(d) The most successful laboratory cell was the magnesium/copper cell, so we will compare this cell with the alkaline dry cell.

Criteria	Mg/Cu cell	Alkaline dry cell
cell potential (voltage)	1.52 V	1.6 V
power output	unable to light an LED faint sound produced with buzzer	lit an LED louder sound produced with buzzer than Mg/Cu cell
portability	cumbersome chemicals need to be sealed	designed to be portable little chance of chemicals leaking
rechargeability	needs to be tested to see if it is rechargeable	not rechargeable (however, other types of dry cells are rechargeable)

Students may include more of their own criteria in the table.

Synthesis

(e) The cells, ordered from smallest to largest predicted cell potentials, are:
Mg/Pb, Mg/Cu, Mg/Ag. This prediction is based on the relative position of the metals. Mg and Pb are closest together on the activity series while Mg and Ag are the farthest apart.

5.9 CONSUMER CELLS AND BATTERIES

TRY THIS ACTIVITY: PICKLE POWER

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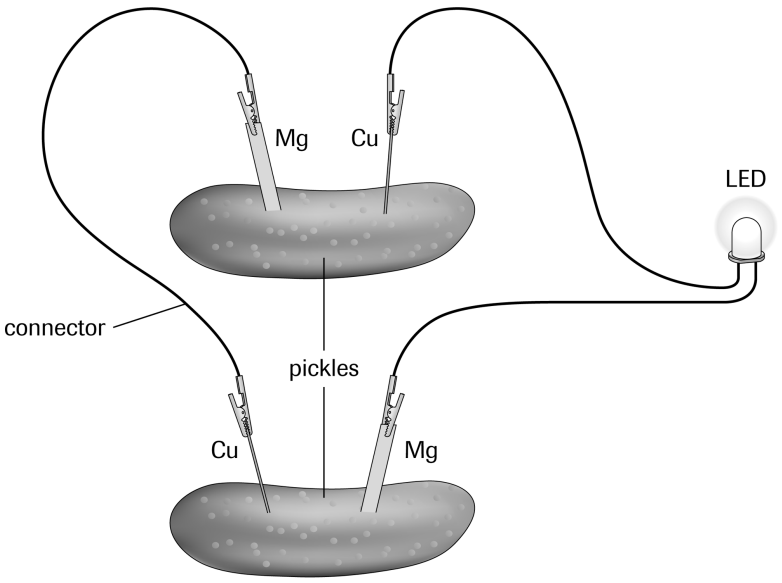
(a)



(b) Connecting the cells in series results in an overall battery potential that was the sum of the individual cell potentials.
(c) 12 V
(d) A cordless phone may contain three 1.2-V Ni–Cd batteries connected in series, for a total cell potential of 3.6 V. A typical portable CD player requires two 1.5-V alkaline dry cells in series, for a total cell potential of 3.0 V.

SECTION 5.9 QUESTIONS

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Understanding Concepts

1. The larger C cells contain more chemicals and can therefore produce more electrical energy than AA cells, and last longer. C cells are therefore more suitable for high-energy demand (but less portable) devices like toy cars.
2. The fabric is necessary to separate the anode and cathode chemicals while still allowing electrolytes to flow throughout the cell.
3. The paste inside a dry cell contains a concentrated solution of a strong base, which is corrosive.
4. The anode and cathode chemicals determine the voltage of a cell.
5. Four 1.5-V cells connected in series would provide a total potential of 6 V. (*Note:* Some 6-V battery designs actually contain eight cells: two sets of four cells in series. The two sets are arranged parallel to each other.)
6. Rechargeable cells, such as those in portable phones, are classified as secondary cells. Primary cells are cells that cannot be recharged. They are often used in low-load devices, such as smoke alarms and electric clocks.
7. (a) Zinc is oxidized; silver oxide is reduced.
   (b) $Ag_2O_{(s)} + H_2O_{(l)} + Zn_{(s)} \rightarrow 2\ Ag_{(s)} + Zn(OH)_{2(s)}$
   (c) The presence of silver in this cell makes it expensive.
   (d) Small size is an important criterion for a watch battery. Also, since the silver oxide battery's energy output is steady for the majority of its lifespan, the watch will operate reliably until the battery needs to be replaced.
8. The lithium cell provides more energy for its size than the alkaline dry cell. This is important since digital cameras, for example, require frequent bursts of energy to light a flash or light up an image screen.

Making Connections

9. Nickel metal hydride cells are the ideal choice for a new portable power tool. They produce plenty of electrical energy, can be recharged many times, and lack the memory effect and most of the environmental toxicity problems associated with Ni–Cd cells/batteries.
10. (a) anode: lead
    cathode: lead(IV) oxide on a metal screen
    electrolyte: sulfuric acid
    (b) An electrical device (known as the alternator) in the engine compartment supplies electrical energy while the car is operating. This electrical energy recharges the lead–acid battery.
    (c) Recycling lead–acid batteries is extremely important because the acid and lead they contain are corrosive and toxic, respectively. Most municipalities have a car battery recycling program. Many auto garages will take your old batteries and pass them on to an appropriate recycling contractor.

Reflecting

11. Student answers will vary. It is probably impossible to change the usage of a familiar word, even if it is being used incorrectly. The best we can do is try to use it correctly.

Exploring

12. The colour-based battery testers commonly found on some dry cells contain two different types of specially designed ink. One type of ink, called thermochromic ink or leucodye, changes colour at a certain temperature. The other ink conducts electricity. The design of battery testers varies depending on the manufacturer. The tester found on Duracell batteries consists of three layers:
    - The first layer of conductive ink has different resistances in different places, so it heats up differentially;
    - The middle layer contains the "Good" and "Replace" messages that you see when you test the battery;
    - The third, outer layer contains thermochromic ink that changes from dark to colourless as its temperature increases, revealing the message of the second layer.

    When you press the test points indicated on the battery, a connection between the positive and negative terminals of the battery is completed. This sends a small amount of current through the layer of conductive ink. As the current passes through, the resistance of the ink generates heat that warms up the thermochromic ink layer, causing it to change in colour from dark colours to light colours. A weak battery generates only enough heat to change the colour of a small region of the thermochromic ink, revealing the message "Replace." A fresh battery generates enough heat to change the entire thermochromic layer to transparent, revealing a message that the battery is good.
13. The capacity of a battery or cell is often expressed as "mA•h" or milliamp-hours. This unit refers to the total quantity of electricity a battery can deliver. If a battery is thought of as being a fuel storage tank, its capacity can be thought of as describing how much fuel the battery can hold. The total fuel available is the product of the flow rate (current) and the time. This information can be found on the packaging on many of the newer types of batteries/cells currently available.

Nickel metal hydride cells from one manufacturer have the following capacities:

Cell size	Capacity (mA•h)
AA	1400
AAA	550

The AA cell will last significantly longer, under the same operating conditions, than the AAA cell because the AA cell is larger and contains more chemicals to produce electricity.

14. Ni–Cd cells/batteries can suffer from "memory effect" that occurs when the battery is repeatedly drained less than its full capacity, and then recharged. This is a particular problem with portable phones. If portable telephones are replaced on the charger after each call, the capacity of the battery becomes greatly reduced. The cell "remembers" the point to which it was repeatedly discharged, and eventually will not discharge beyond that point. Memory effect can be avoided by allowing the battery to fully discharge before placing it back on the charger.

5.10 EXPLORE AN ISSUE: SHOULD NI–CD BATTERIES BE BANNED?

Understanding the Issue

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1. When Ni–Cd batteries in landfills corrode and break open, they release cadmium into the environment. Cadmium is an extremely toxic metal, implicated in a number of serious disorders of vital organs.
2. Ni–Cd batteries are plagued by "memory effect" resulting from improper recharging. If the battery is not fully drained, it may not fully recharge. This is caused by crystal growth at the cadmium anode.
3. Nickel metal hydride batteries have become viable alternatives to Ni–Cd batteries. They deliver high-energy output, can be recharged hundreds of times, and have the advantage of not suffering from "memory effect."

TAKE A STAND: SHOULD THE PRODUCTION OF NI–CD BATTERIES BE BANNED?

(a) Possible alternatives include:
- increasing public awareness of the hazards associated with Ni–Cd batteries
- encouraging recycling programs for Ni–Cd batteries
- promoting the use of environmentally-friendly alternatives through advertising and education programs
- encouraging more research into safer battery alternatives through government and corporate research grants
- developing nickel metal hydride batteries than can be used in existing portable devices

(b) Possible suggestions include:
- reducing the cost of environmentally friendly batteries using government incentives
- increasing the cost of Ni–Cd batteries by applying an "environment" tax
- introducing a mandatory phase-out period for the production of Ni–Cd batteries

(c) Pros and Cons of Ni–Cd Batteries

Pros	Cons
• Ni–Cd batteries remain the most common rechargeable battery. • Many portable devices are specifically designed to work with Ni–Cds. • They can be recharged more often than popular alternatives if handled properly. • They are generally less expensive than the alternatives currently available.	• They contain cadmium, which is hazardous to the environment. • Many alternatives are currently available to replace Ni–Cds. • Ni–Cds suffer from memory effect, which can drastically reduce their lifetime. • General purpose Ni–Cds are becoming more difficult to find

Student answers will vary, and the following Web sites may no longer be available. Resources:
Nelson Chemistry 12 College Preparation
http://www.night-sun.com/htmldocs/faq.html
http://www.matchrockets.com/teamstupid/power.html