TOPIC 5 Portable Power

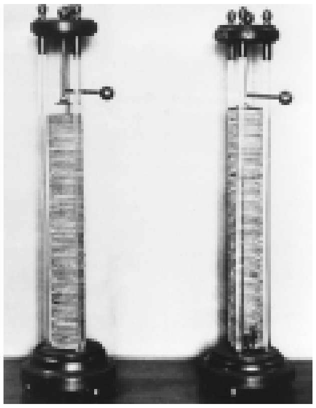


Figure 4.29 "Voltaic piles" like these, invented in 1800, were the first electric batteries.

How many battery-powered devices are in your household? How many batteries do you buy each year in order to transform chemical energy directly into electricity? Worldwide, people buy over 15 *billion* batteries annually. Luigi Galvani (1737-1798), who noticed that a frog's muscle would twitch when touched by two different metals, could hardly have imagined this outcome of his observations.

Galvani believed that the frog's tissues had a unique ability to generate "animal electricity." Later, Alessandro Volta (1745–1827) showed that a voltage could be generated without using living tissue by placing different metals in a solution containing a salt or acid. Today, such a device is called an **electrochemical cell**. You may recall from Topic 2 that a battery is just a series of connected cells.

Find Out ACTIVITY

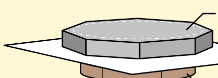
Pile of Power

Volta invented a battery composed of alternating layers of zinc, blotting paper soaked in salt water, and silver. In this activity, you will recreate Volta's design using common materials.

Materials

pennies, nickels, dimes
other coins
copper wires with alligator clips
voltmeter
scissors
paper towels
saturated salt water solution

Safety Precautions



Procedure

Performing and Recording

1. Cut circles about the size of a nickel out of the paper towel and soak them in the salt solution.
2. Construct a single cell as shown in the diagram.
3. Press wires from the voltmeter to the top and bottom coins in the pile. Record the voltage produced.
4. Add another penny and nickel layer to form a two-cell battery. Record the voltage produced.
5. Repeat steps 3 and 4 using more cells, a different arrangement of cell components, or a different combination of coins.

What Did You Find Out?

1. What components and conditions are essential for a cell to operate?
2. Based on your findings, what factors affected the voltage of your battery most?
3. Suggest at least three things you could do to make your battery produce even higher voltages.

Electrochemical Cells

In any electrochemical cell, two metal **electrodes** are surrounded by an **electrolyte**, a substance that can conduct electricity. "Wet cells" use a liquid electrolyte. Car batteries contain several wet cells. "Dry cells," such as those pictured in Figure 4.31, have a paste, plastic, or ceramic solid electrolyte.

Figure 4.30 shows the arrangement of parts in a typical aluminum-copper wet cell, as it could be set up in a laboratory. When the cell supplies current to a circuit, atoms of aluminum become ions and go into the electrolyte solution. As a result, the aluminum strip slowly disintegrates. A similar process occurs in every electrochemical cell: one electrode is consumed as the cell operates. Common "dry cells" sometimes leak when their zinc case, which forms one electrode, is eaten away and the electrolyte paste oozes out of the cell.

The chemical reactions in a cell determine the potential difference (voltage) that the cell can create. Very few single cells can produce more than 2 V. To obtain higher voltages, batteries contain several cells connected in series (Figure 4.31). If a cell cannot be recharged (a **primary cell**), the amount of chemicals it contains determines the total amount of electric energy the cell can produce. A large "D" cell, for example, contains more chemicals than a small "AA" cell, so the "D" cell has a longer working lifetime than an "AA" cell in an identical circuit. Rechargeable **secondary** cells use chemical reactions which can be reversed. In a recharger, electricity is forced through the "dead" cell, rebuilding the original chemicals and allowing the cell to be reused.

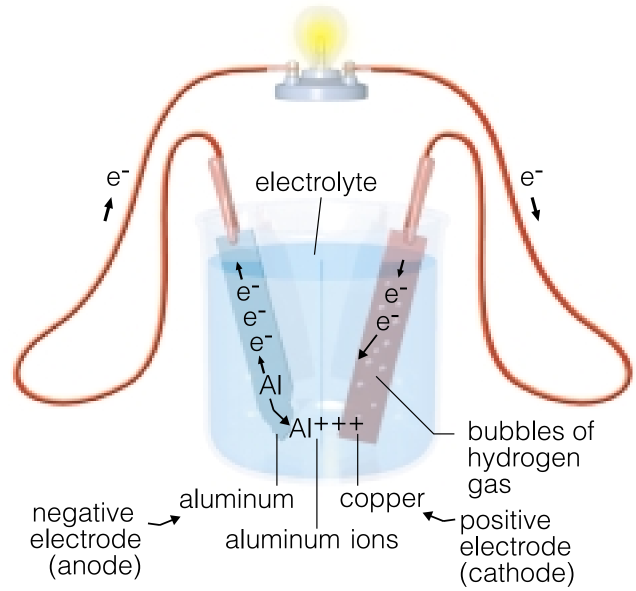


Figure 4.30 Copper and aluminum metal strips are submerged in an acid solution. As electrons move from the aluminum strip to the copper strip through the conducting wire, they light up the light bulb. The circuit is completed by the movement of charged metal ions in the electrolyte.

Figure 4.31 A 9 V battery contains six small 1.5 V cells. Are they connected in series or in parallel?

INQUIRY

INVESTIGATION 4-E

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Super Cell Sleuth

In this investigation, you will study several variations of voltaic cells. You will discover factors that enhance or reduce the usefulness of the cells.

Question

What factors affect the voltage and current from a voltaic cell?

Hypothesis

Formulate a hypothesis about which factors you think will affect the voltage and current produced by a voltaic cell.

Safety Precautions

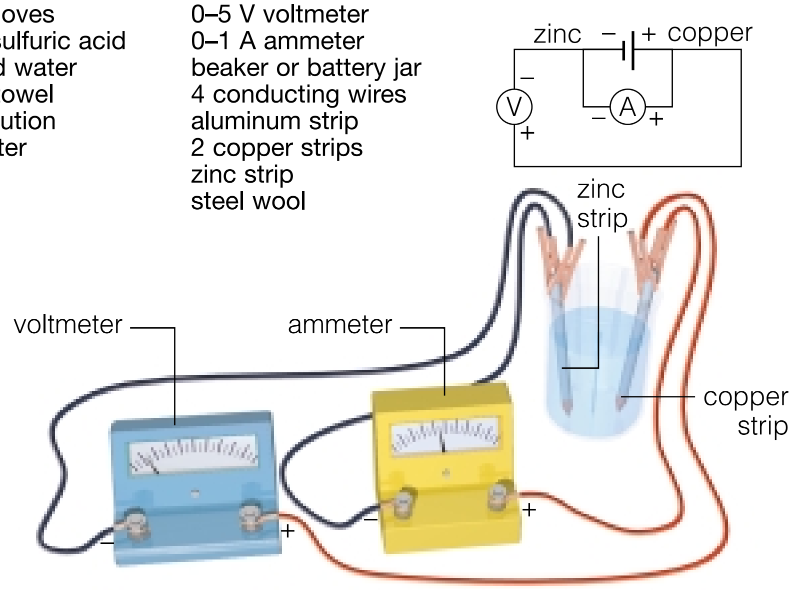
- When handling the metal strips that have been in acid, wear protective gloves and use absorbent paper.
- Inform your teacher if you know you are allergic to latex.
- Sulfuric acid is corrosive. Use only dilute sulfuric acid. If you get acid on your skin or clothing, rinse the area(s) immediately with large quantities of water. Call your teacher at once.

Materials

latex gloves
dilute sulfuric acid
distilled water
paper towel
salt solution
tap water

Apparatus

0–5 V voltmeter
0–1 A ammeter
beaker or battery jar
4 conducting wires
aluminum strip
2 copper strips
zinc strip
steel wool



Procedure

1. Make a table as shown below.
2. Polish both sides of the metal strips with steel wool.
3. Fill the beaker two-thirds full with dilute sulfuric acid.

Factors Affecting a Voltaic Cell

Factor changed	Metal strips	Solution	Current (A)	Voltage (V)	Action at strips
Initial reading	copper and zinc	sulfuric acid			
After running for 5 min	copper and zinc	sulfuric acid			
Wipe bubbles off	copper and zinc	sulfuric acid			
Change surface area of metals in solution	copper and zinc	sulfuric acid			
Use one new metal strip	aluminum and zinc	sulfuric acid			
Use identical strips	copper and copper	sulfuric acid			
Change solution to water	copper and zinc	distilled water			

4. With separate conducting wires, connect the zinc strip to the negative terminal of the voltmeter and the ammeter. Connect the copper strip to the positive terminals of the voltmeter and the ammeter.

5. Check with your teacher to make sure your circuit is wired correctly. Then *carefully* lower the zinc and copper electrodes into the acid solution. Do not let the electrodes or clips on the connecting wires touch.

6. Read and **record** the values for current and potential difference. Note and **record** whether bubbles form on either metal strip.

7. Allow the cell to operate for about 5 min. Watch for the formation of bubbles on the surface of the metal strips. **Record** whether there are more bubbles on the zinc or on the copper strip.

8. Read the meters after the cell has been running for 5 min. **Record** the results.

9. Wearing protective gloves, carefully lift the strips from the solution. Wipe away any bubbles from the metal with paper towel. Put the strips back in the acid solution and repeat step 6.

10. Once again, wipe away any bubbles from the metal strips. Raise the metal strips so that only half of the length is still in the dilute sulfuric acid. Repeat step 6.

11. Remove the copper strip and replace it with an aluminum strip. Repeat step 6.

12. Remove both the zinc and aluminum strips and replace them with two copper strips. Repeat step 6.

13. Rinse the metal strips with tap water and replace the solution in the voltaic cell with the distilled water. Replace one copper strip with a zinc strip. Repeat step 6.

14. Carefully dispose of used paper towel and acid, and clean up acid spills according to your teacher's direction.

15. Clean all surfaces and wash your hands thoroughly.

Analyze

1. What variables did you manipulate in this investigation?

2. What was the responding variable in this investigation?

3. What evidence did you observe on the surface of the copper strip to indicate that a chemical reaction was taking place?

4. What happened to the electric current and electric potential difference as time passed?

5. What effect did each of the following actions have on the **(a)** potential difference; **(b)** the current?
   - Removing the bubbles from the surface of the metal
   - Changing the surface area of the metal strips in the solution
   - Using aluminum and zinc instead of copper and zinc
   - Using identical metals

6. Which factors appear to **(a)** determine the potential difference; **(b)** increase the current?

8. Using the copper and zinc strips, which combination of factors produced the largest current?

9. Which pair of metals produced the largest potential difference: copper and zinc or aluminum and zinc?

10. If you were designing a voltaic cell, which combination of metals and conditions would you use? Why?

Extension

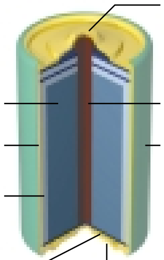
11. Will the voltaic cell still work if the sulfuric acid is replaced with a concentrated salt water solution? Explain. If time permits, ask your teacher for permission to test your prediction.

Types of Cells

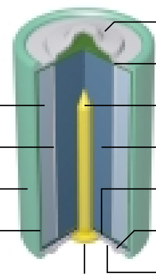
Examine the diagrams below and Table 4.8 to find out more about common types of cells.

Figure 4.32 Modern cells and batteries

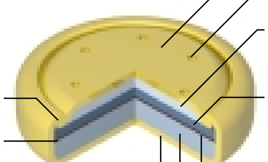
A zinc carbon cell



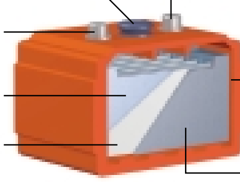
B alkaline cell



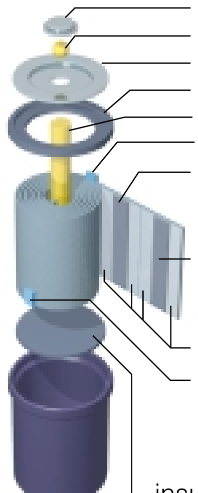
C zinc-air cell



D lead acid cell



E nickel-cadmium cell



F nickel-metal hydride

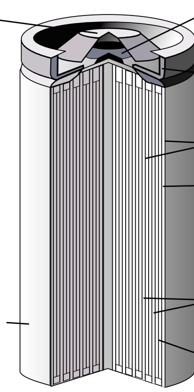


Table 4.7 Commonly Used Cells and Batteries

Name	Primary/ secondary	Dry/wet	Positive electrode	Negative electrode	Electrolyte	Typical uses	Pros and cons
zinc carbon	primary	dry	manganese dioxide and carbon	zinc	flour, starch, and ammonium chloride	flashlights, portable radios, CD players	not efficient at low temperatures
alkaline	primary	dry	see diagrams	see diagrams	see diagrams	flashlights, portable radios, CD players	last longer than zinc carbon, expensive
zinc air	primary	dry	see diagrams	see diagrams	potassium hydroxide	calculators, hearing aids, watches	highest energy per unit mass, discharges rapidly
lead acid	secondary	wet	see diagrams	see diagrams	see diagrams	cars, motorbikes, snowmobiles, golf carts	dependable, heavy, corrosive liquid
nickel cadmium	secondary	dry	see diagrams	see diagrams	potassium hydroxide	electric shavers, laptop computers, power tools, portable TVs	rechargeable hundreds of times
nickel-metal hydride	secondary	dry	see diagrams	see diagrams	potassium hydroxide	cameras, laptops, cell phones, hand tools, toys	less toxic than NiCad, 40% more energy density than NiCad, rechargeable, no memory effect, lose charge when stored

Find Out ACTIVITY

Select a Cell

Each type of cell has characteristics that suit it to particular uses. You would not use car batteries, for example, to power a portable stereo. Can you choose cells which best suit different applications?

Procedure

Analyzing and Interpreting

1. Make a table with three headings: *application*, *cell features*, and *best cell types*.
2. Decide on desirable features of a cell for each application listed at right.
3. Using information from Table 4.7 and from other reference sources, select the most appropriate type of cell for each use.

Applications

laptop computer
electronic wristwatch
emergency warning light
child's toy robot
cave explorer's headlamp
rechargeable flashlight
high-powered camcorder light
hearing aid
emergency locator beacon
digital camera

What Did You Find Out?

1. Which type of cell appeared most frequently in your chart?
2. Which type(s) of cells do you use most frequently? For which applications?
3. What other types of electrochemical cells do you know of in addition to the ones described on these two pages?

PROBLEM-SOLVING

INVESTIGATION 4-F

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building a Battery

Now that you understand how a battery operates, use your knowledge to create a battery using several dry cells in different combinations. Connect dry cells in several different arrangements.

Challenge

Assemble and test different combinations of individual dry cells to create a battery that will light a bulb most brightly.

Design Specifications

A. All batteries must use two or three individual cells.

B. The dry cells can be placed in series or in parallel or both.

C. The results of your tests should be recorded in a table such as the one below. For each trial, draw a diagram using the proper number and arrangement of cell symbols to show how the battery was constructed.

Safety Precaution

Cells in Series and in Parallel	Voltage (V)	Brightness of bulb (same, brighter, dimmer)
One cell		standard for comparison
Two cells in series		
Three cells in series		
Two cells in parallel		
Three cells in parallel		
Series batteries with one cell reversed		

Plan and Construct

1. With your group, predict which arrangement of cells will produce the most powerful battery.

2. Lay out the circuit illustrated below. Make sure the positive (red) terminal of the voltmeter is connected to the positive terminal of your battery.

3. Measure and record the voltage across the dry cells.

Evaluate

1. Which of your batteries lit the bulb most brightly?

2. Is there any relationship between the voltage of the battery and the brightness of the bulb? If there is, write a statement describing the relationship.

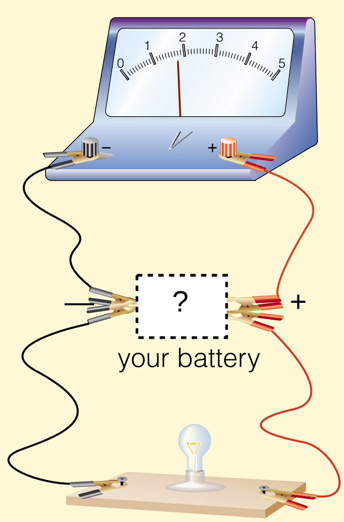
3. Write a statement that describes any advantage gained by putting two or more cells

(a) in series with each other

(b) in parallel with each other

(Be sure to include information about voltage and current in your answers.)

4. How did you reach your conclusions about current when you did not use an ammeter?



5. Explain what happened when the three cells were connected with the third in a direction opposite from the first two.

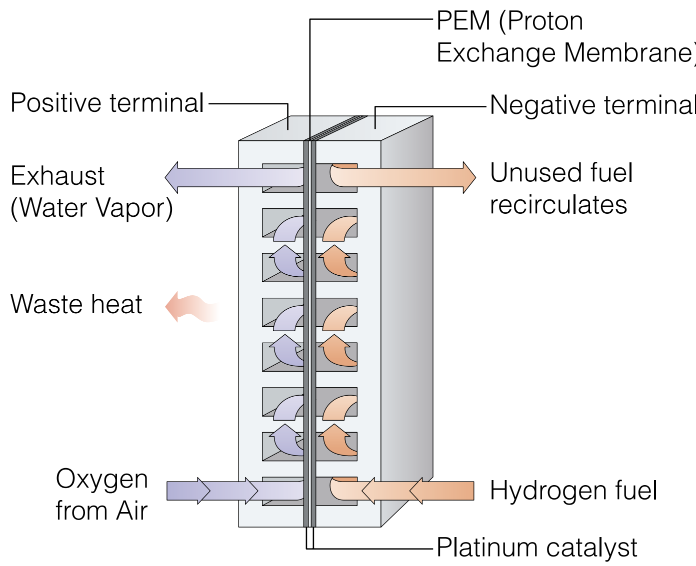
Across Canada

Automobile companies are investing millions of dollars to develop electric vehicles powered by fuel cells, instead of traditional batteries. Ballard Power Systems, in Burnaby, B.C., is a world leader in fuel cell technology. The company was established in 1979 to research and develop high-energy lithium batteries. By 1983, Ballard's engineers were developing, manufacturing, and marketing proton exchange membrane (PEM) fuel cells. Today, the company is working with other world leaders in fuel cell technology to create products for the mass market.

Ballard Power System's technology allows the production of efficient, environmentally friendly power sources for automobiles, electric equipment, and portable power production. This company's fuel cells boast zero emissions of harmful chemicals. To create electricity, Ballard's fuel cells combine hydrogen and oxygen without combustion. Electricity, heat, and pure water are the only by-products of the fuel cell's reaction. Unlike other electrochemical cells, fuel cells are not limited by the supply of chemicals inside them. As long as the proper fuel is supplied, the cell continues to produce electricity.

Another benefit of fuel cells is their efficiency. Proton-exchange membrane fuel cells are 50–85% efficient. Traditional automobile engines are only 25–40% efficient and emit harmful pollutants into the atmosphere.

Ballard Power Systems, along with international companies including DaimlerChrysler, Ford, GPU International, and ALSTROM, are working together to make Ballard fuel cells more readily available. Developing an efficient, inexpensive, and non-polluting source of hydrogen fuel for the cells is one focus of current research.



TOPIC 5 Review

1. What are the main components in a voltaic cell? Describe the function of each component.

2. How do batteries differ from cells? What arrangement of three cells will result in the greatest electric current? Which arrangement would result in the greatest longevity for the battery?

3. Describe three factors within a voltaic cell that you could manipulate in order to produce a cell with the highest possible voltage. For each factor describe how you would manipulate it.

4. Explain the difference between
   (a) wet cells and dry cells
   (b) primary and secondary cells

5. Describe the advantages and disadvantages of using fuel cells compared to other types of electrochemical cells.

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

electric energy
heat
thermocouple
thermo-electric generator
thermopile
piezoelectric effect
photovoltaic cell (PV)
electrodes
electrolyte
fuel cell

Reviewing Key Terms

1. In your notebook, write the key term that best matches each of the following words or phrases.
   (a) a form of energy that is always transferred from a warmer substance to a cooler one (4)
   (b) device that converts heat to a small amount of electric energy often used in temperature sensors. (4)
   (c) a push-button barbeque lighter produces a small electric current (4)
   (d) thermocouples combined to produce greater amounts of electricity (4)
   (e) a device, usually composed of silicon, that can be used to produce electricity from light (4)
   (f) different types of metals in a voltaic cell that have different attractions for electrons (5)
   (g) a substance that can conduct an electric current through the movement of ions (5)

Understanding Key Concepts

2. Identify three devices that convert electrical energy into light, and give an advantage and disadvantage of each one. (4)
3. Copy the diagram of the thermocouple into your notebook. Add labels and arrows to show the key parts and movement of charge. (4)
4. Describe an advantage of thermocouples over regular liquid thermometers. (4)
5. Why are thermo-electric generators most often used in remote locations? (4)
6. What was Luigi Galvani's hypothesis about "animal electricity?" Did Volta's "pile" support that hypothesis? (5)
7. For each of the following voltaic cells, describe whether it would produce a voltage. Explain your reasons for each prediction. (5)
   (a) a cell with copper and zinc electrodes in an acid electrolyte
   (b) a cell with two copper electrodes in a salt water electrolyte.
   (c) a cell with zinc and carbon electrodes in a distilled water electrolyte
8. If two D-cells are connected positive end to positive end, how much voltage would a voltmeter across the total array indicate? Give a reason for your response.(5)
9. Describe at least two possible benefits and two possible drawbacks of passing a law requiring that all new cars be powered by electricity generated by fuel cells. (5)