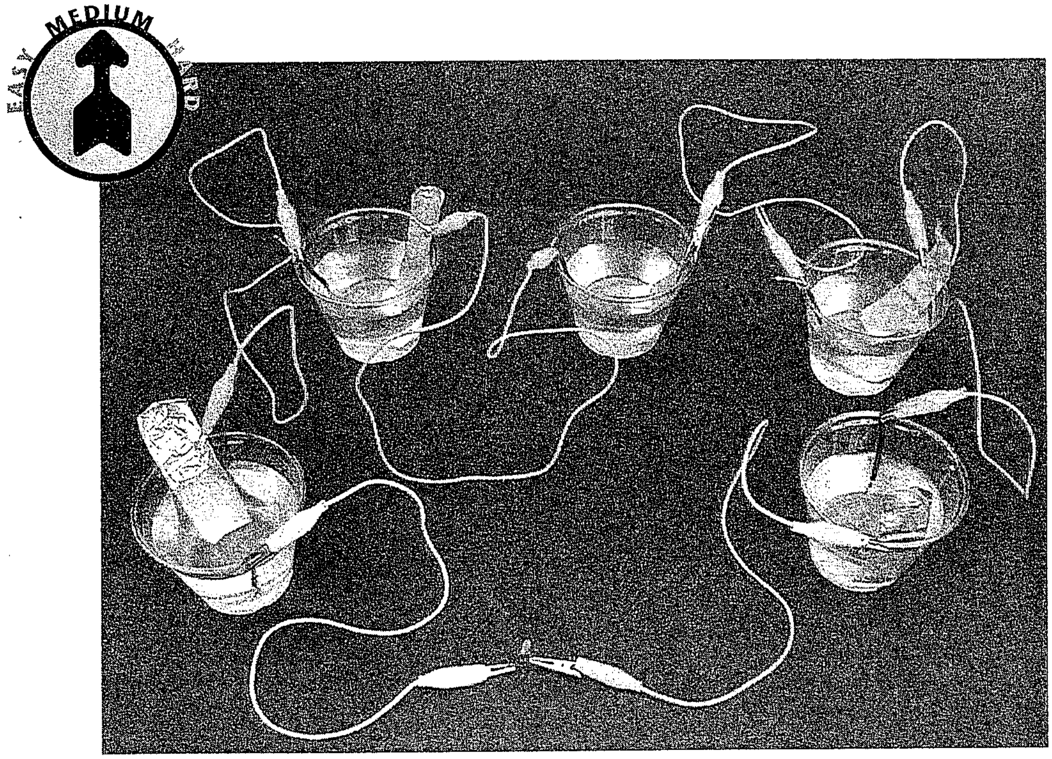
Saltwater Pentacell

Current events in electrochemistry.

Make your own battery! Create five simple cells from aluminum foil, copper wire, and salt water, and connect them in a series. Together, they produce enough current to light an LED.



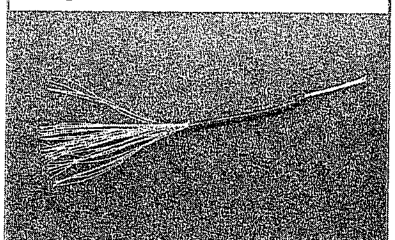
Materials

- scissors
- 20 in (50 cm) of stranded copper wire, 18 or 20 gauge; ordinary lamp cord works well—just split the two strands of a 10-in (25-cm) piece
- wire strippers
- aluminum foil, about 8 in (20 cm) from a normal 12-in-wide (30-cm) kitchen roll
- table salt (sodium chloride), about 2 tablespoons (30 mL)
- water, about 1 quart (1 L)
- pitcher or bowl with a spout
- 5 plastic cups
- 6 alligator-clip leads (e.g., RadioShack #278-1156 or #278-1157; the latter have heavier-gauge wire)
- light-emitting diode (LED); RadioShack #276-330 is an inexpensive LED that works very well for this application (some LEDs glow a little more brightly than others, but most seem to work satisfactorily)
- vinegar (acetic acid), about 1 tablespoon (15 mL); possibly optional—see Helpful Hint

ASSEMBLY

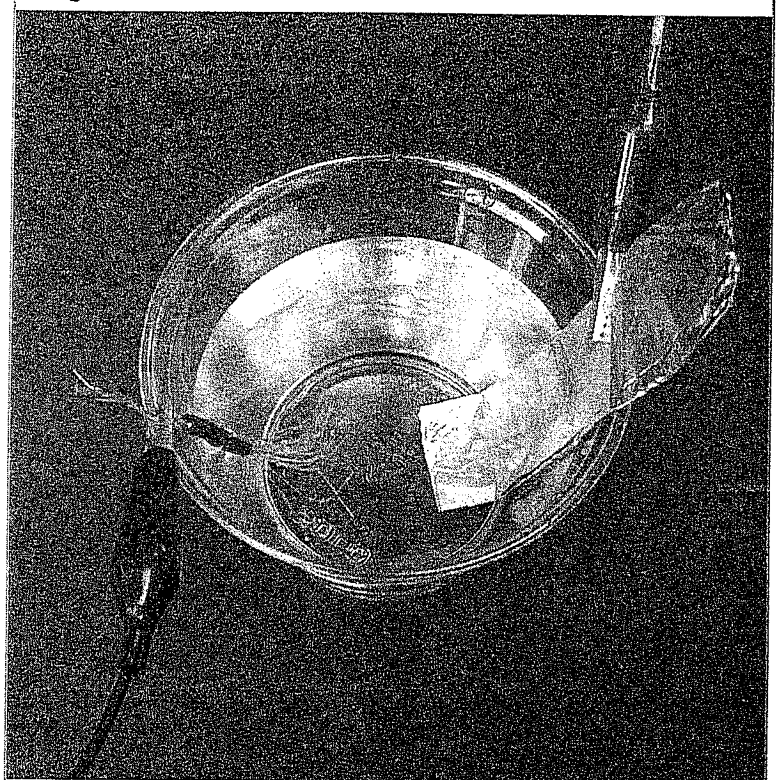
1 Cut the wire into five sections of 4 inches (10 cm) each. Strip 2 inches (5 cm) of insulation off one end of each of the five pieces, and then strip 1 inch (2.5 cm) of insulation off the other end of each piece. This will leave a 1-inch (2.5-cm) piece of insulation on each piece that will act as a sleeve holding the bundle of fine wires together. Twist the strands at the 1-inch (2.5-cm) end of each piece tightly together. Then separate the strands of each 2-inch (5-cm) end so that the loose strands look something like a broom (see figure 1). These are your copper electrodes.

Figure 1



Copper electrode

Figure 2



Clip electrodes to the top of each cup.

2 Cut five pieces of aluminum foil, each about 4 inches × 4 inches (10 cm × 10 cm). Fold each piece in half, and then again in half parallel to the first fold, so that it ends up four layers thick, with final dimensions approximately 1 inch × 4 inches (2.5 cm × 10 cm). These are your aluminum electrodes.

3 Add the salt to the water and stir. This is the *electrolyte solution*—a liquid that can conduct electricity.

4 Fill each cup about three-quarters full of the electrolyte solution. Then put one aluminum electrode and one copper electrode in each cup. The broomlike end of the copper electrode should be in the solution.

5 Each cup and its electrodes make up one saltwater cell. Connect the cells in series by clipping alligator-clip leads from the copper electrode of one cup to the aluminum electrode of the next cup, and so on, until all five cells are connected (see the opening photo). As you attach each alligator clip to an electrode, you can simultaneously clip the electrode to the top of the cup to hold it in place as shown in figure 2. When you are done, the aluminum electrode in the first cup and the copper electrode in the fifth cup should be left unconnected.

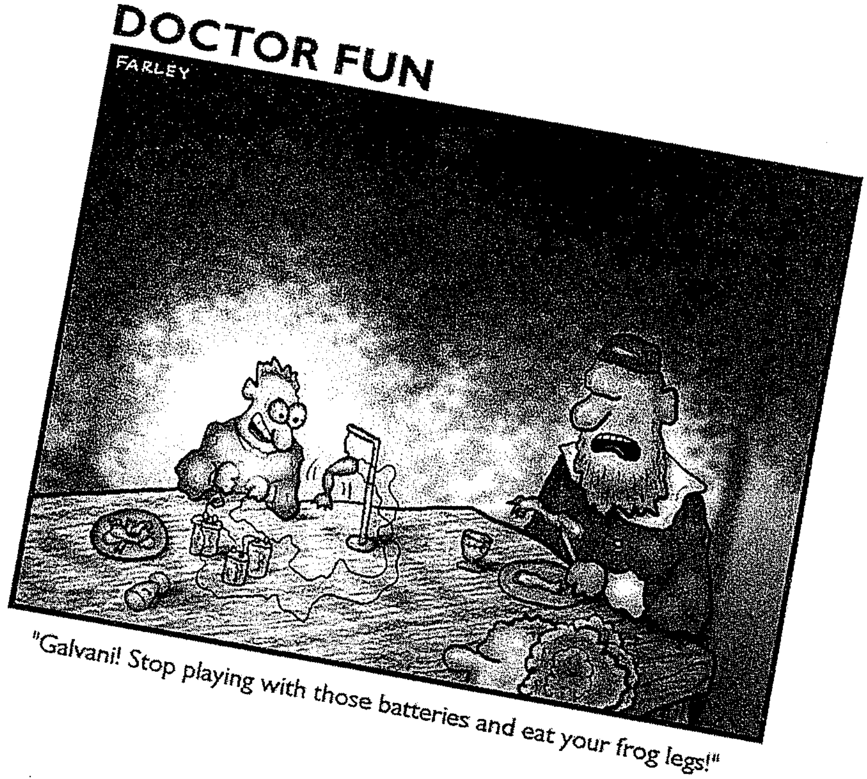
6 Adjust the two electrodes inside each cup as necessary to make sure that they do not touch each other.

7 Use alligator-clip leads to connect the aluminum electrode in the first cup to one leg of the LED and the copper electrode in the fifth cup to the other leg.

To Do and Notice

Did the LED light? Sometimes you have to look directly into the end of an LED to tell if it is lit or not. If you are in doubt, darken the room or cup your hands around the LED to block the room light. If the LED isn't lit, reverse the legs. (A diode—in this case a light-emitting diode, or LED—allows current to flow in only one direction. If it's connected "backwards," it won't light.) If the LED still doesn't light, add vinegar to each cup (see Helpful Hint).

Try using four cells to light the LED. If it lights, then try using three cells. What is the smallest number of cells that will do the job?

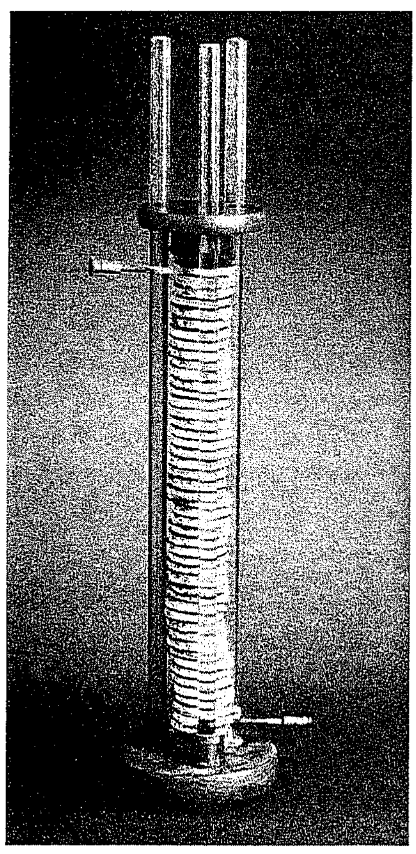


Helpful Hint

If the LED won't light after you have followed the normal procedure, try adding a half teaspoon (2.5 mL) of vinegar to each cup and stirring. The acidity of water varies from place to place, and if your water is not acidic enough, the vinegar may make a difference. If your water is already acidic enough, you probably won't need to use the vinegar.

What's Going On?

Each cup, with its electrodes and the electrolyte solution, is a simple electrochemical cell. The two electrodes are made of dissimilar materials (in this case, two different metals) with different chemical activities. A tug-of-war for electrons occurs between the two electrodes, resulting in a potential difference, or voltage. In the cells you have made, aluminum is the more active metal—atoms of aluminum lose their electrons more easily than do atoms of copper. The potential difference causes electrons lost by the atoms in the aluminum electrode to travel through the LED to the copper electrode, and this flow of electrons is the electric current that lights the LED.



Each layer in this stack is an electrochemical cell. The entire pile is a battery, known as a voltaic pile.

If this flow of electrons continued, and nothing else happened, then fairly quickly there would be a buildup of electrons on the copper electrode and a shortage of electrons on the aluminum electrode.

Because electrons have a negative charge, this would result in the copper electrode becoming negatively charged and the aluminum electrode becoming positively charged. Additional electrons that tried to move from the aluminum to the copper would be repelled by the copper and attracted back to the aluminum, and electron flow would stop.

This is where the saltwater electrolyte solution comes into play. Salt is sodium chloride, and when it's dissolved in water, it forms positive sodium ions and negative chloride ions. The positive sodium ions are attracted to the negative copper electrode, where they participate in neutralizing the extra negative charge through chemical reactions. Likewise, the negative chloride ions are attracted to the positive aluminum electrode, where they participate in neutralizing the extra positive charge. Therefore, there's a constant flow of charge from one electrode through the LED to the other electrode and then through the electrolyte solution, forming a complete circuit.

The five cells make up a *battery* when they are connected in series. (A battery is two or more electric cells that are joined together.) The five-cell battery has five times the voltage of each individual cell.

The chemical reactions that occur at the electrodes of a simple cell can be summarized in chemical equations. The equations for some simple cells can be found in high school and college chemistry texts. The detailed chemistry of some batteries, however, is quite complicated, and in many cases is not completely known.

It takes a minimum voltage to light an LED. If you don't have enough cells, you won't provide the necessary voltage.

So What?

The big idea in this very simple battery is the difference in the abilities of two materials to lose and gain electrons. This same idea is at the heart of the wide variety of batteries used for everything from flashlights to digital watches. The materials, size, and shape of these batteries may differ from those of this saltwater pentacell, but the general principle remains the same.

Did You Know?

Voltage and Current Are Different!

In any electrochemical cell, the greater the difference in the activity of the two materials making up the electrodes, the greater the strength (voltage) of the cell. The larger the size of the electrodes, the greater the number of electrons that can be pulled per second and the larger the current (measured in amperes, or amps).

Going Further

A Solid Choice?

Why does this snack use stranded wire with the wires spread apart? Try substituting a piece of 18- or 20-gauge solid copper wire. Do you get the same results?

Metals Are Not Created Equal

Try using other metals for electrodes. Can you find metals that will allow you to light the LED using fewer cells? Galvanized nails can be used for zinc, regular iron nails for iron, old silverware for silver, and brass hardware for brass. (A commonly available nonmetal that can also act as an electrode is carbon pencil lead.)

Measure It

If you have an electrical meter available, try making quantitative measurements of voltage and current for different combinations of metals.

Make a Buzz

Try substituting a 1- to 3-volt piezoelectric buzzer for the LED (e.g., RadioShack #273-065 or #273-075).

Credits & References

We were introduced to this snack by Art Morrill.

Kluger-Bell, Barry. "Pickle Power." *Exploratorium Quarterly* (Electricity Issue) Vol. 14, No. 3, Fall 1990, pages 25–29. This article describes the author's experiments with homemade batteries that use easily obtainable household materials. Also included are instructions for making a simple ammeter to detect electric current.

Shakashiri, Bassam. *Chemical Demonstrations: A Handbook for Teachers of Chemistry*, Vol. 4. Madison: University of Wisconsin Press, 1992. See pages 91–95 for a general discussion of batteries.