Science Unit: *The Electron: Conductivity and Chemistry*
Lesson 3: *How Batteries Work*

School Year:	2011/2012
Developed for:	Trafalgar Elementary School, Vancouver School District
Developed by:	James Day (scientist); Kathryn Coulter-Boisvert and Christy Shea (teachers)
Grade level:	Presented to grades 6 and 7; appropriate only for grades 6 and 7.
Duration of lesson:	1 hour and 20 minutes
Notes:	The content of this lesson (in particular, the chemistry) is rather advanced and the students should be familiar with basic chemical formula notations. Whether or not the skit is practiced and performed in the same 80-minute lesson is left to the discretion of the teacher.

Objectives

1. Learn the basic anatomy of a battery.
2. Learn the basic concepts behind the operation of a battery.
3. Practice communicating their understanding of batteries through creative outlets.

Background Information

There exist many different types of batteries, but the basic concept which describes their function is the same. When a device is connected to a battery, a reaction occurs that produces electrical energy. Originally stored within the battery as chemical energy, this conversion is known as an electrochemical reaction. The process was first discovered in 1799 when Italian physicist Alessandro Volta created a simple battery from metal plates and brine-soaked paper. Since then, scientists have greatly improved upon Volta's original design to create batteries made from a variety of materials and coming in a variety of sizes.

Batteries are ubiquitous today. They power our watches, calculators, laptops, hearing aids, smoke detectors, power tools, iPods, submarines, and more---and they do it for months at a time! These portable power packs are so prevalent, it's very easy to take them for granted. This lesson should help students to better appreciate all that batteries can do for us, as well as aid in their understanding of how they work.

Vocabulary

electrochemical cell:	A device which either derives electrical energy from chemical reactions, or which facilitates chemical reactions through the introduction of electrical energy.
Battery:	One or more electrochemical cells that convert stored chemical energy into electrical energy. Batteries are a common power source for many household and industrial applications. There are two types of batteries: primary batteries (disposable batteries), which are designed to be used once and discarded, and secondary batteries (rechargeable batteries), which are designed to be recharged and used multiple times.

Circuit:	An interconnection of electrical elements (such as resistors, inductors, capacitors, transmission lines, voltage sources, current sources and switches) that forms a closed loop, giving a return path for the current.
Terminal:	The outer connections of a battery: one positive and one negative.
Load:	A device that makes use of the electric charge produced by a battery, such as a light bulb or a motor (something that has electrical resistance).
Electrode:	Where the chemical reactions occur inside a battery. There are two types of electrodes: the cathode, which connects to the positive terminal; and the anode, which connects to the negative terminal.
Separator:	A barrier between the cathode and anode, preventing the electrodes from touching while allowing electrical charge to flow freely between them.
Electrolyte:	The medium that allows the electric charge to flow between the cathode and anode.

Materials

- A combination of used AAA, AA, C, D, and 9-volt batteries.
- Cartoon picture of the inside of a battery, included as file alkalineschematic.bmp (6 images/sheet).
- “The battery skit” instructions.
- Masking tape; felt markers (1 per student).

In the Classroom

Introductory Discussion

1. Have the students imagine a world where everything that used electricity had to be plugged in. Have the students list some common items that would be too awkward if plugged in: flashlights, hearing aids, cell phones, iPods, etc. Even cars couldn't be started with the simple turn of a key; a strenuous cranking would be required to get the pistons moving. Highlight that, without batteries, wires would be strung everywhere, creating a safety hazard and an unsightly mess. Thankfully, batteries provide us with a mobile source of power that makes many modern conveniences possible.

2. Provide the students with some batteries and ask them to make some observations (e.g., draw a picture into their notebook). They should notice that it has two different terminals. One terminal is marked (+), or positive, while the other is marked (-), or negative. In the most common types of batteries, (AAA, AA, C, or D cell), the terminals are located on the ends. On a 9-volt battery (or a car battery), however, the terminals are next to each other and on the top of the unit. They should also notice that the battery has an outer casing (which keeps the chemicals in!).

3. Distribute the cartoon diagram to the students and have them affix it into their notebook, next to their drawing (so that comparisons and contrasts may be drawn). Use this diagram to help explain to students how a standard alkaline battery works.

Explanation:

In short, the zinc (the anode) has electrons that it will easily give away, and the MnO_2 *(manganese dioxide, the cathode) will readily take electrons when they are available. If put immediately side-by-side, electrons would flow directly from the anode to the cathode. In an alkaline battery, KOH (potassium hydroxide, the separator) is placed in between the two, preventing the direct flow of electrons (it prevents mixing of the anode and cathode, but allows for the conduction of ions). When a wire connects the positive terminal of a battery to its negative terminal, electrons can then directly get from the anode to the cathode along this wire. They do just that, and this flow of electrons is what we call “electricity.” Many appliances and devices require electricity to operate. This can't happen forever, though. As electrons* *leave the anode and arrive at the cathode, some "chemistry" happens (facilitated by the presence of the KOH): Zn slowly turns into ZnO, which is not willing to give up any more electrons. When all of the Zn has been changed into ZnO, the battery is dead.*

The half-reactions (if actually presented to the class) are as follows:

(1) $Zn + 2OH^- \text{--->} ZnO + H_2O + 2e^-$
(2) $2MnO_2 + 2e^- + H_2O \text{--->} Mn_2O_3 + 2OH^-$

Request that students take notes and definitions in their scientific notebooks as the lesson is given. Let them know that they will be relying on these notes to perform the skits (upcoming activity) and to help in making their own food batteries (following week).

Point out to students what would happen if you connected a wire between the two terminals (the electrons will flow from the negative end to the positive end as fast as they can---this will quickly wear out the battery and can also be dangerous, particularly on larger batteries). To properly harness the electric charge produced by a battery, you must connect it to a load. The load might be something like a light bulb, a motor or an electronic circuit like a radio.

4. To complement the above, teachers might consider supplementing the explanation with either or both of the PhETs: Battery Voltage; Battery-Resistor Circuit.

5. Briefly describe the battery hands-on activity (the battery skit).

6. Highlight that students should focus on recording their observations (and whatever questions arise) into their notebooks, as well as communicating their ideas and understanding in creative ways.

Science Activity

Activity Title: The battery skit

Purpose of Activity: To develop an improved conceptual understanding of how a battery works.

Set-up prior to experiment:

- Teachers should be familiar with the skit before working with students. The dialogue from this skit is taken from the YouTube video "How batteries work," which does a nice job of explaining the chemistry that happens inside a battery. Watching this 2 minute video will greatly help the teacher understand how the kids will need to be organized and directed.
  - http://www.youtube.com/watch?v=CJK2kwF6Am4
- Have copies of the script printed and ready to distribute.
- Teachers should create the groups (given below, roughly equal #number of students in each) before the activity begins.
- Make a large outline of a battery on the floor using masking tape.
- Provide each group with felt markers (one per student is ideal).
- Have paper props (electrons, ions, and molecules) already created. Distribute them to the appropriate groups.

1. Gather the four groups together: Group Anode; Group Cathode; Group Electrolyte; Group Wire. Give all the groups at least 10 minutes to read through and practice their lines and actions for the skit. Preferably, give students a full day to become familiar with the lines.

2. Groups Anode, Cathode, and Electrolyte will move to their respective places in the battery outline.

3. Group Wire will form a line parallel but away from the battery outline.

4. The groups begin reading their lines and performing their actions from the script. There should be time for at least one practice run through before a final skit is videotaped.

5. One or two rehearsals of the skit will take place. On the second (or third) attempt, the skit will be videotaped.

Closure Discussion

1. Why do batteries come in different sizes?

2. Can you list ways in which you think scientists are working to improve battery technology?

3. What is the most important battery-powered piece of equipment you can think of?

References

1. <http://en.wikipedia.org/wiki/Battery_(electricity)> 'Battery (electricity)' entry on Wikipedia [Describes how to construct a lemon battery.]

2. <http://electronics.howstuffworks.com/everyday-tech/battery.htm> 'How Batteries Work' entry from the website "How Stuff Works" [Provides a brief history of batteries, the basic anatomy of a battery, battery reactions and chemistry, and much more information.]

3. <http://phet.colorado.edu/en/simulation/battery-voltage> 'Battery Voltage' PhET (Physic Education Technology) from the University of Boulder, Colorado. One of many from a suite of research-based interactive computer simulations for teaching and learning physics, chemistry, math, and other sciences. [Small, simple program that allows the user to look inside a battery, to see how it works. You can select the battery voltage and little stick figures move charges from one end of the battery to the other. A voltmeter tells the user the resulting battery voltage.]

4. <http://phet.colorado.edu/en/simulation/battery-resistor-circuit> 'Battery-Resistor Circuit' PhET (Physic Education Technology) from the University of Boulder, Colorado. One of many from a suite of research-based interactive computer simulations for teaching and learning physics, chemistry, math, and other sciences. [Small, simple program that allows the user to look inside a resistor, to see how it works. The user may increase the battery voltage to make more electrons flow though the resistor, or increase the resistance to block the flow of electrons. It allows the user to watch the current and resistor temperature change.]

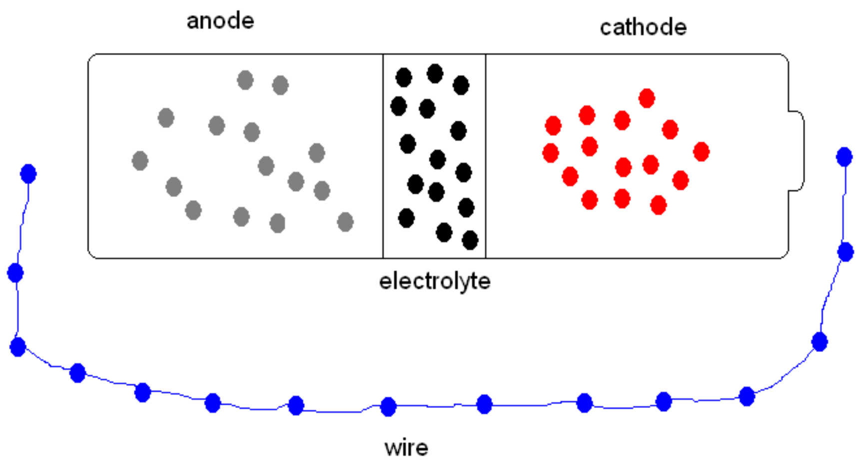
5. <http://www.youtube.com/watch?v=CJK2kwF6Am4> A short YouTube video, title "How batteries work" which explains the chemical processes that take place when a battery is connected to a load.

The Battery Skit

There are four groups in this skit, as shown schematically in the figure below: Anode (grey); Cathode (red); Electrolyte (black); and Wire (blue).

A tape outline will be placed on the floor, outlining the walls of the battery.

Have all four groups standing in their starting positions, as shown below. Each group will need a couple of felt markers, as well as the props described below.



- Each member of the Anode group will begin with a name tag that reads "Zn" and two electrons.
  - an electron will be represented by a circle of blue paper, with an "e-" written on it.

- Each member of the Cathode group will begin with a name tag that reads "MnO_2".

- Each member of the Electrolyte group will have a K^+ ion and a hydroxide/water molecule.
  - a potassium ion will be represented by a circle of green paper, with a "K+" written on it.
  - the hydroxide/water molecule will be represented by a circle of green paper, with "OH-" written on one side and "H_2O" written on the other side.

- The members of the Wire group will not have any props to begin with.

Once all of the groups have been formed, they should practice their lines together for about 10 minutes.

The script that follows will make much more sense if the teacher is first familiar with the YouTube video "How batteries work." The lines and the choreography will be made clear if one has watched this video in advance. It can be accessed at:
http://www.youtube.com/watch?v=CJK2kwF6Am4

Script

(Every time the words “electrons,” “hydroxide ions,” “potassium ions,” or “water” is said, the group holding the relevant prop card should wave it over their heads.)

Electrolyte: (speaking to Cathode)
Hey, manganese dioxide, it seems to me that you would like to get some electrons.

Cathode: (speaking to Electrolyte)
Definitely! I'd love to get some electrons. But I don't know where to get any.

Electrolyte: (speaking to Cathode)
Don't worry! Zinc, over here, has a bunch. I'll arrange to get some for you.

Electrolyte: (speaking to Anode)
Hey zinc, my friend manganese dioxide would really like to have your electrons. I am willing to give you my negatively charged hydroxide ions if you are willing to give up your electrons.

Anode: (speaking to Electrolyte)
That sounds great! If I gave up some electrons, I would really like to have your hydroxide ions. But how am I going to get my electrons over there? I' would pass them along through you if I could, but your hands are full.

Wire: (yelling excitedly)
We can help! We can help! We love passing electrons!

Anode and Cathode: (speaking together to Wire)
Who are you?

Wire: (speaking to Anode and Cathode)
I'm a copper wire, silly. I love passing electrons!

Anode: (speaking to Wire)
Hey, this is great! Can you please pass these electrons to manganese dioxide?

Wire: (speaking to Anode)
Absolutely! Yeah!

(Wire then connects one end of the battery to the other. The electrons are passed along the wire, from the Anode to Cathode. Wire should shout “electricity” as the electrons are passed along.)

Anode: (speaking to Electrolyte)
Now that I've given away my negatively charged electrons, I'm left feeling rather positive. Are you ready to separate from your negatively charged hydroxide ions to help balance me out.

Electrolyte: (speaking to Anode)
A promise is a promise! Here are my negatively charged hydroxide ions. Let's do some chemistry!

(The hydroxide ions are passed over to the Electrolyte members. When they get these cards, they should use a marker to change their name tag from “Zn” to “ZnO.” Then they should flip over the card so that it shows water and hand it back to Electrolyte. The groups should dance around a bit and shout “chemistry” while this exchange is going on.)

Electrolyte: (speaking to everyone)
In giving up those negatively charged hydroxide ions, I have become positively charged potassium ions and water!

Cathode: (speaking to everyone)
Thank you so much for the electrons! With the electrons and the water that the Electrolyte now has, I'm going to become dimanganese trioxide!

(Electrolyte hands the water molecules over to the Cathode members, who then change their name tags from “MnO_2” to “Mn_2O_3.” Then they should flip over the card s that it shows the hydroxide ion. The groups should dance around a bit and shout “chemistry” while this exchange is going on.)

Electrolyte: (speaking to Cathode)
Hey, can I have those negatively charged hydroxide ions that you didn't use in your reaction? That's what I had to give up to get you those electrons.

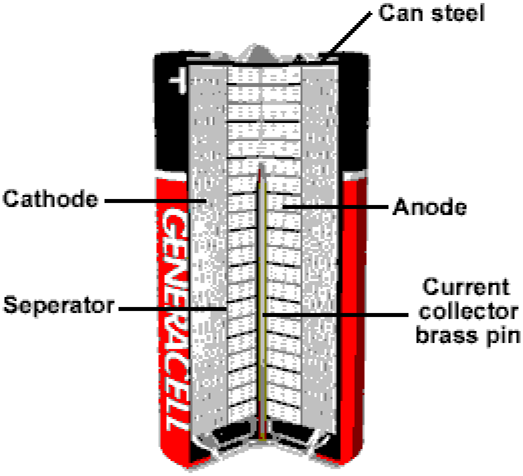
Cathode: (speaking to Electrolyte)
Sure you can! I really don't need them.

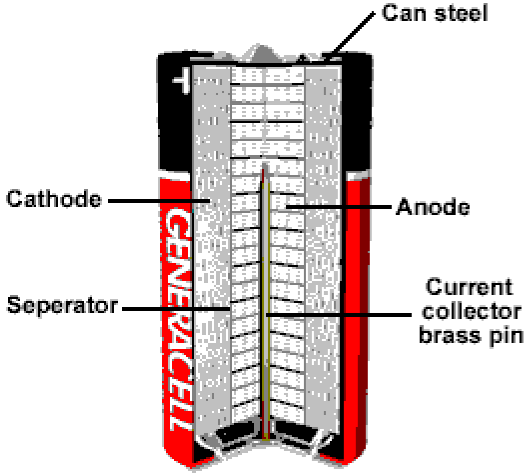
(Cathode members hand the hydroxide ions back to the Electrolyte members. The groups should dance around a bit and shout “chemistry” while this exchange is going on.)

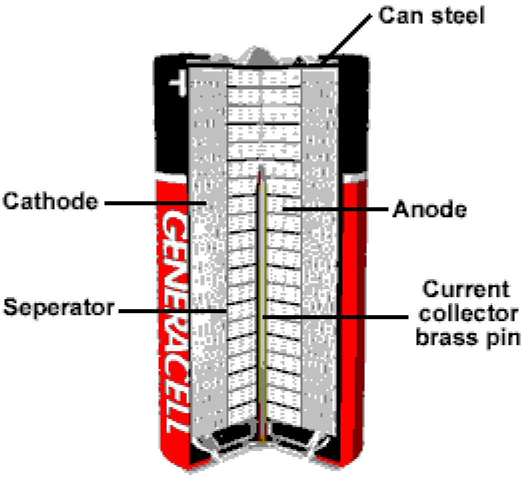
Electrolyte: (speaking to Cathode)
Thanks! After all of that, I'm still potassium hydroxide.

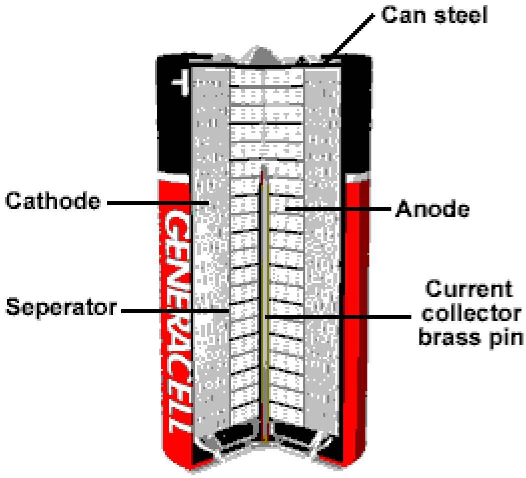
Cathode and Anode: (speaking to everyone)
And now we're done reacting: the battery is fully discharged!

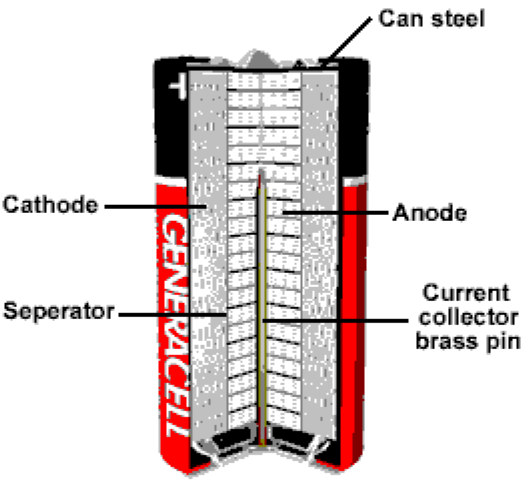
(Everyone falls to the floor now that the battery is “dead”.)

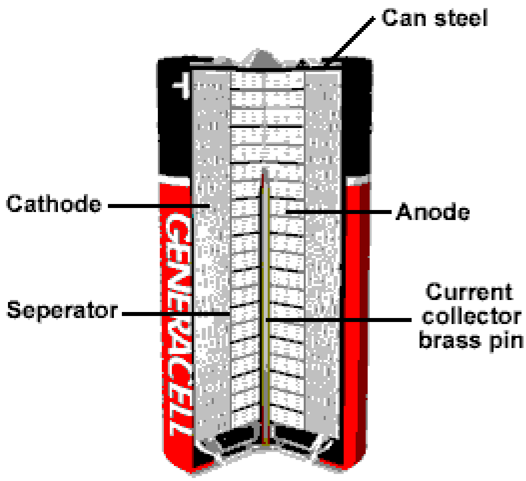

Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL


Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL


Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL


Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL


Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL


Can steel
Cathode
Anode
Seperator
Current collector brass pin
GENERACELL