

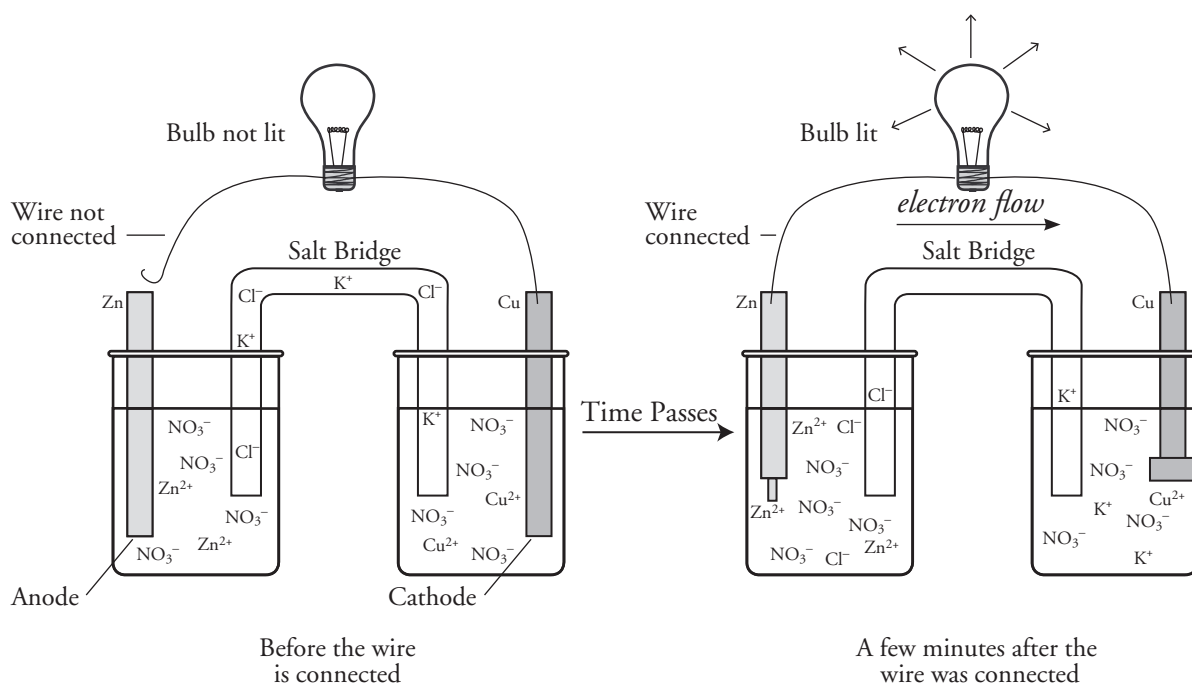
Batteries

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.

The solution must be neutral. Two zinc ions have a +4 charge, so four nitrate ions are needed to balance the charge.

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.

Answers will vary.

The zinc electrode appears to be disintegrating or getting smaller, while the copper electrode gains mass or gets larger. There are fewer copper ions in solution.

3. Examine the diagram in Model 1.

a. Which piece of solid metal loses mass (gets smaller) as the reaction proceeds?

Zinc.

b. Does the number of zinc ions (Zn^{2+}) in solution increase or decrease as the reaction proceeds?

Increases.

c. Circle the half-reaction below that represents the change in the metal identified in part a.



d. Is the reaction circled in part c an oxidation or reduction reaction?

Oxidation.

4. Examine the diagram in Model 1.

a. Which piece of solid metal is gaining mass as the reaction proceeds?

Copper.

b. Where do those metal atoms come from? Explain.

The copper ions in solution gain two electrons and become solid copper atoms.

c. Circle the half-reaction below that represents the change in the metal identified in part a.



d. Is the reaction circled in part c an oxidation or reduction reaction?

Reduction.

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.

Electricity can only flow with the wire is connected. This allows the light bulb to light.

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?

Zinc metal gives up its electrons.

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.

See Model 1.

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?

Oxidation.

- What type of half-reaction (oxidation or reduction) is occurring at the piece of metal labeled **cathode** in Model 1?

Reduction.

- 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.

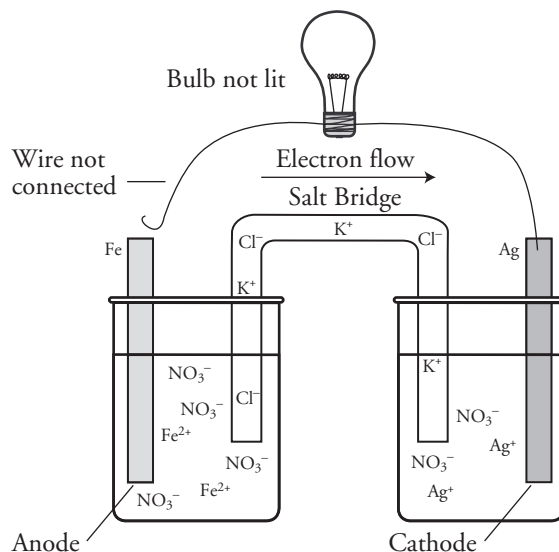
An ox = oxidation occurs at the anode.

Red cat = reduction occurs at the cathode.

9. Explain how the direction of electron flow in a voltaic cell is consistent with what you would predict from the activity series?

Zinc is more active than copper, so electrons will be transferred from zinc metal to copper ions.

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 (Ag^+), iron ions (Fe^{3+}), and nitrate ions (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.

Iron metal will give up electrons to silver ions since iron is more active than silver.

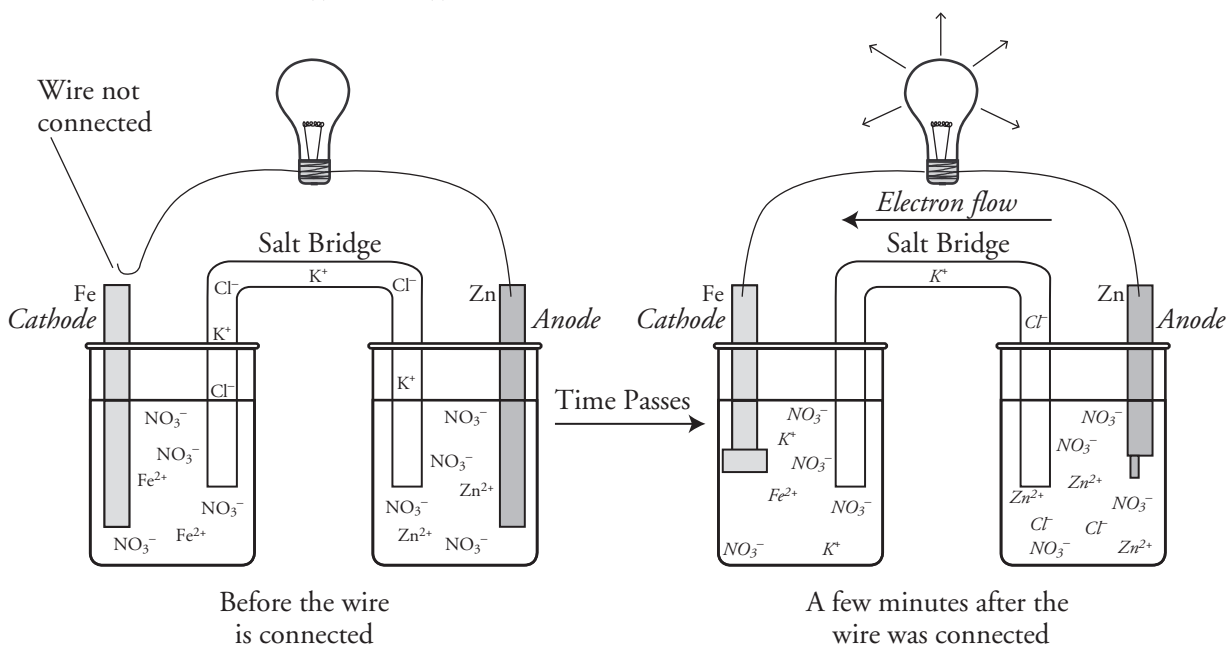
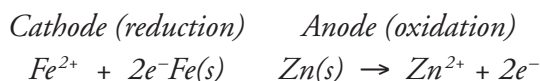
12. Draw an arrow on your diagram in Question 10 to indicate the direction of electron flow through the voltaic cell once the wire is connected.
13. Use Model 1 to complete the table.

	Initially	After a Few Minutes
Number of zinc ions (Zn^{2+}) dissolved in solution	2	3
Number of copper ions (Cu^{2+}) dissolved in solution	2	1
Number of nitrate ions (NO_3^-) dissolved in solution	4	4
Number of potassium ions (K^+) dissolved in solution	0	2
Number of chloride ions (Cl^-) dissolved in solution	0	2

14. Even though ions and electrons move around in a voltaic cell, the cell must stay electrically neutral.
- a. 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.
- The solution in the anode half-cell gained a +2 ion (zinc), but also gained two -1 ions (chloride) from the salt bridge, so it remained electrically neutral.*
- b. 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.
- The solution in the cathode half-cell lost a +2 ion (copper), but also gained two +1 ions (potassium) from the salt bridge, so it remained electrically neutral.*
- c. What is the role of the salt-bridge in a voltaic cell?
- To provide ions to the solutions to keep them electrically neutral.*

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.

If a metal electrode is placed in a solution of ions from another metal, the metal may react directly with those ions rather than sending the electrons through the wire.

Teacher Resources – Batteries

Learning Objectives

1. Identify the anode and cathode in a voltaic cell drawing given one of the following: the direction of the electron flow in the wire, the half-cell reactions or identity of the electrodes, or the activity series of metals.
2. Describe the purpose of the salt bridge in a voltaic cell.

Prerequisites

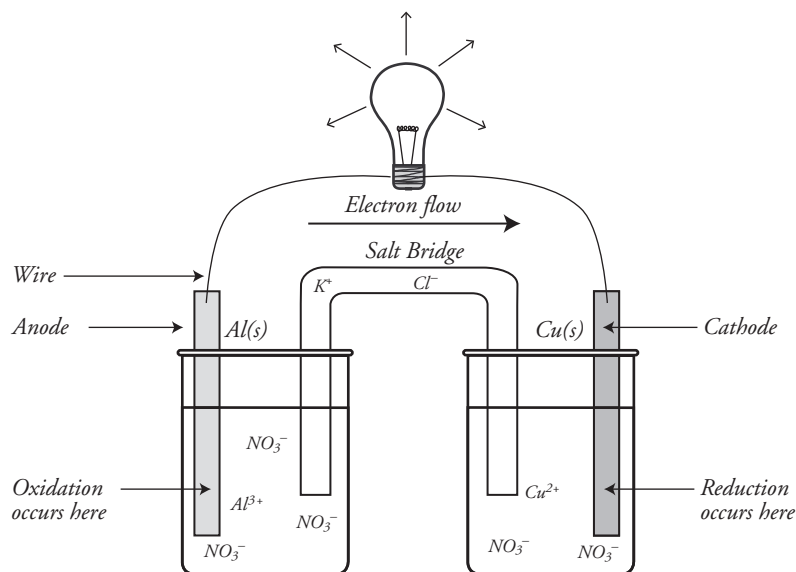
1. Students should be able to predict the spontaneous direction of a redox reaction between two metals using the activity series of metals.
2. Students should be familiar with writing half-reactions for redox processes.
3. Students should understand the basic concepts of electrical circuits.

Assessment Questions

1. As the voltaic cell (battery) produces electricity, the anode will:
a. lose electrons. *b.* gain electrons. *c.* not react.
2. A salt bridge is needed in a battery (voltaic cell) so that:
a. the salt has somewhere to be.
b. the circuit is completed and electrons can travel through the aqueous solutions.
c. salt ions can move into the solutions to balance the overall charge in each solution and keep it neutral.
d. it has no special function and is not needed.
3. Draw a voltaic cell that includes Al and Cu as the metals. Label the following parts of your drawing: metals, ions, anode, cathode, site of reduction, site of oxidation, salt bridge, wires, bulb, and an arrow to show the direction of electron flow.

Assessment Target Responses

1. a.
2. c.
- 3.



Teacher Tips

- It might be helpful for students to see the voltaic cell in Model 1 as a demonstration or lab experience before working on this activity. The color change in the copper solution is not evident on paper.
- This activity does not address the idea that the number of electrons lost at the anode must equal the number of electrons gained at the cathode. Examples were chosen carefully so that this would not become an issue for students as they work through the activity. However, if this is an objective for your course, Question 10 is a good lead-in for this conversation.
- The following web-based simulation may greatly enrich student understanding of galvanic (voltaic) cells (accessed December 2011).

<http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/voltaicCell.html>

Notes