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The Inner Workings of Electrochemical Cells

PART 1: Voltaic Cells

Voltaic cells, also known as batteries, are used to convert chemical energy from a spontaneous chemical reaction into electrical energy that can be used or stored. In a voltaic cell, there is a flow of ions and a flow of electrons. Batteries are so common and important in our everyday lives, so this simulation activity will help us understand how batteries actually work!

By the end of this activity you will be able to:

- Identify and label the parts of a voltaic cell, including the anode, cathode, and salt bridge when given the reaction equation.
- Identify the direction of electron flow in the external circuit and the direction of ion diffusion through the salt bridge when given the reaction equation.
- Identify each half-cell as the site of oxidation or reduction by interpreting the reaction equation.
- Explain the function of each cell component.

Previous skills you will need:

- ✓ Rules for assigning oxidation numbers
- ✓ Ability to write oxidation and reduction half-reactions

→ If you are still struggling with either of these skills, see Ms. Monaghan for a mini-lesson now before you begin the simulation activity.

Access the simulation by clicking on the "Voltaic Cell Simulation" link on the Unit 11 page on my website.

→ Be patient, it may take a moment or two for all elements of the diagram to appear.
→ **MAKE SURE THE SOUND IS ON AND VOLUME IS UP SO YOU CAN HEAR! ****

Look and listen carefully at the working model; use the buttons at the bottom of the page to get a close up view of each of the component parts of the cell. As you explore the simulation, answer the key questions and application questions below. "Re-watch" any parts of the simulation as necessary.

A voltaic cell (also sometimes called a galvanic cell) consists of a cathode, an anode, and a salt bridge. When the voltaic cell is operating, electrons flow through an external circuit, and ions diffuse through the salt bridge

Key Questions: The Anode and Cathode

1. Identify the zinc metal and copper metal as the correct electrode (either anode or cathode).

   Zn electrode: Anode Cu electrode: Cathode

2. Which way do electrons flow through the wire? (Circle your choice.)

   From the anode to the cathode **OR** From the cathode to the anode

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3. Zoom in on the zinc electrode. Describe, in terms of zinc atoms and zinc ions, what is happening in the zinc half-cell. Include discussion of what is happening to the overall **mass** of the electrode.

Zinc atoms are oxidized to $Zinc^{+2}$ ions and the mass of the Zn electrode decreases

4. Zoom in on the copper electrode. Describe, in terms of copper atoms and copper ions, what is happening in the copper half-cell. Include discussion of what is happening to the overall **mass** of the electrode.

$Copper^{+2}$ ions are reduced to Copper atoms and the mass of the Cu electrode increases

5. Is the reaction that is occurring at the anode oxidation or reduction? Oxidation

Write the half-reaction: $Zn^0 \rightarrow Zn^{+2} + 2e^-$

6. Is the reaction at the cathode oxidation or reduction? reduction

Write the half-reaction: $Cu^{+2} + 2e^- \longrightarrow Cu^0$

7. Zoom back out to the original model. Find evidence to support your answers to questions 5 & 6?

→ electrons flow from Zn to Cu electrodes

→ Zn electrode loses mass / Cu electrode gains mass

8. Identify the energy conversion that took place in this cell: (circle one)

Electrical to Chemical OR Chemical to Electrical

Application Questions:

1. Review the work you have done for this model and look at table J. What do you notice about the relative placement of the two metals on Table J?

Zn is up higher than Copper on Table J

2. Make a big picture claim.... come up with a rule that will always allow you to use Table J to predict which of two metals in a battery will act as the anode and which will act as the cathode.

metal higher on table J and will be oxidized, therefore being the anode.

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Key Questions: The Salt Bridge

The purpose of the salt bridge is to connect the circuit, keeping the half cells in contact without having the solutions mixing. The ionic solutions produce mobile ions that move through the salt bridge (as compared to the mobile electrons that move through the wire).

1. If the salt bridge contains $NaNO_3$ (aq), what two ions are present that can move through the salt bridge?

Na^{+1} NO_3^{-1}

2. Which of the two ions (the positive or negative ion) moves from the salt bridge **into the cathode** half-cell? Why do you think this occurs? *(Hint: Without this would the cell eventually be too positive or too negative? Why?)*

Na^{+1} will move into the cathode ½ cell to "replace" the positive charge as the Cu^{+2} is reduced to Cu^0 and ⊕ charge is lost

3. Which of the two ions (the positive or negative ion) moves from the salt bridge **into the anode** half-cell? Why do you think this occurs?

NO_3^{-1} will move into the anode ½ cell to "balance out" the positive charge as the Zn^0 is reduced to Zn^{+2} and ⊕ charge builds up.

4. What is the overall purpose of the salt bridge? Why is it a necessary component? Think: what would happen if the salt bridge were to be removed from the set-up? Explain.

The salt bridge is necessary to balance out the charge as the reaction occurs, otherwise the anode ½ cell would become too positive and the cathode ½ cell would become too negative.

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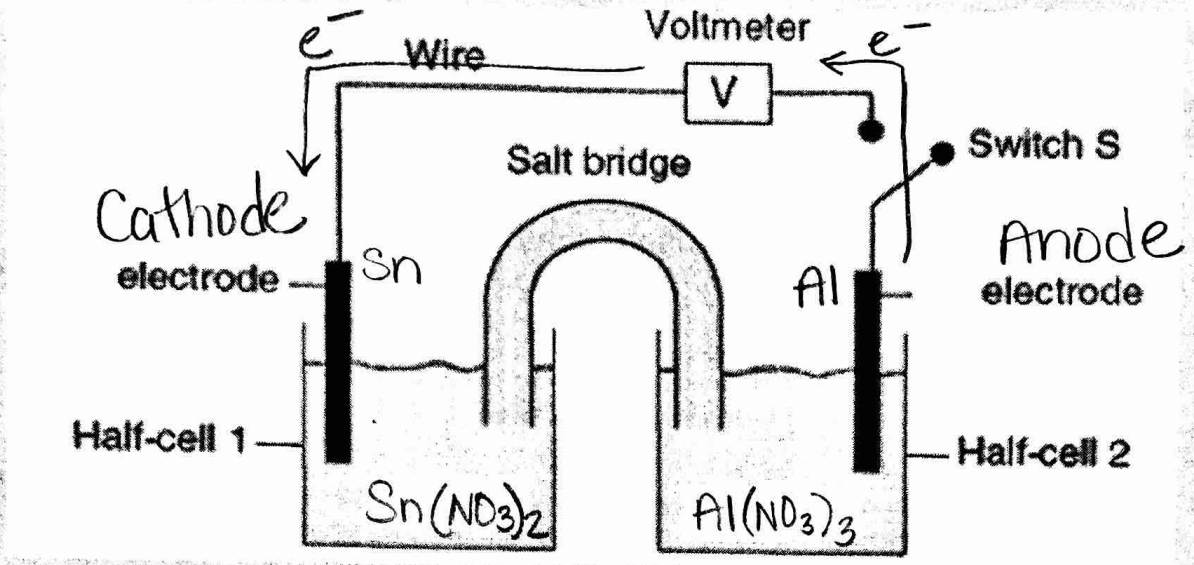
Putting it all Together: Show Me You Understand How a Voltaic Cell Battery Works!

Two half-cells are prepared by a student in the laboratory and are connected as shown in the diagram below:



Half-cell 1 contains a tin electrode in a solution of $Sn(NO_3)_2$ (aq).
Half-cell 2 contains an aluminum electrode in a solution of $Al(NO_3)_3$ (aq).
The salt bridge contains a solution of $NaNO_3$ (aq).

When the switch is closed, the following reaction occurs:

$$2\,Al^{0} + 3\,Sn^{2+} \rightarrow 2\,Al^{3+} + 3\,Sn^{0}$$

1. Label the electrode and solution in each of the half-cells on the diagram above.

2. Write the oxidation half-reaction that occurs.

$Al^{0} \longrightarrow Al^{+3} + 3e^{-}$

3. Write the reduction half-reaction that occurs.

$Sn^{+2} + 2e^{-} \longrightarrow Sn^{0}$

4. Based on your answers to previous questions, decide which electrode is the anode and which electrode is the cathode. Label each in the diagram above.

5. When the switch is closed, the circuit will be completed. Use an arrow to mark the direction of electron flow in the cell in the diagram above.

anode → cathode

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PART 2: Electrolytic Cells

Electrolytic cells use electrical energy to force a non-spontaneous chemical reaction to produce a desired result. This process is commonly used to recharge batteries as well as to plate metal coatings onto other metals or materials. This animation activity will help us understand how this process of electroplating actually works!

By the end of this activity you will be able to:

- Identify and label the parts of an electrolytic cell, including the anode, cathode.
- Identify the direction of electron flow in the external circuit.
- Identify each electrode as the site of oxidation or reduction.
- Explain the function of each cell component.

Previous skills you will need:

- ✓ Rules for assigning oxidation numbers
- ✓ Ability to write oxidation and reduction half-reactions

→ If you are still struggling with either of these skills, see Ms. Monaghan for a mini-lesson now before you begin the simulation activity.

Access the animation by clicking on the "Electrolytic Cell Animation- Electroplating" link on the Unit 11 page on my website.

Read carefully the information listed and look carefully at the animated diagram before clicking the arrow to see the next portion. Answer the key questions and application questions below as you move through the animation. "Re-watch" the animation as necessary.

In an electrolytic electroplating cell there is a solid metal electrode (the solid Nickle rod in our animation) and another metal electrode (the spoon in our animation) onto which the metal will be plated. Both are placed in a solution that contains ions of the solid metal and connected to the nodes of a battery or power source.

Key Questions: Anode and Cathode

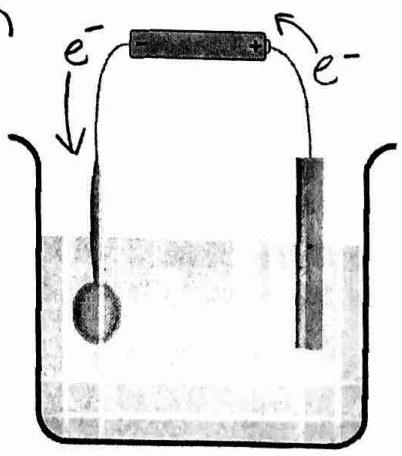
1. Identify which electrode is the anode and which is the cathode. Also label them in the diagram below.

   $Ni_{(s)}$ Electrode: anode Spoon Electrode: cathode

2. Identify the process (oxidation or reduction) that occurs at each of the electrodes and write the respective ½ reactions. Also label them in the diagram.

   $Ni_{(s)}$ Electrode: oxidation | Spoon Electrode: Reduction

   $Ni^{0} \rightarrow Ni^{+2} + 2e^{-}$ | $Ni^{+2} + 2e^{-} \rightarrow Ni^{0}$



3. Identify which node of the battery (+ or -) that each electrode is connected to.

   $Ni_{(s)}$ Electrode: + Spoon Electrode: −

4. Identify the direction electrons flow through the external circuit: (circle one)

   (Anode to Cathode) OR Cathode to Anode

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5. Describe, in terms of Nickle atoms and Ni^{+2} ions and mass gained and lost, the process of electroplating the spoon.

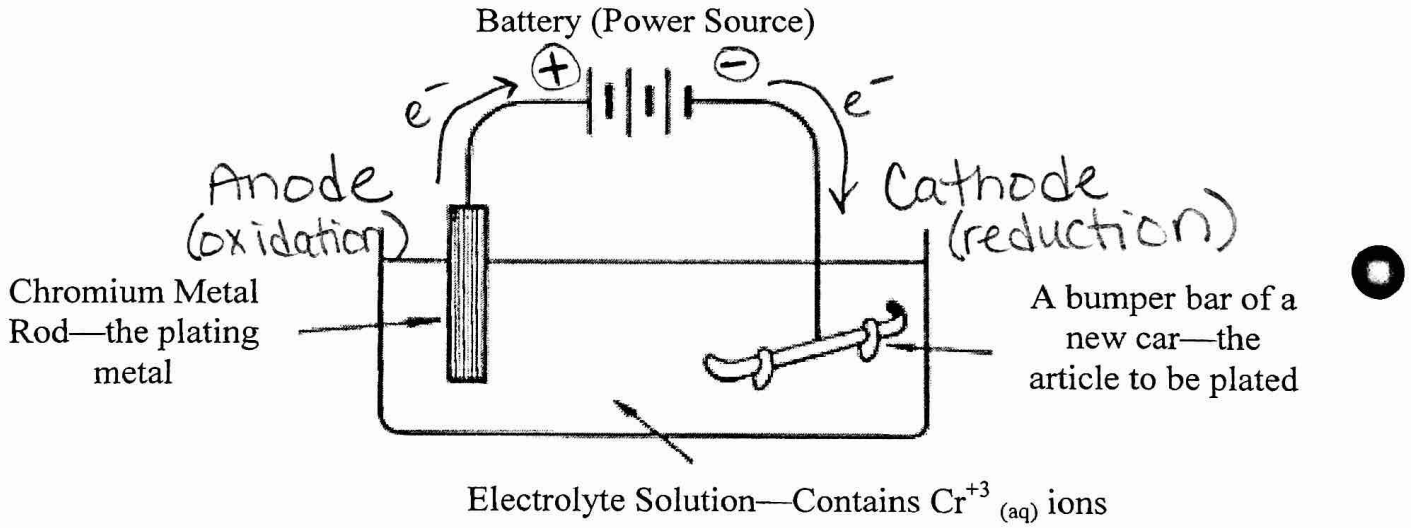
Ni^{+2} ions in solution are reduced to solid Ni^{0} at the surface of the spoon and the spoon gains mass. The Nickle electrode loses mass as $Ni^{0}_{(s)}$ is oxidized to Ni^{+2} to replace ions in solution

6. Identify the energy conversion that took place in this cell: (circle one)

(Electrical to Chemical) OR Chemical to Electrical

Application Questions

The diagram below represents a system used to plate chromium metal onto a less expensive metal bumper bar to create a shiny chrome bumper for a new car.



1. Identify and label the following in the diagram above:
   a. Anode
   b. Cathode
   c. Site of Oxidation
   d. Site of Reduction
   e. Positive Node of the battery
   f. Negative Node of the battery
   g. Direction of Electron Flow

2. Write the two half reactions that occur at the anode and cathode in the cell:
   a. Half-reaction at the Anode: $Cr^{0} \longrightarrow Cr^{+3} + 3e^{-}$
   b. Half-reaction at the Cathode: $Cr^{+3} + 3e^{-} \longrightarrow Cr^{0}$

3. Describe, in terms of Chromium atoms and Cr^{+3} ions and mass gained and lost, the process of electroplating the bumper bar.

The chromium anode loses mass as Cr^{0} oxidizes to Cr^{+3} ions in solution. As Cr^{+3} ions in solution are reduced to $Cr^{0}_{(s)}$ on the surface of the bumper, Cr mass is added to the bumper (coated on)