Hewitt/Lyons/Suchocki/Yeh

Conceptual Integrated Science

Chapter 13
CHEMICAL REACTIONS

Chemical Reactions and Equations

During a chemical reaction, one or more new compounds are formed as a result of the rearrangement of atoms.

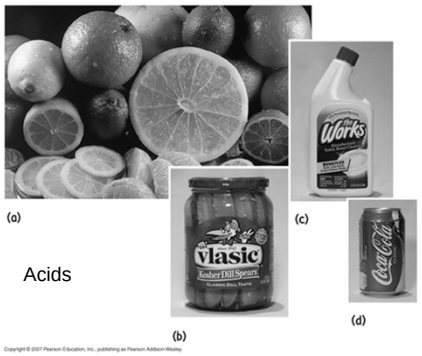
Reactants → Products

Chemical Reactions and Equations

Law of Mass Conservation: No atoms are gained or lost during any reaction.

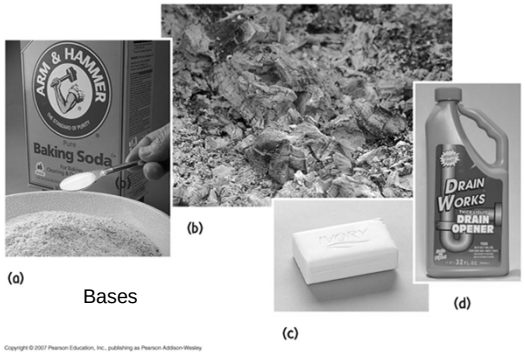
The number of times atoms appear before the arrow must be equal to the number of times they appear after the arrow.

Acid–Base Reactions



Acids

Acid–Base Reactions



Bases

Acid–Base Reactions

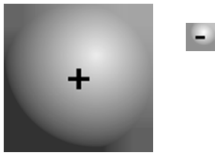
Acid

- A chemical that donates a hydrogen ion, H^+

Base

- A chemical that accepts a hydrogen ion, H^+

The hydrogen atom



H

The hydrogen ion

H^+

Base **A**ccepts **A**cid **D**onates

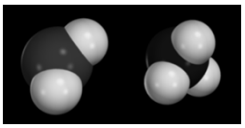
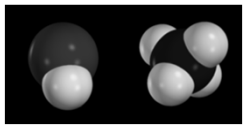
$HCl + H_2O \rightarrow Cl^- + H_3O^+$

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

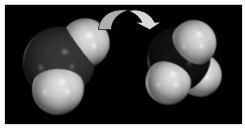
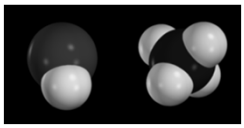
donor acceptor

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

(acid) (base)

$H_2O + NH_3 \rightarrow OH^- + NH_4^+$

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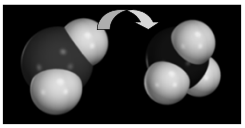
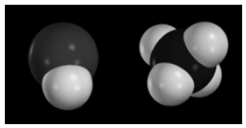

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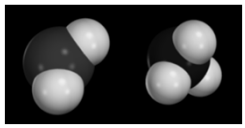
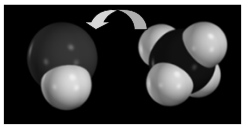
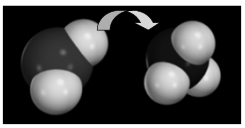
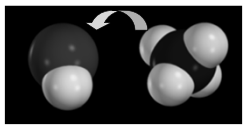



$H_2O + NH_3 \leftarrow OH^- + NH_4^+$

(base) (acid)

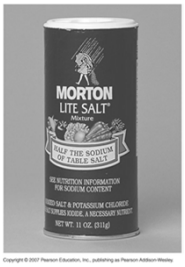



$H_2O + NH_3 \rightleftharpoons OH^- + NH_4^+$

(acid) (base) (base) (acid)

Salts

Salt: An ionic compound formed from the reaction of an acid and a base.



Salts

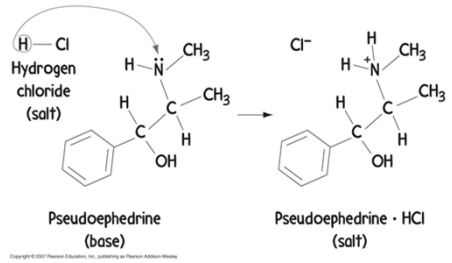
Salt: An ionic compound formed from the reaction of an acid and a base.

Table 13.1 Acid–Base Reactions and Salts Formed

Acid		Base		Salt		Water
HCN	+	NaOH	→	NaCN	+	H_2O
HNO_3	+	KOH	→	KNO_3	+	H_2O
2 HCl	+	$Ca(OH)_2$	→	$CaCl_2$	+	2 H_2O
HF	+	NaOH	→	NaF	+	H_2O

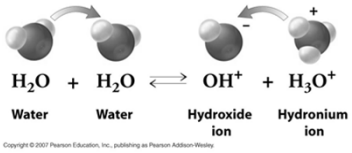
Salts

Salt: An ionic compound formed from the reaction of an acid and a base.



Solutions: Acidic, Basic, or Neutral

Water can behave as an acid or a base.



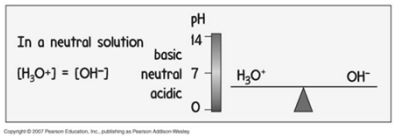
Solutions: Acidic, Basic, or Neutral

Water can behave as an acid or a base.

In pure water, for every one hydronium ion, H_3O^+, formed, there is a hydroxide ion, OH^-, formed.

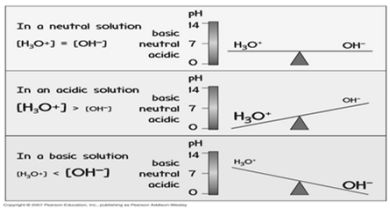
Solutions: Acidic, Basic, or Neutral

So, in pure water, $[H_3O^+] = [OH^-] = 0.0000001\ M = 10^{-7}\ M$.



Solutions: Acidic, Basic, or Neutral

Add hydronium ions, H_3O^+, and the solution is "acidic."
Add hydroxide ions, OH^-, and the solution is "basic."



The pH Scale

pH is a measure of the concentration of hydronium ions, H_3O^+.

$$pH = -\log [H_3O^+]$$

For pure water:

$$pH = -\log (10^{-7})$$
$$pH = -(-7)$$
$$pH = 7$$

The pH Scale

The "log" of a number is simply the power to which ten is raised. The log of 10^3, for example, is 3.

Quiz Time

What is the log of 10^2?

Log $10^2 = 2$

(the power to which 10 is raised)

The pH Scale

$$pH = -\log [H_3O^+]$$

For acidic water pH < 7, for example:

$$pH = -\log (10^{-5})$$
$$pH = -(-5)$$
$$pH = 5$$

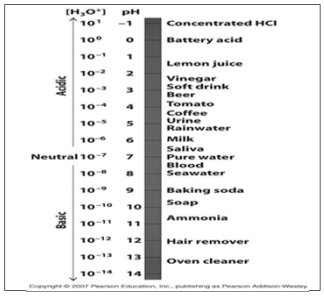
The pH Scale

$$pH = -\log [H_3O^+]$$

For basic water pH > 7, for example:

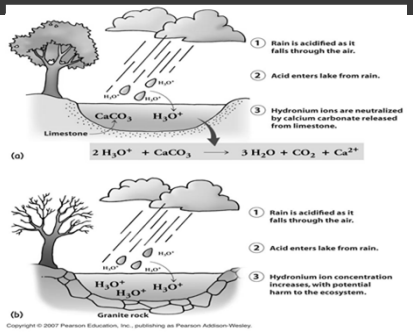
$$pH = -\log (10^{-9})$$
$$pH = -(-9)$$
$$pH = 9$$

The pH Scale



Integrated Science—Earth Science

Acid Rain



Oxidation-Reduction Reactions

Acid–Base reactions: transfer of proton

Oxidation-Reduction reactions: transfer of electron

Oxidation-Reduction Reactions

Oxidation: The loss of an electron

$2\ Na \Rightarrow 2\ Na^+ + 2\ e^-$ "Leo"

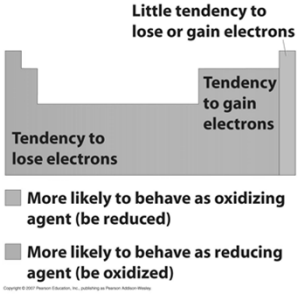
Reduction: The gain of an electron

$Cl_2 + 2\ e^- \Rightarrow 2\ Cl^-$ "Ger"

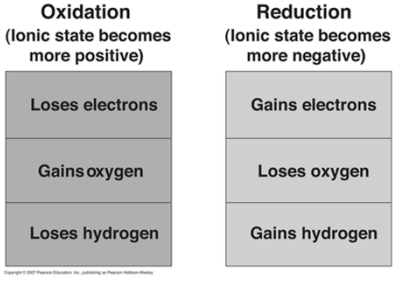
Oxidation-Reduction Reactions

$2\ Na + Cl_2 \Rightarrow 2\ Na^+ + 2\ Cl^-$

Oxidation-Reduction Reactions



Oxidation-Reduction Reactions



Corrosion and Combustion

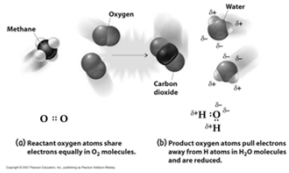
Corrosion: The process whereby a metal deteriorates through oxidation-reduction reactions.

Corrosion and Combustion

Corrosion can be prevented by coating the metal with zinc, which oxidizes first.

Corrosion and Combustion

Combustion: An oxidation-reduction reaction between a nonmetallic material, such as wood, and oxygen.



Reaction Rates

Reaction rate: The speed with which products form from the reactants.

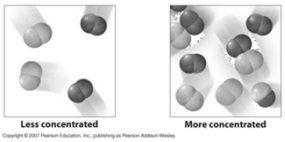
Affected by
- Concentration
- Temperature
- Catalyst

Premise:

Reactant molecules have to make physical contact with each other in order to transform into products.

Reaction Rates

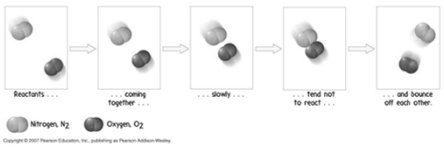
Affected by
- Concentration



The more concentrated a sample of nitrogen and oxygen, the greater the likelihood that N_2 and O_2 molecules will collide and form nitrogen monoxide.

Reaction Rates

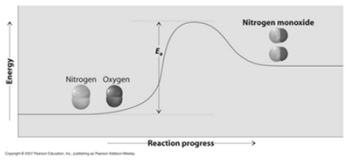
Affected by
- Temperature



Slow-moving molecules may collide without enough force to break the bonds. In this case, they cannot react to form product molecules.

Reaction Rates

Affected by
- Catalysts

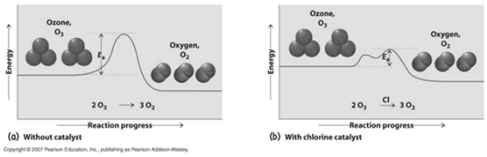


Reactant molecules must gain a minimum amount of energy, called the activation energy, E_{act}, in order to transform into product molecules.

Reaction Rates

Affected by

- Catalysts



A catalyst has the effect of lowering the activation energy, which allows for the reaction to proceed at a quicker rate.

Exo- and Endothermic Reactions

Exothermic reaction: A chemical reaction that results in the net production of energy.

reactants ⇨ products + energy

Endothermic reaction: A chemical reaction in which there is a net consumption of energy.

energy + reactants ⇨ products

Exo- and Endothermic Reactions

Table 13.2 Selected Bond Energies

Bond	Bond Energy (kJ/mole)	Bond	Bond Energy (kJ/mole)
H—H	436	O—O	138
H—C	414	Cl—Cl	243
H—N	389	N—N	159
H—O	464	N═O	631
H—F	569	O═O	498
H—Cl	431	O═C	803
H—S	339	N≡N	946
C—C	347	C≡C	837

Use the bond energies below to determine whether the following reaction is exothermic or endothermic:

$H_2 + Cl_2 \rightarrow 2\ HCl$

H-H (bond energy: 436 kJ/mol)
Cl-Cl (bond energy: 243 kJ/mol)
H-Cl (bond energy: 431 kJ/mol)

✓ A. Exothermic with more than 50 kJ of energy released.
✗ B. Endothermic with more than 50 kJ of energy absorbed.
✗ C. Endothermic with less than 50 kJ of energy absorbed.
✗ D. Exothermic with less than 50 kJ of energy released.

[Default]

Entropy and Chemical Reactions

It is the natural tendency of energy to disperse from where it is concentrated to where it is dilute.

Examples

A hot pan radiates heat
Gasoline combusts into smaller molecules
Marbles bouncing on the floor come to a stop

Entropy and Chemical Reactions

It is the natural tendency of energy to disperse from where it is concentrated to where it is dilute.

Entropy: The term used to describe the degree to which energy has become dispersed.

Reactions that result in an increase in entropy (energy dispersal) tend to occur on their own.

Entropy and Chemical Reactions

- Exothermic reactions tend to be self-sustaining because they lead to large increases in entropy.

Example: A campfire

- Endothermic reactions tend to require the continual input of energy.

Example: Photosynthesis