

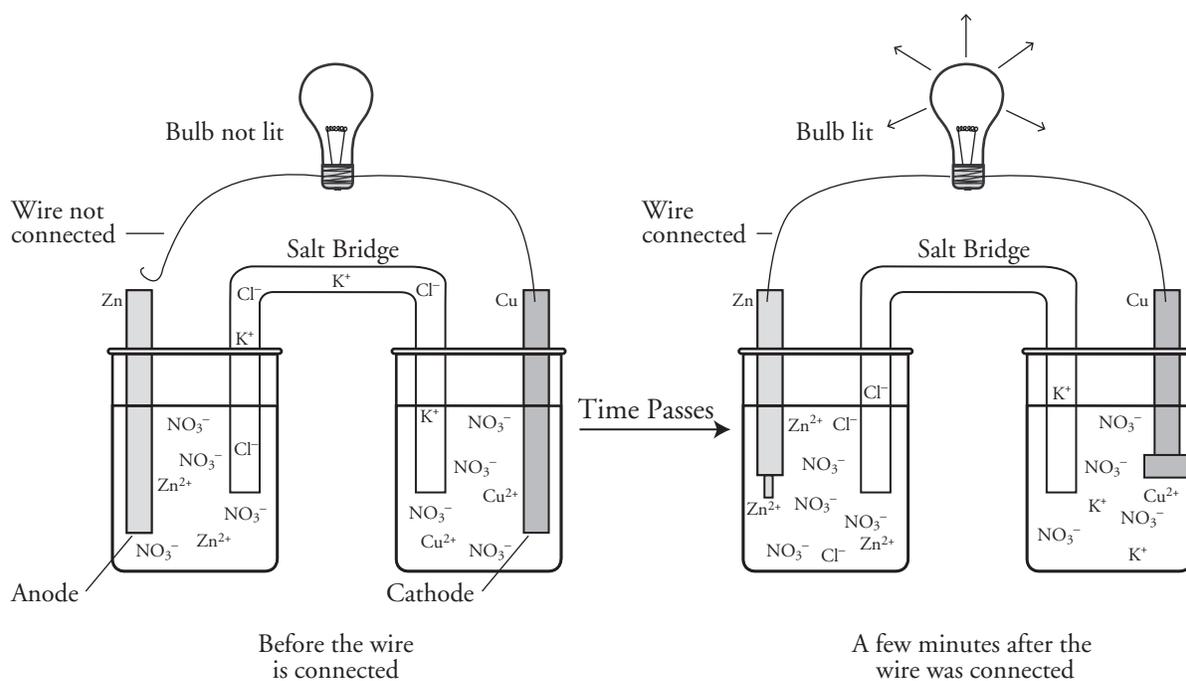
# Batteries

How does a battery (voltaic cell) work?

## Why?

When we use portable devices like MP3 players and cell phones we need a ready source of electricity to provide a flow of electrons. Batteries are the common solution to this challenge. In a battery or voltaic cell, oxidation and reduction reactions provide electrons which power our devices. In this activity we will explore the chemistry of voltaic cells or batteries.

## Model 1 – Voltaic Cell



1. Consider the reaction in Model 1. Notice that there are two zinc ions ( $Zn^{2+}$ ) in the beaker on the left before the wire is connected. Explain why the number of nitrate ions ( $NO_3^-$ ) present in that beaker is correct.
2. Examine the system in Model 1 both before the wire is connected and after it is connected. Identify two specific pieces of evidence that a chemical reaction has occurred as time passes with the wire connected.

3. Examine the diagram in Model 1.

- Which piece of solid metal loses mass (gets smaller) as the reaction proceeds?
- Does the number of zinc ions ( $\text{Zn}^{2+}$ ) in solution increase or decrease as the reaction proceeds?
- Circle the half-reaction below that represents the change in the metal identified in part *a*.  
 $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$        $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$   
 $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$        $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$
- Is the reaction circled in part *c* an oxidation or reduction reaction?

4. Examine the diagram in Model 1.

- Which piece of solid metal is gaining mass as the reaction proceeds?
- Where do those metal atoms come from? Explain.
- Circle the half-reaction below that represents the change in the metal identified in part *a*.  
 $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$        $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$   
 $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$        $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$
- Is the reaction circled in part *c* an oxidation or reduction reaction?

5. Electricity is the flow of electrons. Look back at Model 1. In which diagram can the electrons flow through the wire, the one when the **bulb is not lit** or the one when the **bulb is lit**? (Circle one.) Explain your answer.

6. Based on your answers in Questions 3 and 4, which piece of solid metal is giving up electrons, and therefore losing them into the wire?

7. On the drawing of the voltaic cell in Model 1, draw an arrow to depict the direction that the electrons are traveling through the wire.

8. Consider the reactions occurring in Model 1.
- What type of half-reaction (oxidation or reduction) is occurring at the piece of metal labeled **anode** in Model 1?
  - What type of half-reaction (oxidation or reduction) is occurring at the piece of metal labeled **cathode** in Model 1?
  - Explain how the phrase “an ox and a red cat” can help students remember the type of half-reaction that occurs at each electrode in an electrochemical cell.
9. Explain how the direction of electron flow in a voltaic cell is consistent with what you would predict from the activity series?
10. Draw an unconnected voltaic cell similar to the one on the left side of Model 1 using iron and silver as electrodes. The solutions should include silver ions ( $\text{Ag}^+$ ), iron ions ( $\text{Fe}^{3+}$ ), and nitrate ions ( $\text{NO}_3^-$ ). Use a salt bridge identical to that in Model 1.
11. Use the activity series of metals to determine which metal in the voltaic cell in Question 10 should be the anode. Explain your choice.

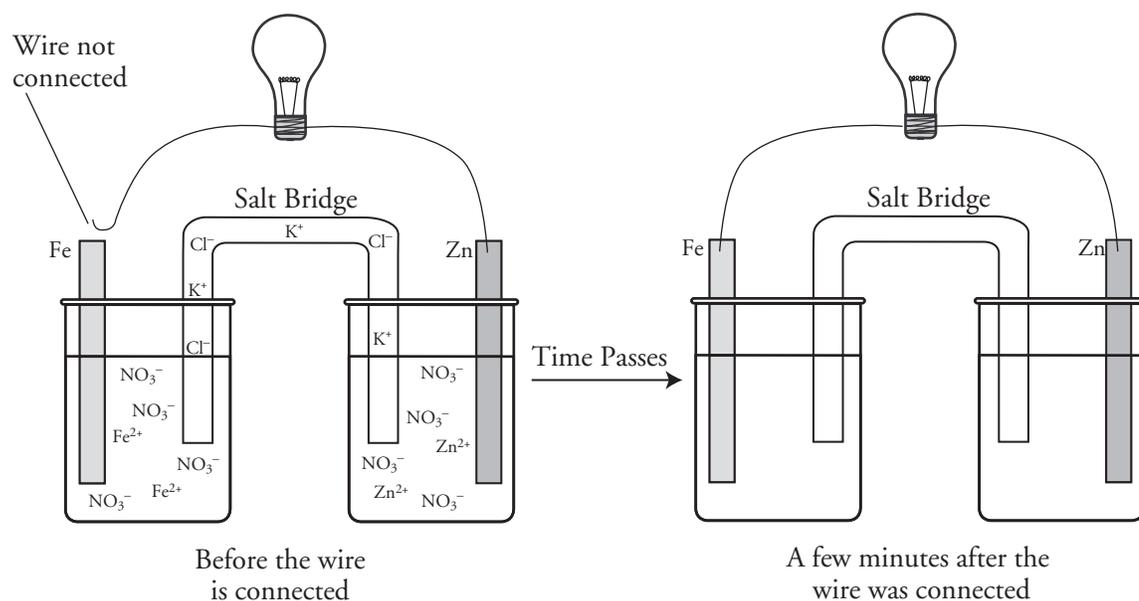
12. Draw an arrow on your diagram in Question 10 to indicate the direction of electron flow through the voltaic cell once the wire is connected.
13. Use Model 1 to complete the table.

	<b>Initially</b>	<b>After a Few Minutes</b>
Number of zinc ions ( $\text{Zn}^{2+}$ ) dissolved in solution		
Number of copper ions ( $\text{Cu}^{2+}$ ) dissolved in solution		
Number of nitrate ions ( $\text{NO}_3^-$ ) dissolved in solution		
Number of potassium ions ( $\text{K}^+$ ) dissolved in solution		
Number of chloride ions ( $\text{Cl}^-$ ) dissolved in solution		

14. Even though ions and electrons move around in a voltaic cell, the cell must stay electrically neutral.
- Explain how the anode half-cell in Model 1 remains electrically neutral (no charge) even though zinc ions are being formed from neutral zinc metal. Refer to the table in Question 13 to support your answer.
  
  - Explain how the cathode half-cell in Model 1 remains electrically neutral (no charge) even though copper ions are being removed from the solution. Refer to the table in Question 13 to support your answer.
  
  - What is the role of the salt-bridge in a voltaic cell?

## Extension Questions

15. Work with your group to apply everything you have learned about batteries to label the voltaic cell diagram below. Use the path and direction that the electrons are traveling to help you.
- Label the following items on the diagram.  
 Site of oxidation                      Site of reduction  
 Anode                                      Cathode
  - Complete the “few minutes after” drawing to show what ions would be in the beakers and the salt bridge, and how the electrodes may have changed.
  - Write the oxidation and reduction half-reactions for the voltaic cell.



16. Propose a reason why it is necessary to place the metal electrodes in solutions of their own ions to make a battery.