HIDDEN POWER

BATTERIES

How do chemicals make electricity?

GOAL:

Visitors will understand that batteries convert chemical energy to electricity, store energy for later use, and can be rechargeable.

MATERIALS:

- Chemical battery apparatus (Voltaic cell) – includes zinc sulfate and copper sulfate solutions, rubber stoppers, and zinc and copper rods
- Voltmeter and leads
- Battery model

PROCEDURE:

Set-up:

1. Before setting up, connect the Voltaic cell to the voltmeter (see setup instructions below) and check that it is producing a voltage. Leave the alligator clips connected to the rods.

2. Set out the Voltaic cell, voltmeter, leads, and the model on the cart.

3. Move the positive (red) ion ball on the model to the high energy position.

Doing the demonstration:

1. Ask visitors if they are carrying anything that uses a battery for electricity. If visitors have any devices with a battery compartment that can be opened, ask them if they would be willing to open it to see the battery inside. Explain that batteries use chemical reactions to produce electricity.

2. Show visitors the chemical battery (Voltaic cell), pointing out the high energy side and the low energy side. Have a visitor touch the free ends of the leads to the base of the screws on the voltmeter to connect the battery (red to red, black to black) and show that the battery produces about 1 volt. Explain that positive charges (ions) are moving through the liquid while negative charges (electrons) are moving through the wire to create electricity.

3. Explain that the chemical battery setup is not rechargeable, unlike other batteries that are used in many mobile electronic devices. Introduce the model as how a rechargeable lithium ion battery works inside a portable music player.

4. Ask visitors what they predict will happen if they push the positive ion (red) ball; it will fall from the high energy to the low energy position. Also ask them to predict what will happen to the electron (blue) ball as the ion falls; it will get dragged down to the low energy position. Have them test their

prediction. Explain that the ion moves inside the battery, while the electron moves through the circuit, creating electricity that allows the device to play music.

5. Ask visitors what they do when their electronics run out of charge. Explain that when you connect a device to a charger and plug it in, you are reversing the reaction by converting electrical energy back into chemical energy in order to move the electron back up to the high energy level. Ask visitors to predict what will happen to the red ion as the blue electron is pulled back up by the energy from the recharger; the ion will get dragged along to the high energy position. Have them test their prediction.

Clean-up:

1. Disconnect the leads from the chemical battery apparatus. Make sure rubber stoppers are secure.

2. Gather all other supplies and return to storage.

EXPLANATION:

All batteries have a high energy side (i.e. high energy for electrons), a low energy side, an electrolyte (a solution containing charged ions), and a separator. Negatively charged electrons and positively charged ions move from one side of a battery to the other. When the charged particles move from high to low energy, electricity is produced. The ions moves through the battery, undergoing a chemical reaction in the electrolyte solution, while the electrons move through the circuit outside of the battery. A separator inside the battery prevents a short circuit. The separator allows ions to move through it, but not electrons.

In the chemical zinc-copper battery (Voltaic cell), the electrolytes are the zinc sulfate and copper (II) sulfate solutions, the high energy side is the zinc rod, and the low energy side is the copper rod. In this battery, the foam plug is the separator.

In the case of lithium-ion batteries, the high energy side is made from carbon, usually in the form of graphite, the low energy side is a metal oxide (such as lithium cobalt oxide), and the electrolyte is usually a lithium salt in an organic solvent. The Li^+ ion cannot move through the wiring, and so moves through the electrolyte and separator. As the Li^+ moves to the lower energy state, electrons are also forced to move from high energy to low energy. Electrons move through wire more easily than through the electrolyte, so they take a path through the wiring in the device to the low energy side. When a lithium-ion battery is recharged, energy is added back into the battery and the electron moves back through the recharging device, pulling the lithium ion back through the separator inside the battery and up to the higher energy state.

Note: While visitors may have heard of the terms *anode* and *cathode*, they are somewhat confusing when describing the function of rechargeable batteries. Ions and electrons always move away from anode and towards the cathode. Therefore when the device is in functioning mode, the high energy side is the anode while the low energy side is the cathode. When recharging, the direction of movement – and therefore the terms – are reversed; the low energy side is now the anode and the high energy side is the cathode. It is best to avoid these terms in your explanation.

WHAT COULD GO WRONG?

Make sure the stoppers are tightly secured in the Voltaic cell to avoid spills if it gets knocked over.

If the Voltaic cell is not producing a voltage, first check to make sure that the leads are connected correctly. Next, check to see that the zinc and copper rods are in contact with the electrolyte solutions. If that doesn't work, pour out the solutions, rinse the apparatus with water, and refill with fresh solutions.

GENERAL MAINTENANCE:

Preparing stock solutions for the Voltaic cell

Materials:

- 500 ml beaker
- Zinc sulfate powder, heptahydrate (formula weight 287.56)
- Copper (II) sulfate powder, anhydrous (formula weight 159.61)
- Distilled water (available at grocery stores)
- 2 squirt bottles for storage

You will also need a balance. For safety, wear gloves and eye protection while preparing solutions. Once prepared, the stock solutions can be stored indefinitely.

0.5 M copper sulfate solution:
Measure 40g copper (II) sulfate powder and pour into the beaker. Add distilled water to make 500 ml. Stir until powder is dissolved. The solution will be blue. Store the solution in a squirt bottle.

0.5 M zinc sulfate solution:
Measure 72g zinc sulfate powder and pour into the beaker. Add distilled water to make 500 ml. Stir until powder is dissolved. The solution will be clear. Store the solution in a squirt bottle.

Setting up the Voltaic cell

Use the squirt bottle to add the zinc sulfate solution into the "high energy" side, filling it up about halfway (below the Y-junction). Use the other squirt bottle to add the copper sulfate solution into the "low energy" side, filling it up about halfway (below the Y-junction). Then, simultaneously squirt each solution into its respective side until the tubes are filled to within ½" of the top. (If you don't squirt simultaneously, the first solution will permeate through the separator plug and begin filling up the other side.)

Plug the high energy side tightly with the zinc rod and stopper. Plug the low energy side tightly with the copper rod and stopper. Make sure the liquid level is high enough that the zinc and copper rods are in contact with their respective salt solutions.

Connect the alligator clip on the black lead to the top of the zinc rod. Connect the alligator clip on the red lead to the top of the copper rod. To complete the circuit during the demonstration, have visitors touch the free ends of the leads to the base of the corresponding colored screws on the voltmeter.

The Voltaic cell can remain set up between uses; make sure the stoppers are tight. Once assembled, the shelf life of the Voltaic cell is several weeks. Check with the voltmeter prior to each use to make sure the setup is still working. If the zinc and copper rods need cleaning, rub them down with steel wool.