

## Electrochemical Cells

An **electrochemical cell** is any device that uses redox reactions to either produce or use electricity.

### Basic Cell Design

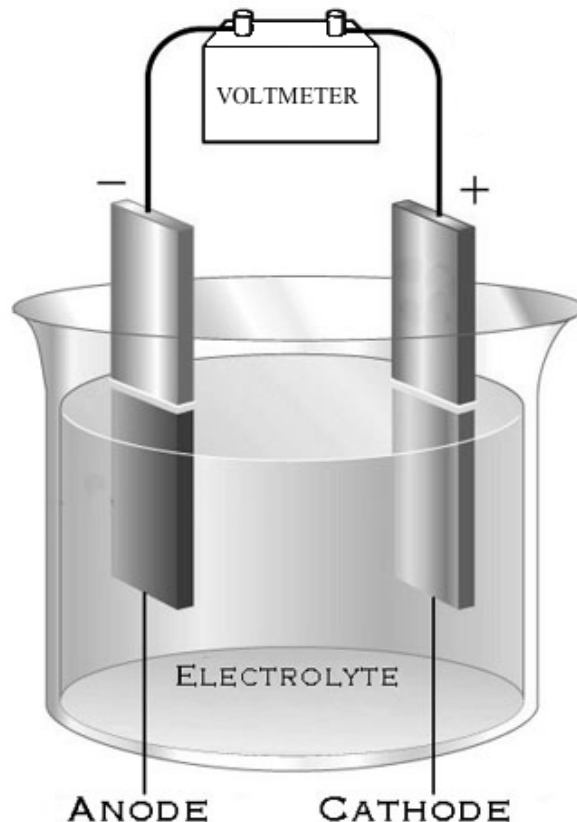
A typical electrochemical cell is composed of two **electrodes**—an anode and a cathode—and an **electrolyte** (a solution of dissolved ions that will conduct electricity).

In the cells we buy for home use, the electrolyte is usually a moist paste, containing only enough conducting solution to make the cell function.

The electrodes are usually two metals, or graphite and a metal. In some designs, one of the electrodes is the container of the cell.

In an electrochemical cell, the cathode is the positive electrode and the anode is the negative electrode.

In order for a cell to produce an electric current, there must be an external conducting pathway (e.g. a wire) connecting the anode and the cathode. As long as such a pathway exists, electrons will flow from the anode of the cell to the cathode.



### Types of Electrochemical Cells

There are two types of electrochemical cells, those that produce electricity and those that use electricity. Those that produce electricity as the result of spontaneous redox reactions are called **voltaic cells**. A battery consists of one or more voltaic cells.

Electrochemical cells in which electrical energy drives nonspontaneous redox reactions are called **electrolytic cells**. Electrolytic cells are used to plate precious metals onto jewelry, to purify metals, and to obtain active metals from their compounds.

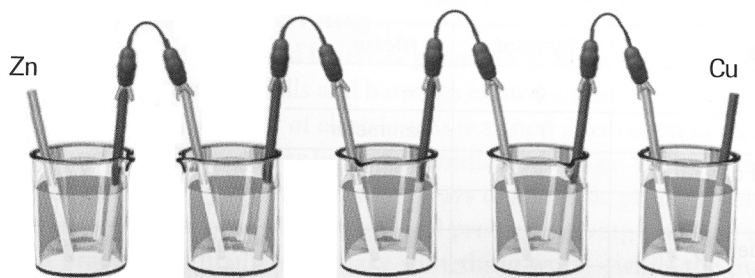
## Voltaic Cells

In the late 1700s, Luigi Galvani made an important observation while dissecting frogs. While cutting a frog leg, Galvani's steel scalpel touched a brass hook that was holding the leg in place, causing the leg to twitch. After further experiments confirmed this effect, Galvani concluded that he was observing something he called "animal electricity," the life force within the muscles of the frog.

Some 30 years later, Galvani's observation served as inspiration for a fellow scientist, Alessandro Volta. Volta realized that the electricity observed by Galvani was not the result of some "life force," but rather was a direct result of the contact between two metals in the presence of moisture.

This realization led Volta to develop the first electric cell in 1800. Though his first electric cells produced very little electricity, Volta was able to improve on his design by joining several cells together. A **battery** is a group of two or more electric cells connected to each other, in series, like railway cars in a train.

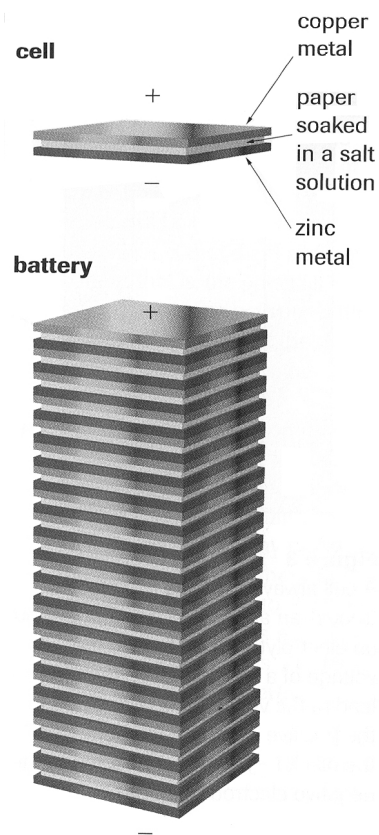
Volta's first battery consisted of several bowls of brine (salt water) connected by metals that dipped from one bowl into the next, as shown below. This arrangement produced a steady flow of electric current.



Volta improved the design of this battery by replacing the strips of metal with flat sheets, and replacing the bowls with paper soaked in brine. This produced more electric current for a longer period of time.

As shown in the diagram to the right, Volta stacked cells on top of each other to form a battery, known as a **voltaic pile**. When a loop of wire was attached to the top and bottom of this voltaic pile, a steady electric current flowed. Volta assembled voltaic piles containing more than 100 cells.

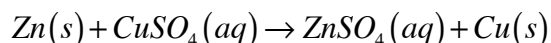
Volta's invention was an immediate success because it produced an electric current more simply and more reliably than other methods that depended on static charges. It also produced a steady electric current—something no other device could do.



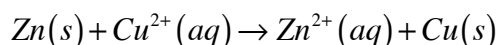
Electric cells adapted for scientific study are often called **galvanic cells** or **voltaic cells**.

### Overview of Voltaic Cells

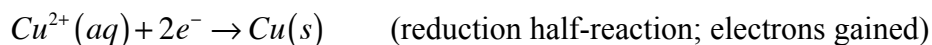
All voltaic cells operate in a similar fashion and share certain common features. We will use the spontaneous redox reaction between zinc metal and a solution of copper sulfate to illustrate the main ideas.



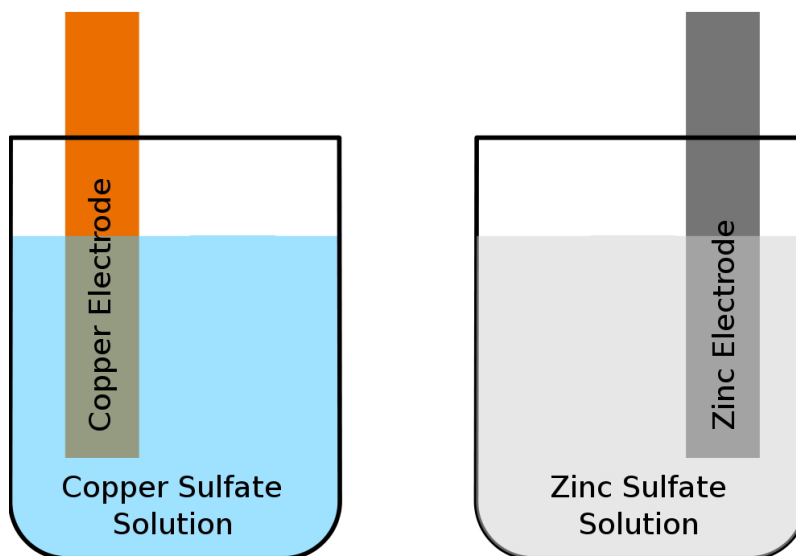
The following net ionic equation illustrates the electron transfer that occurs.



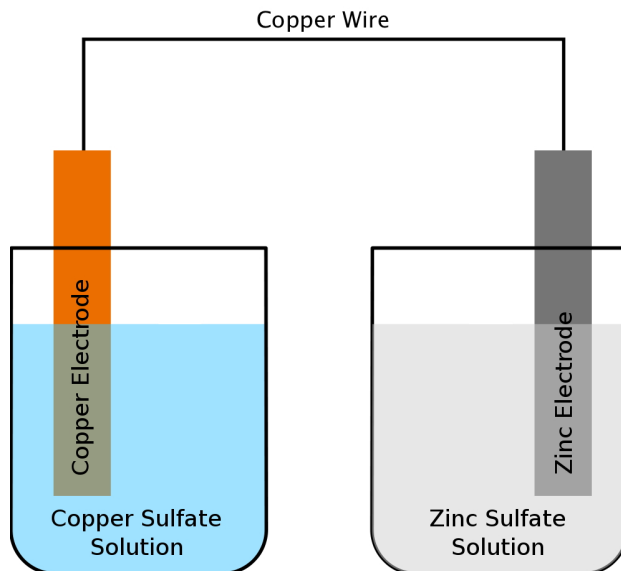
Two half-reactions make up this redox process:



What would happen if we separated the oxidation half-reaction from the reduction half-reaction? Can redox occur? Consider the image below, in which a zinc strip is immersed in a solution of zinc sulfate, and a copper strip is immersed in a solution of copper(II) sulfate.



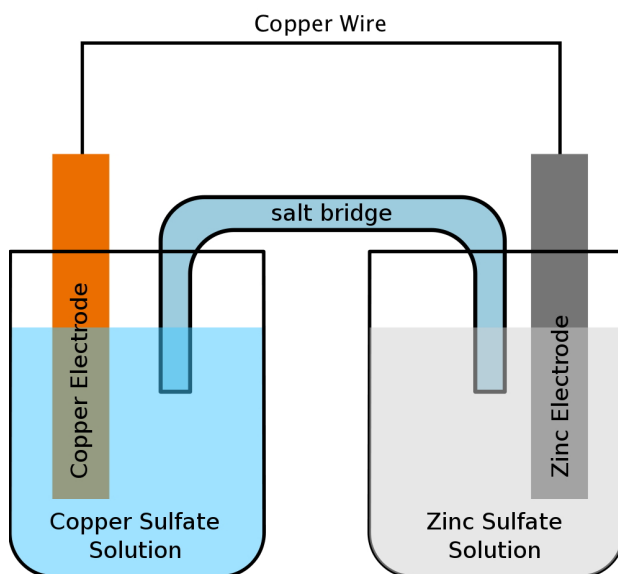
Two problems prevent a redox reaction in this situation. First, with this setup, there is no way for zinc atoms to transfer electrons to copper(II) ions. This problem can be solved by connecting a metal wire between the zinc and copper strips, as shown in the next image.



The wire serves as a pathway for electrons to flow from the zinc strip to the copper strip.

Even with the wire, another problem prevents the redox reaction. The build up of positive zinc ions on the left prevents the oxidation of zinc atoms. On the other side, the build up of negative ions prevents the reduction of copper ions.

To solve the second problem, a salt bridge must be built into the system. A salt bridge is a pathway constructed to allow the passage of ions from one side to another, as shown in the following image.



A salt bridge consists of a tube containing a conducting solution of a soluble salt (such as  $KCl$ ) held in place by some sort of plug. The ions can move through the plug, but the solutions in the two beakers cannot mix.

When the metal wire and the salt bridge are in place, electrons flow through the wire from the oxidation half-reaction to the reduction half-reaction while positive and negative ions move through the salt bridge.

A flow of charged particles, such as electrons, is called an electric current. The flow of electrons through the wire and the flow of ions through the salt bridge make up the electric current. This current can be used to power a light bulb, run an electric motor, etc.