

Electrochemistry (Chapter 21)

21.1 Electrochemical Cells

Review- Metals are good conductors because of the ease at which their valence electrons can move. The movement of ions in solution can also carry an electric current.

An **Electrochemical cell** is a device that uses redox reactions to produce or use electricity.

Electrodes are conductors within electrochemical cells made of metals or graphite and provide a surface for the redox reactions to occur. The electrodes are individually separated into compartments and are sites for either oxidation **or** reduction.

Voltaic cells (Galvanic cells) are electrochemical cells that produce electricity as the result of spontaneous redox reactions (e.g. batteries).

Electrolytic cells are electrochemical cells that use electricity to drive nonspontaneous redox reactions (e.g. electroplating).

**Section review on page 685*

21.2 Voltaic Cells

Luigi Galvani- first noticed the electrochemical phenomenon while dissecting frog legs

Alessandro Volta- made the first battery in 1800 consisting of alternating disks of dissimilar metals separated by pieces of leather soaked in salt water

-The voltaic cell is separated into oxidation and reduction **half-cells** to permit only the indirect transferring of electrons. The oxidation *half-reaction* occurs in the oxidation half-cell and the reduction half-reaction occurs in the reduction half-cell.

- The electrode where oxidation occurs is called the **anode** (-).
- The electrode where reduction occurs is called the **cathode** (+).

-Electrons move spontaneously from the anode (negative electrode) to the cathode (positive electrode).

A **salt bridge** filled with an electrolyte solution connects the two half-cells. This tube allows ions to move between the two compartments without having the solutions mix appreciably.

The **cell potential** represents the difference in electrical potential energy between both electrodes within a voltaic cell. This driving force moves electrons from the anode to the cathode and is measured in **volts (V)**. *Cell voltage* is a measure of the cell's ability to drive an electric current through a wire and do work.

-Voltaic cells *always* have a positive cell potential (voltage is positive)!

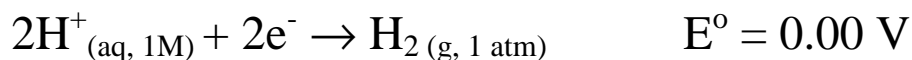
Standard cell potentials are measured values of different voltaic cells with 1M solution concentrations and at standard-state conditions (25°C, 1 atm for gases).

The **cell potential (E)** is considered to be the sum of the **oxidation potential (E_{oxidation})** and **reduction potential (E_{reduction})**. If the cell operates at standard-state conditions, then the **standard electrode potentials** are used to solve for the standard cell potential.

$$E^{\circ} = E^{\circ}_{\text{oxidation}} + E^{\circ}_{\text{reduction}}$$

A *reference* standard hydrogen electrode is used to measure *all* (relative) standard electrode potentials and **hydrogen's standard reduction potential is measured at exactly zero.**

Figure 21.10 on page 692 shows you how it's done.



-Standard oxidation and reduction potentials are easily found in a **Standard Reduction Potentials Table** (p.693). *Standard Oxidation potentials are obtained by simply reversing the sign of the standard reduction potential.*

-The more positive the standard reduction potential of a molecule or ion, the more readily that species is reduced. Thus, a list of standard reduction potentials give you information as to the relative ease with which a molecule or ion is oxidized or reduced. (*A list of standard reduction potentials is essentially an activity series of metals discussed in previous chapters. Can you reason why this is so?*)

**Sample 1 on pages 694 and 695(solving a standard cell potential)*

**Practice problems and section review on page 696*

21.3 Common Batteries

Rechargeable batteries use reversible redox reactions while those that cannot be recharged use nonreversible redox reactions.

-Dry cells contain pasty electrolytes

Components of a Common Dry Cell (e.g. flashlight battery):

- a) **Zinc container** (zinc is oxidized)
- b) **Anode paste** containing zinc chloride and water
- c) **Cathode paste** containing manganese (IV) oxide (manganese is reduced), ammonium chloride (aids in reducing manganese), and water
- d) **Porous paper liner** serves as salt bridge
- e) **Graphite rod** serves as the cathode (inexpensive electrode)

Reactions and diagram on pages 697 and 698, respectively

Advantages	Disadvantages
Low cost	It's not rechargeable
	Large voltage drop under high current loads
	Poor shelf life due to zinc reacting with the acidic ammonium ions

Components of an Alkaline Dry Cell Battery:

- a) *Anode paste* containing powdered zinc (oxidized), potassium hydroxide (aids in oxidizing zinc) and water
- b) *Cathode paste* containing manganese (IV) oxide (manganese is reduced), graphite and water (aids in reducing manganese)
- c) *Porous paper or fabric* (serves as salt bridge)
- d) *Brass anode*

Diagram and reactions on page 698

Advantages	Disadvantages
Longer shelf life than the common dry cell (zinc doesn't react as readily with the potassium hydroxide)	Higher cost due to its elaborate design
Maintains a steady voltage under high current loads	
50% more energy than a common dry cell	

Components of a Lead Storage Battery:

- a) Contains **six 2 volt voltaic cells** totaling 12 volts
- b) **Lead sheets** serve as anodes
- c) **Lead (IV) oxide sheets** serve as cathodes
- d) **Sulfuric acid** serves as the electrolyte
- e) Both produce insoluble lead (II) sulfate during discharge which adhere to both electrodes (permits recharging)
- f) A direct electrical current is used to reform the anode and cathode

Diagram and reactions on pages 699 and 700, respectively

Advantages	Disadvantages
Can be recharged thousands of times	Driving dislodges the lead (IV) sulfate
Relatively simple, inexpensive, and reliable	It's heavy
	Proper disposal

Components of the Nickel-Cadmium Battery:

- Cadmium anode** (oxidized to form Cd^{2+})
- OH^- ions react with the cadmium ions to form insoluble cadmium hydroxide
- Nickel (IV) oxide present in the *cathode paste* is reduced to form insoluble Nickel (II) hydroxide
- Both insoluble products formed in the electrode reactions adhere to the electrode surfaces (permits recharging)

Reactions on page 703

Advantages	Disadvantages
Rechargeable	Discharge “Memory” (should be discharged completely before being recharged)
Lightweight	
Produces a constant voltage during discharge	Proper disposal

Components of Fuel Cells (the Hydrogen-Oxygen fuel cell is the most common):

- Fuel** (hydrogen and oxygen) is constantly supplied from an external reservoir to the voltaic cell
- Hydrogen** is oxidized by oxygen to form water
- The *anode* is porous graphite impregnated with nickel; the **anode compartment** is where the hydrogen is oxidized
- The *cathode* is porous graphite impregnated with nickel and nickel (II) oxide; the **cathode compartment** is where oxygen is reduced
- OH^- ions supplied by the potassium hydroxide found in the cell participate in the electrode reactions

Reactions and Diagram on pages 703 and 704, respectively

Advantages	Disadvantages
Doesn't run down (fuel is constantly supplied)	Expensive
Very efficient (about 90%)	
Used in the space program	
The product is water (can be used for drinking while in space)	

**Section review on page 704*