Chemistry for Changing Times
11th Edition
Hill and Kolb

Chapter 8
Oxidation and Reduction

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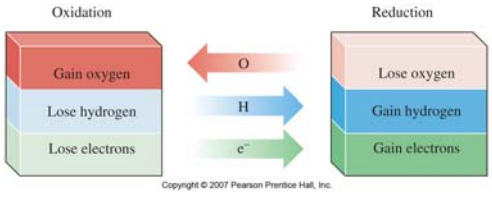
Burn and Unburn

- Oxidation and reduction always occur together.

$(NH_4)_2CrO_7 \rightarrow Cr_2O_3 + N_2 + 4\ H_2O$

Oxidation and Reduction



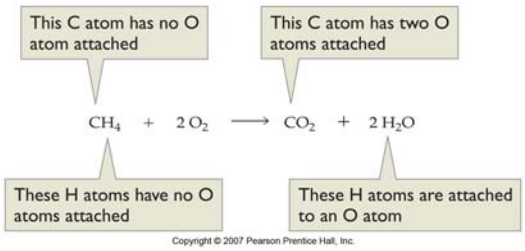
Oxidation and Reduction

Use mnemonic: "LEO the lion goes GER."

LEO: Loss of Electrons is Oxidation

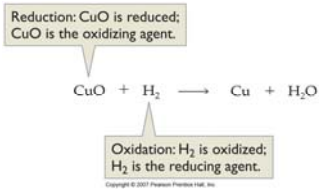
GER: Gain of Electrons is Reduction

Oxidation and Reduction



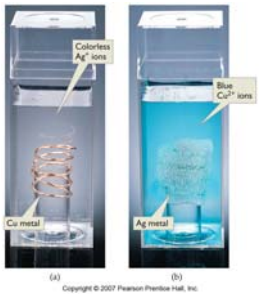
Oxidizing and Reducing Agents

Oxidizing agents cause oxidation.
Reducing agents cause reduction.



Electrochemical Cells and Batteries

Oxidation and reduction reactions can be used to produce electricity.



Electrochemical Cells and Batteries

Electrodes: Pieces of metal where electrons are transferred.

Anode: Electrode where oxidation occurs.

Cathode: Electrode where reduction occurs.

Electrochemical Cells and Batteries

The oxidation and reduction reactions can be represented as half-reactions:

oxidation: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$

reduction: $2\ Ag^+(aq) + 2\ e^- \rightarrow 2\ Ag(s)$

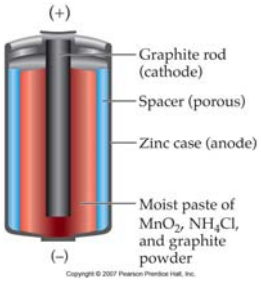
Overall reaction: $Cu(s) + 2\ Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2\ Ag(s)$

Electrochemical Cells and Batteries

Electrochemical Cells and Batteries

Dry Cell:

$Zn + 2\ MnO_2 + H_2O \rightarrow Zn^{2+} + Mn_2O_3 + 2\ OH^-$



Electrochemical Cells and Batteries

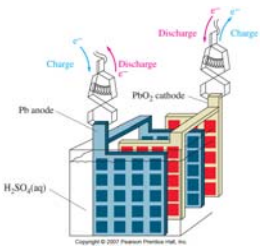
Lead Storage Batteries:

Discharge:

$Pb + PbO_2 + 2\ H_2SO_4 \rightarrow 2\ PbSO_4 + 2\ H_2O$

Recharge:

$2\ PbSO_4 + 2\ H_2O \rightarrow Pb + PbO_2 + 2\ H_2SO_4$



Electrochemical Cells and Batteries

Nickel-cadmium batteries are used in portable radios and cordless appliances. They use cadmium anodes and nickel-oxide cathodes.

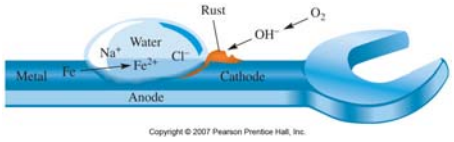
Fuel cells are an interesting kind of battery. The fuel is oxidized at the anode and O_2 is reduced at the anode. The electrons are allowed to flow through a wire and do work.

Corrosion

Rusting of iron:

$$2\ Fe + O_2 + 2\ H_2O \rightarrow 4\ Fe(OH)_2$$

$$4\ Fe(OH)_2 + O_2 + 2\ H_2O \rightarrow 4\ Fe(OH)_3$$



Corrosion

Protection of Aluminum

Aluminum is more reactive than iron. However, corrosion of aluminum is not a serious problem. Aluminum oxide is very tough and prevents further corrosion.

Corrosion

Silver Tarnish

Silver tarnish is the result of the oxide on the silver surface reacting with hydrogen sulfide (H_2S) in air. This leaves a black film of silver sulfide (Ag_2S).

Polishing the tarnished silver will restore the shine but at the expense of some of the silver metal. An alternate is to allow aluminum to reduce the silver in the presence of a solution of sodium bicarbonate electrolyte.

Explosive Reactions

Chemical explosions are often the result of redox reactions. Redox reactions that occur rapidly with the production of gases (often nitrogen) are often explosive.

ANFO: Ammonium Nitrate/Fuel Oil

$$52\ NH_4NO_3(s) + C_{17}H_{36}(l) \rightarrow 52\ N_2(g) + 17\ CO_2(g) + 122\ H_2O(g)$$

Oxygen: An Abundant and Essential Oxidizing Agent

Oxygen is the most common oxidizing agent. It comprises 20% of air and about 50% of the Earth by mass. In the atmosphere, it can exist as oxygen molecules (O_2) or ozone (O_3). It reacts with metals and nonmetals, forming oxides.

Oxygen: An Abundant and Essential Oxidizing Agent

Ozone (O_3) is a powerful oxidizing agent. In the lower atmosphere, it is harmful to both plants and animals. However, in the stratosphere, it serves to protect life on Earth from harmful ultraviolet radiation.

Other Common Oxidizing Agents

Hydrogen peroxide (H_2O_2) is a common oxidizing agent used as a disinfectant or to bleach hair.

Other Common Oxidizing Agents

Potassium dichromate ($K_2Cr_2O_7$) will oxidize alcohols and turns green when reduced to chromium (III). It is used in Breathalyzers.

Benzyl peroxide is an antiseptic and used to treat acne.

Chlorine is used as a disinfectant in the treatment of drinking and wastewater.

Bleaches (NaOCl, $Ca(OCl_2)$) are oxidizing agents used on fabrics.

Some Reducing Agent of Interest

Metallurgy Reducing Agents

Coke (C) is produced by heating coal to drive off volatile compounds. It is used as a reducing agent in smelting of metals such as tin:

$$SnO_2 + C \rightarrow Sn + CO_2$$

Aluminum is used to reduce chromium oxide to chromium metal:

$$Cr_2O_3 + 2\ Al \rightarrow Al_2O_3 + 2\ Cr$$

Some Reducing Agent of Interest

Reduction in Photography

Black and white photographic paper contains a coating of silver bromide (AgBr). The silver ions that are exposed to light react with the developer (hydroquinone, $C_6H_4(OH)_2$) to form metallic silver.

$$C_6H_4(OH)_2 + 2\ Ag^+ \rightarrow C_6H_4O_2 + 2\ Ag + 2\ H^+$$

The silver ions not exposed are removed using a solution of sodium thiosulfate. This produces a negative where the metallic silver is deposited.

Some Reducing Agent of Interest

Reduction in photography: Shown here is a photographic negative and positive print.

Some Reducing Agent of Interest

Antioxidants are reducing agents in foods. Ascorbic acid (vitamin C), tocopherol (vitamin E), and vitamin A are such antioxidants.

Some Reducing Agent of Interest

Hydrogen as a Reducing Agent

Hydrogen is an excellent reducing agent for both metal and nonmetal reagents.

Hydrogen can reduce metallic oxides to their metals:

$$WO_3 + 3\,H_2 \rightarrow W + 3\,H_2O$$

Hydrogen can also reduce double bonds to single bonds.

$$C_2H4 + H_2 \rightarrow C_2H_6$$

Nickel or platinum is used as a **catalyst** for this reaction. Catalysts increase the rate of a chemical reaction by lowering the activation energy.

A Closer Look at Hydrogen

Hydrogen is the most abundant element in the universe. It is an important element on Earth. It is seldom found in the free state on Earth. The majority is combined with oxygen in water.

$$H_2 + O_2 \rightarrow 2\,H_2O$$

Hydrogen is used in the manufacture of ammonia and methanol. It is also used to hydrogenate vegetable oils to make margarines and shortening.

A Closer Look at Hydrogen

Hydrogen gas can be prepared by reacting zinc with hydrochloric acid.

A Closer Look at Hydrogen

Hydrogen has a very low density and has been used in zeppelins and blimps. Less flammable gases such as helium are now used.

Oxidation, Reduction, and Living Things

Oxidation and reduction reactions are critical to life on Earth. Energy is obtained from food by oxidizing the food. One example is the oxidation of glucose:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$

The reactions of photosynthesis are a series of reductions that are the reverse of the above reaction.

$6\ CO_2 + 6\ H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$

Oxidation, Reduction, and Living Things

Photosynthesis is the only process that produces the elemental oxygen that is essential for animals on Earth.