

Electrochemical Cells

As the name implies, an **electrochemical cell** involves both electricity and chemicals. Electricity is a flow of electrical charge. In solids, electricity is a flow of electrons. In solutions, electricity is a flow of ions. Remember! Pure water is a poor conductor of electricity because it does not contain ions. Water solutions of electrolytes (acids, bases or soluble salts) conduct electricity. A normal direct current power source (battery) has a + and a - pole. The poles of a battery are often called electrodes or terminals. **The - electrode of a battery is a source of electrons.** Electrons flow away from the - electrode of a battery. **The + electrode of a battery receives electrons.** This agrees with our concept that opposite electric charges attract and like charges repel. **Electrochemical cells involve redox reactions.** Something must be **oxidized (lose e⁻)** and something must be **reduced (gain e⁻)**.

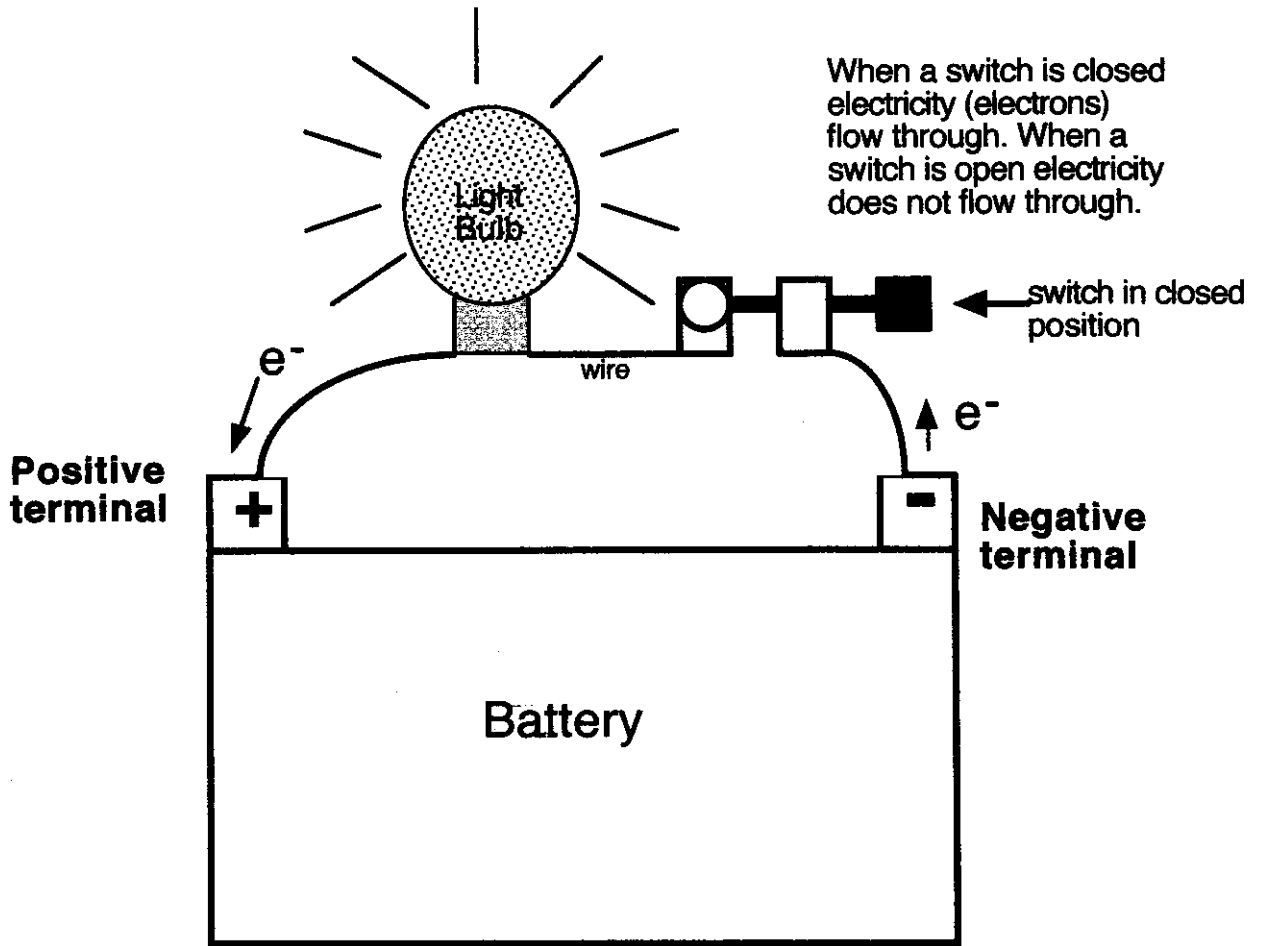
In any electrochemical cell **oxidation** occurs at the **anode**. **Reduction** occurs at the **cathode**.

Table J is used to determine if a redox reaction is spontaneous and which element will be oxidized and which element will be reduced in an electrochemical cell. The element that is closer to the top will be oxidized. The element that is closer to the bottom will be reduced.

Table J	
Most Active	Metals
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>Top oxidized Lose e⁻ Anode</p> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>What do active metals do? Active metals easily lose electrons to join compounds or become + ions. Active metals are easily oxidized. Metals close to the top are considered active. Active metals will replace less active elements in a single replacement reaction.</p> </div>
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>Think of metals as people. Active people join clubs. Active metals join compounds. Active people move around. Active metals are able to move around as ions.</p> </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>What do less active metals do? Less active metals gain electrons from more active metals. Less active metals are easily reduced. They tend to leave compounds and stay by themselves as free elements.</p> </div>
<p>Voltaic Cells produce electricity. "Volts"</p>	<div style="border: 1px solid black; padding: 5px;"> <p>Li Rb K Cs Ba Sr Ca Na Mg Al Ti Mn Zn Cr Fe Co Ni Sn Pb **H₂ Cu Ag Au</p> </div>
	Least Active

Understanding a Battery

A battery has a + and a - terminal (electrode). Electrons are negative. Electrons are pushed away from the negative terminal. Electrons are pulled towards the positive terminal. Remember, "opposites attract".



Can electricity flow through an open switch? _____

Can electricity flow through a closed switch? _____

We have seen that a redox reaction transfers electrons from the species (atom or ion) that is oxidized to the species (atom or ion) that is reduced. When transferred electrons are forced to travel to their destination through a wire a useful electrical current is obtained. That current can be harnessed. What we are describing is an electrical cell. When 2 of more electrical cells are electrically connected it is known as a battery. A **voltaic cell** converts chemical energy to electrical energy using a **spontaneous redox reaction**.

Understanding Voltaic cells: The diagram on the next page shows the most common type of voltaic cell. It uses 2 separate containers. Each container contains a solid piece of metal surrounded by a solution of its aqueous salt (usually a nitrate salt). The solid pieces of metal are called **electrodes**. The electrodes are connected to each other by wire. In between the 2 electrodes is a switch to turn the voltaic cell on or off and a voltmeter or light bulb to detect the electrical current. Loss of electrons (**oxidation**) occurs in one container. Gain of electrons (**reduction**) occurs in the other container. A **salt bridge** connects the 2 containers. A salt bridge allows ions to travel from one container to the other without actually mixing the solutions of the 2 containers. The flow of ions is necessary to complete the electrical circuit (flow of electricity) and maintain electrically neutral solutions.

The **anode** of a voltaic cell is -. It is a source of electrons. Electrons flow away from the anode the same as electrons flow from the - electrode of a battery.

The **cathode** of a voltaic cell is +. Electrons flow towards the cathode in a voltaic cell the same as electrons flow towards the + electrode of a battery.

The redox reaction that occurs in a voltaic cell can be separated into an oxidation half and a reduction half. These halves are called **half-reactions**.

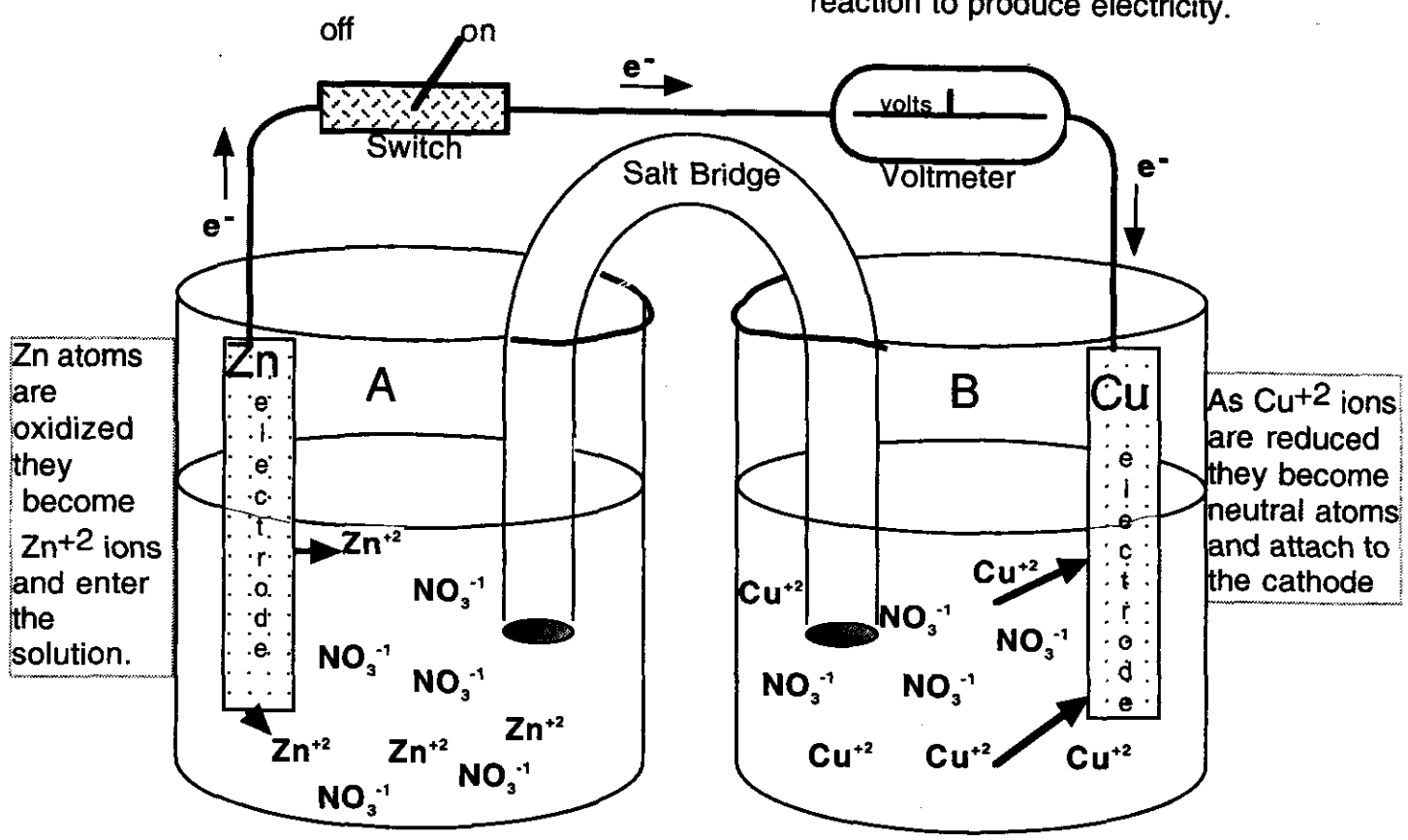
You are required to:

1. Identify the parts of a voltaic cell.
2. State their functions.
3. Predict what will happen if a piece is removed.
4. Predict which cell and electrode will experience oxidation or reduction (use Table J).
5. Predict which electrode will gain or lose mass.
6. Predict the direction of the flow of electrons.
7. Write a balanced reduction half-reaction for the reduction cell.
8. Write a balanced oxidation half-reaction for the oxidation cell.

The following page shows a **voltaic cell**.

Voltaic Cell Note Packet #24

A voltaic cell uses a spontaneous redox reaction to produce electricity.



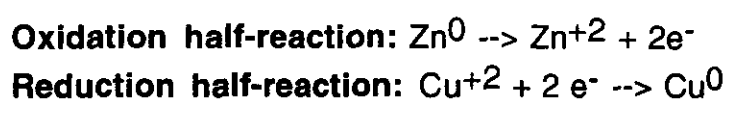
Zn atoms are oxidized they become Zn^{+2} ions and enter the solution.

As Cu^{+2} ions are reduced they become neutral atoms and attach to the cathode

Container **A** is the oxidation half-cell. Zn is higher on Table J than Cu, therefore, Zn is oxidized and Cu is reduced. The electrode that experiences oxidation is called the anode. $Zn_{(s)}$ is the anode. Container A contains a solution of zinc nitrate $Zn(NO_3)_{2(aq)}$. Zinc nitrate is ionic and soluble. It separates into + and - ions in water. $Zn_{(s)}$ is oxidized which means that it loses electrons. When the switch is closed the lost electrons travel through the wire to the solid copper which is reduced (gain of electrons). As

Container **B** is the reduction half-cell. Cu is lower on Table J than Zn, therefore, Cu is reduced and Zn is oxidized. Reduction occurs at the cathode. $Cu_{(s)}$ is the cathode. Container B contains a solution of copper II nitrate $Cu(NO_3)_{2(aq)}$. Copper II nitrate is ionic and soluble. It separates into + and - ions in water. Cu^{+2} ions are reduced. They gain electrons and become $Cu_{(s)}$ and attach to the solid copper cathode. The solid copper

The **salt Bridge** contains an unreactive aqueous salt, usually $KNO_3(aq)$. **Ions travel through the salt bridge.** Ion flow is necessary to maintain neutral solutions. - ions travel towards the oxidation container. + ions travel towards the reduction container. **Ions travel through liquids, not wire!**



Electrons only flow through solids. In a voltaic cell **electrons flow from the anode through the wire to the cathode.**

Electrolytic Cells use an external source of electricity to force a non-spontaneous chemical reaction. Electrolytic cells use electricity, they do not produce electricity.

Electrolysis is the process that occurs in an electrolytic cell.

The anode is + in an electrolytic cell.

The cathode is - in an electrolytic cell.

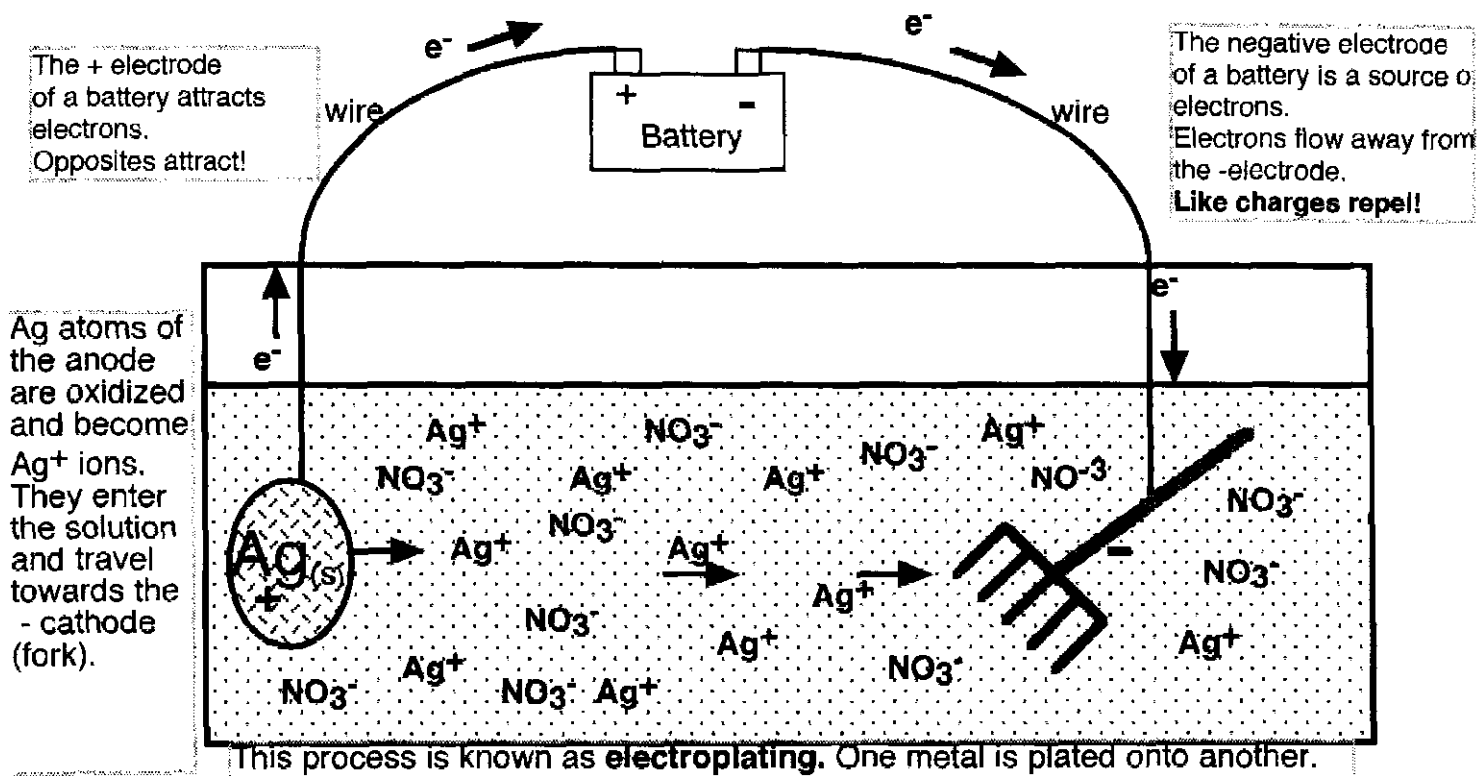
You are required to:

- a) Identify the parts of an electrolytic cell.
- b) State their functions.
- c) Predict which electrode will experience oxidation or reduction.
(use Table J).
- d) Predict which electrode will gain or lose mass.
- e) Predict the direction of the flow of electrons.
- f) Write half-reactions for the electrolytic cell.

The following 3 pages contain diagrams of common **electrolytic cells**.

Electrolytic Cell (Electroplating)

An electrolytic cell uses an external electrical source (battery) to force a **non-spontaneous** reaction. An electrolytic cell has a + anode and a - cathode. Oxidation occurs at the anode. Reduction occurs at the cathode. Ag^0 is reduced at the cathode (fork). The fork gains mass as silver coats it. Ag^0 is oxidized at the anode. The anode loses mass as Ag^0 atoms change to Ag^+ ions and enter the solution.



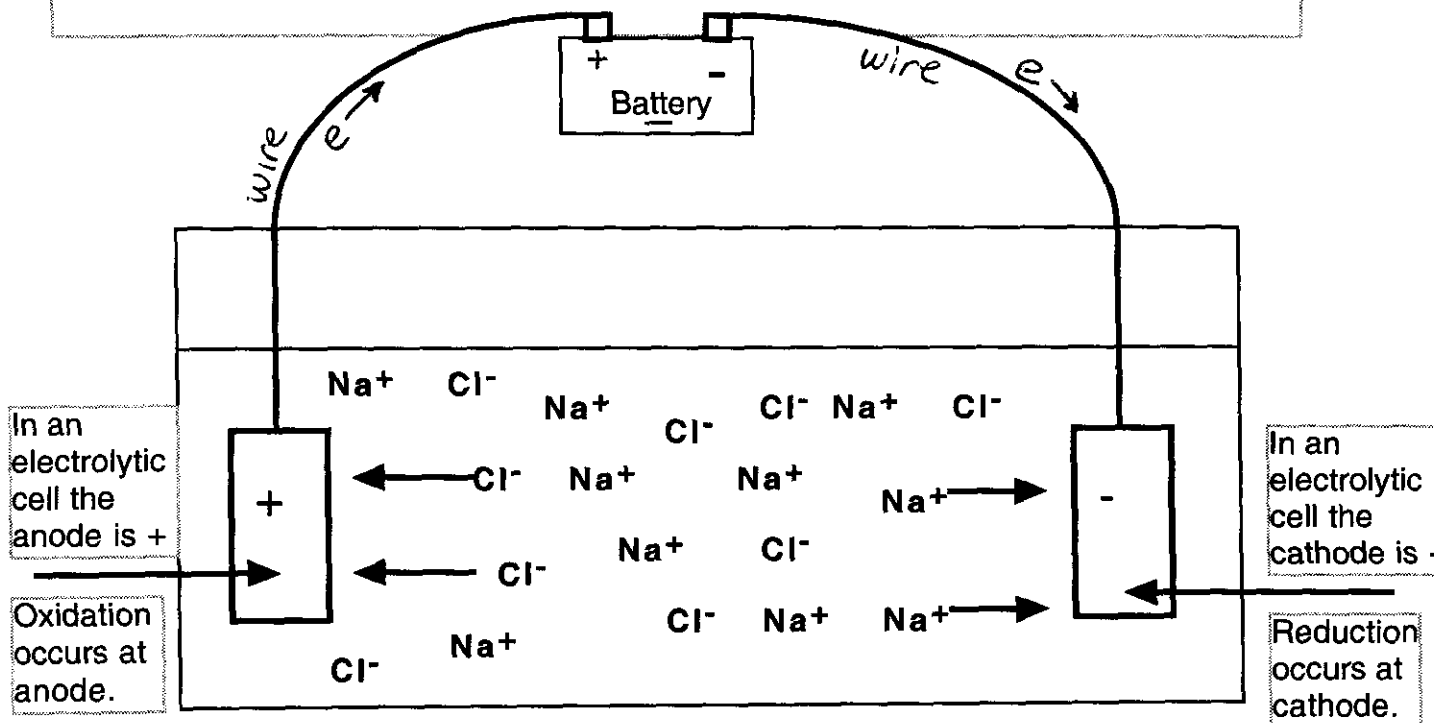
This diagram of an electrolytic cell shows an external electrical source (battery). The + electrode of the battery is attached to a solid piece of silver metal. The - electrode of the battery is attached to the metal fork. The silver metal and the fork are immersed in a solution of silver nitrate AgNO_3 . Silver nitrate is ionic and soluble. It separates into + and - ions. Solid silver is oxidized at the + anode producing + silver ions. + silver ions are reduced at the - cathode.



Think of it this way. + silver ions are attracted to the - fork. + silver ions are repelled by the + solid silver anode and travel away. **Remember! Opposites attract!**

Electrolytic Cell (Electrolysis of fused NaCl)

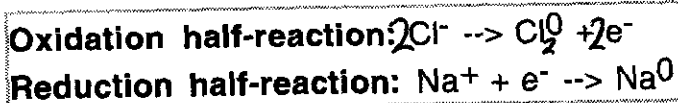
When an ionic compound, such as NaCl, is melted (fused), its ions become mobile. Melted NaCl is composed of Na^+ and Cl^- . An electrolytic cell uses an external electrical source (battery) to force a **non-spontaneous** reaction. Na^+ is reduced at the cathode. Cl^- is oxidized at the anode. An electrolytic cell has a + anode and a - cathode. Oxidation occurs at the anode. Reduction occurs at the cathode.



This diagram of an electrolytic cell shows an external electrical source (battery). Na^+ is attracted to the - cathode. Cl^- is attracted to the + anode. Remember! Opposites attract. Oxidation occurs at the anode. Cl^- ions lose electrons at the anode and become Cl atoms. Reduction occurs at the cathode. Na^+ ions gain electrons at the cathode and become Na atoms.

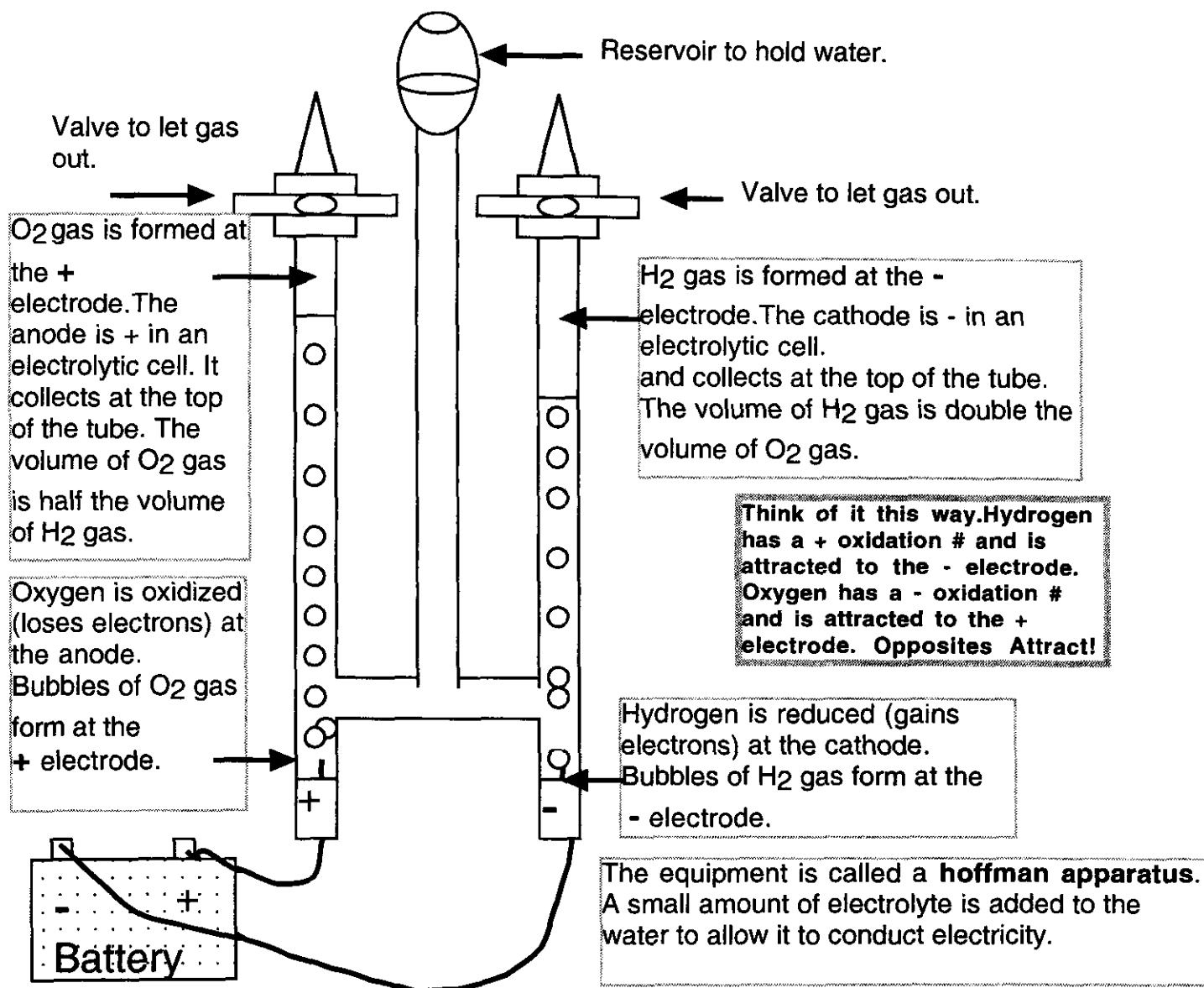
Think of it this way.

- + sodium ions are attracted to - electrode.
 - chloride ions are attracted to the + electrode.
- Remember! Opposites attract!**



Lose electrons oxidation **Leo**
 Gain electrons reduction **Ger**

Electrolysis of Water by use of a Hoffman Apparatus



This process is called **electrolysis** of water. Electrolysis is the process that occurs in an **electrolytic cell**. Electrolysis is a non-spontaneous reaction driven by an external electrical source (battery).

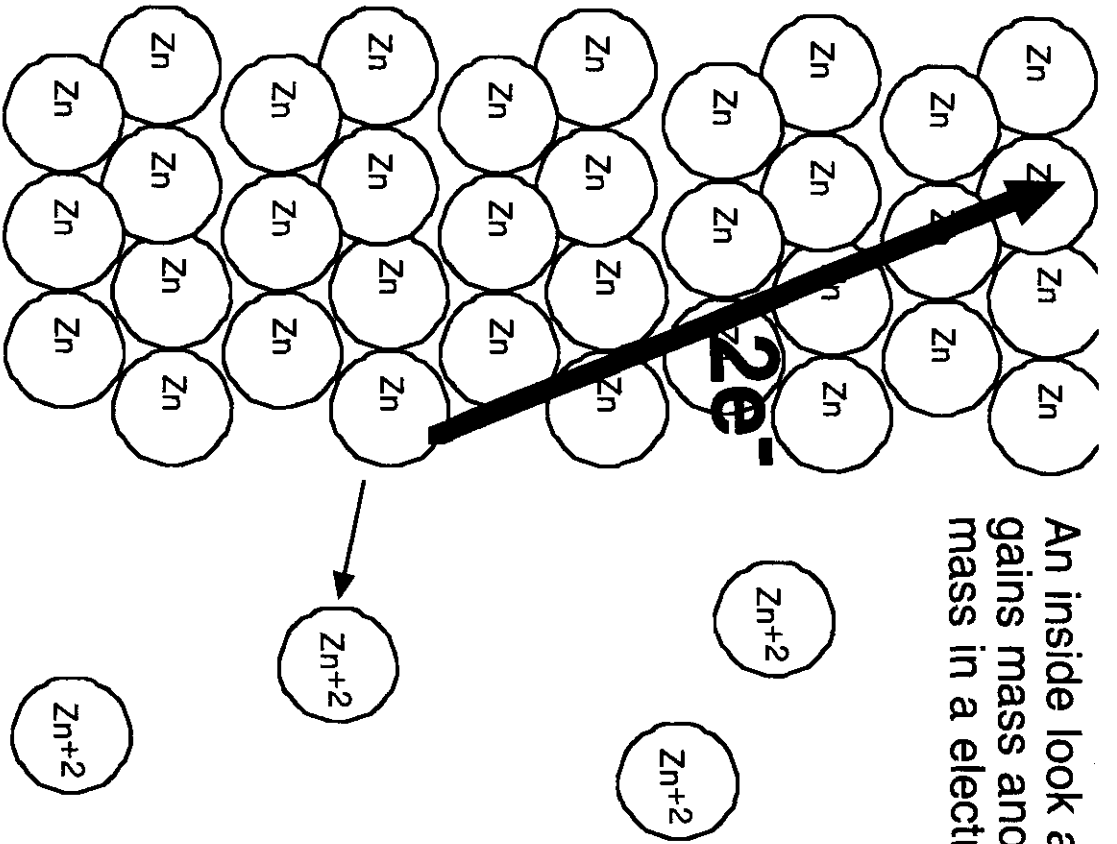
In an **electrolytic cell**, the **cathode is negative** and the **anode is positive**.

In both voltaic and electrolytic cells, **oxidation occurs at the anode** and **reduction occurs at the cathode**. Remember **oxidation is a loss** of electrons and **reduction is a gain** of electrons.

$\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$ is the reaction for electrolysis of water. This is a redox reaction since one or more items have a change of oxidation #. This reaction can be separated into an oxidation half-reaction and a reduction half-reaction. Hydrogen starts with a + 1 oxidation # and ends with an oxidation # of 0 as a free element. Oxygen starts with an oxidation # of - 2 and ends with an oxidation # of 0 as a free element.

Oxygen is oxidized. Oxidation half-reaction: $2 \text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$

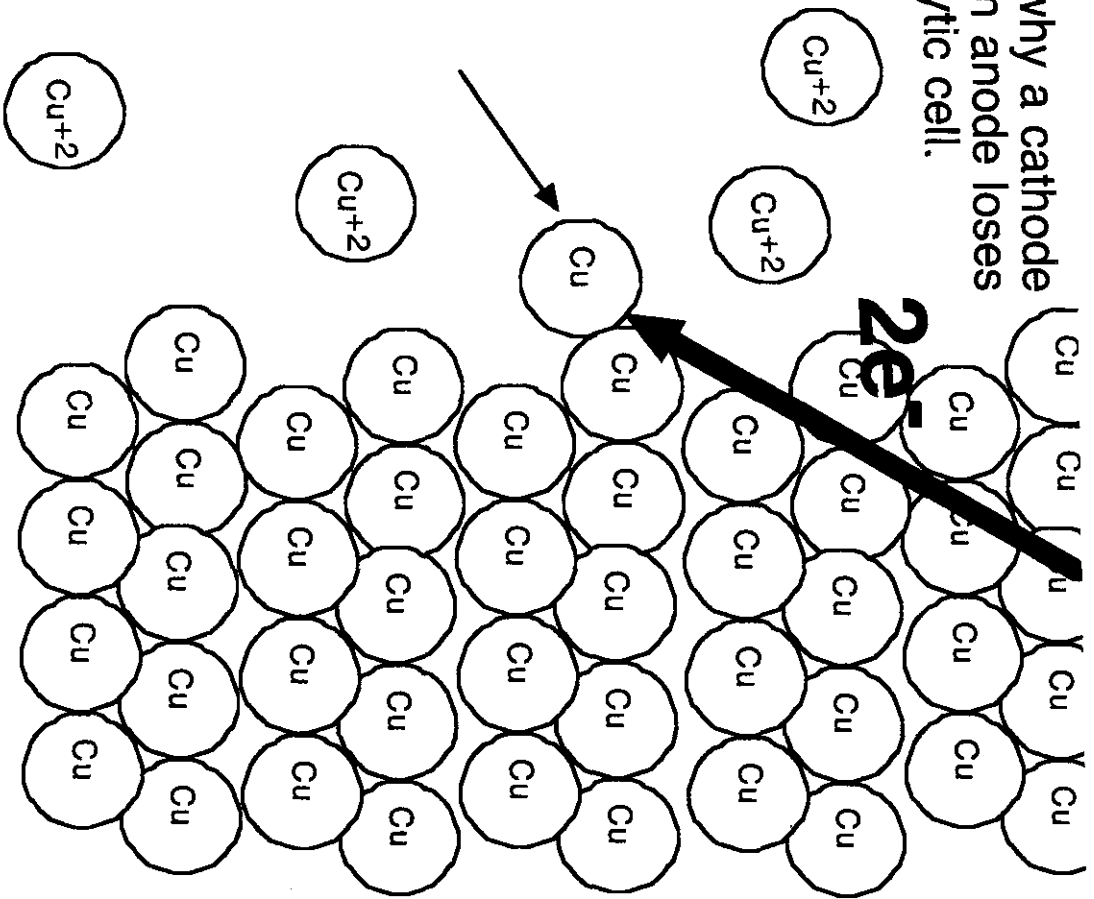
Hydrogen is reduced. Reduction half-reaction: $4 \text{H}^+ + 4 \text{e}^- \rightarrow 2 \text{H}_2$



An inside look at why a cathode gains mass and an anode loses mass in a electrolytic cell.

Anode

Oxidation occurs at the anode. Zinc atoms lose electrons to become ions. The ions dissolve in the solution. The result is the anode loses mass.



Cathode

Reduction occurs at the cathode. Dissolved copper ions gain electrons to become copper atoms and attach to the cathode. The cathode gains mass.

IMPORTANT!
**DIFFERENCES BETWEEN VOLTAIC CELLS
AND ELECTROLYTIC CELLS:**

Voltaic Cell

Spontaneous reaction
Produces electricity
Negative anode
Positive cathode

Electrolytic Cell

Non-spontaneous reaction
Uses electricity
Positive anode
Negative cathode

IMPORTANT!
SIMILARITIES BETWEEN VOLTAIC CELLS AND ELECTROLYTIC CELLS:

Voltaic Cells and Electrolytic Cells

Redox Reaction occurs
Oxidation at anode
Reduction at cathode
Anode loses mass
Cathode gains mass

Electrochemical Cell questions:

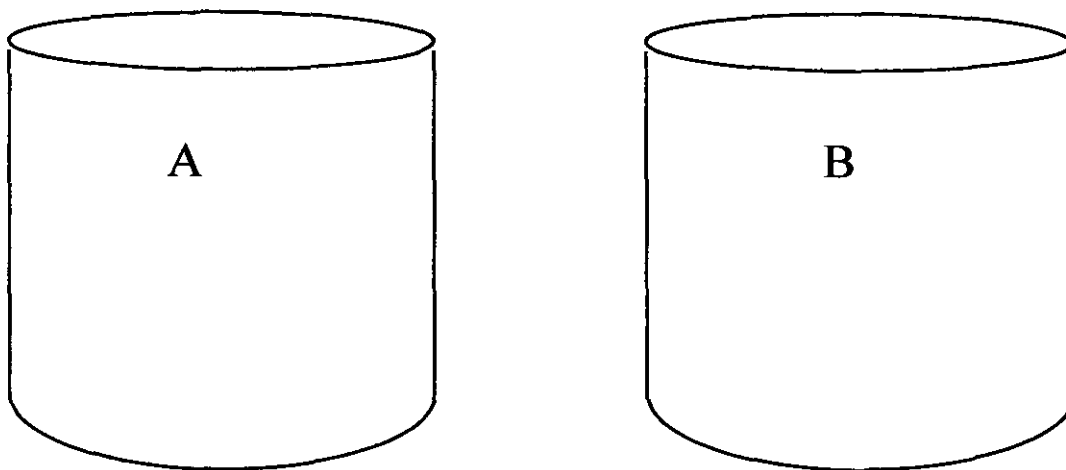
1. Describe how to determine which container of a voltaic cell will experience oxidation and which container will experience reduction.

2. Which direction do the + ions flow in a salt bridge.

3. What will happen if a salt bridge is removed?

4. Describe where the electrons come from and go to? How do they get there?

6. Draw and label the necessary parts to complete this voltaic cell. Use zinc metal and a solution of zinc nitrate in container A. Use copper metal and a solution of copper II nitrate in container B.



7. Which container experiences oxidation?

8. What happens to the mass of the zinc electrode?

9. What happens to the mass of the copper electrode?

10. Which way do the electrons flow?

11. Which electrode is - ?

12. Which electrode is +
13. What will happen if the salt bridge is removed?
14. Write the half-reaction for container A.
15. Write the half-reaction for container B.

14. What are the similarities between a voltaic cell and an electrolytic cell?
List at least 4.

15. What are the differences between a voltaic cell and an electrolytic cell?
List at least 4.

16. Write the half-reactions for the electrolysis of water. Look at the diagram if you must.

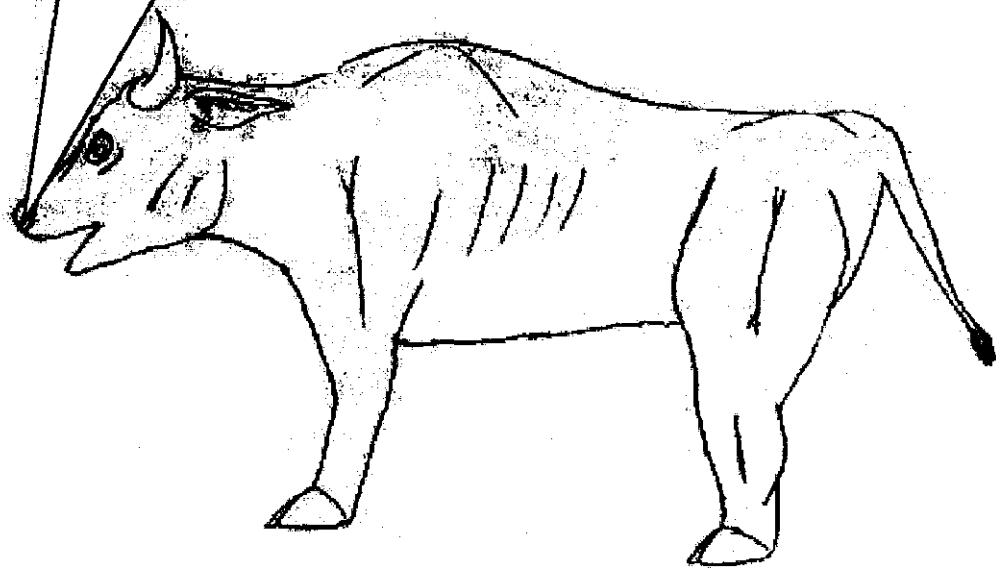
17. Write the half-reactions for the electrolysis of fused (melted) sodium chloride. Look at the diagram if you must.

18. Write the half-reaction for the electroplating of silver onto a metal fork. Look at the diagram if you must.

19. Explain why a Hoffman apparatus produces twice the volume of hydrogen gas as it does oxygen gas.

20. Why is it necessary to add some electrolyte to a Hoffman apparatus?

HELLO! I am **an ox**.
In an electrochemical
cell **oxidation** occurs
at the **anode**. The
anode loses mass as
atoms change to ions
and dissolve.



I am a fat red cat. In an electrochemical cell **reduction** occurs at the **cathode**. The fat cat cathode gains mass. The fat cat gains mass.



