The Nature of Molecules

Chapter 2

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Atomic Structure

All **matter** is composed of **atoms**.

Understanding the structure of atoms is critical to understanding the nature of biological molecules.

Atomic Structure

Atoms are composed of

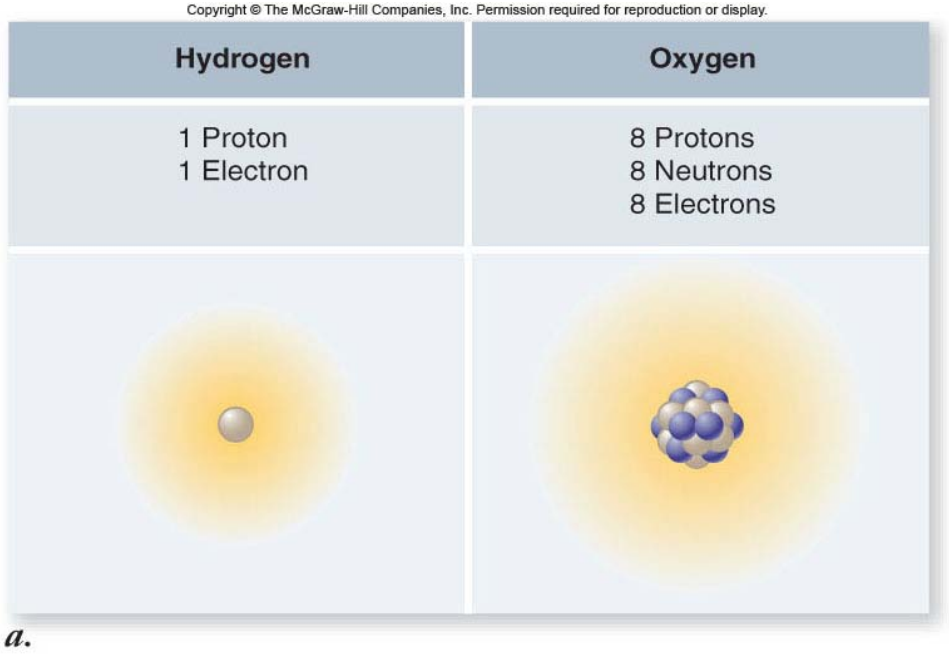
-**protons** – positively charged particles

-**neutrons** – neutral particles

-**electrons** – negatively charged particles

Protons and neutrons are located in the **nucleus**. Electrons are found in orbitals surrounding the nucleus.

Atomic Structure



Atomic Structure

Every different atom has a characteristic number of protons in the nucleus.

atomic number = number of protons

Atoms with the same atomic number have the same chemical properties and belong to the same **element**.

Atomic Structure

Each proton and neutron has a mass of approximately 1 dalton.

The sum of protons and neutrons is the atom's **atomic mass**.

Isotopes – atoms of the same element that have different atomic mass numbers due to different numbers of neutrons.

Atomic Structure

Carbon-12	Carbon-13	Carbon-14
6 Protons 6 Neutrons 6 Electrons	6 Protons 7 Neutrons 6 Electrons	6 Protons 8 Neutrons 6 Electrons
		

Atomic Structure

Neutral atoms have the same number of protons and electrons.

Ions are charged atoms.

-**cations** – have more protons than electrons and are positively charged

-**anions** – have more electrons than protons and are negatively charged

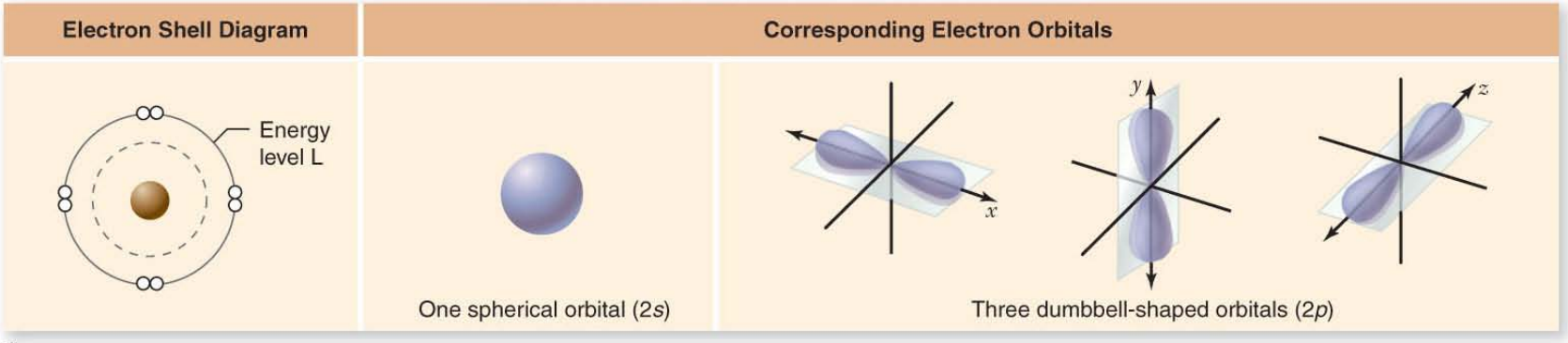
Atomic Structure

Electrons are located in orbitals surrounding the nucleus.

Each orbital can contain only 2 electrons.

Electrons possess potential energy, with electrons far from the nucleus having the most energy.

Atomic Structure



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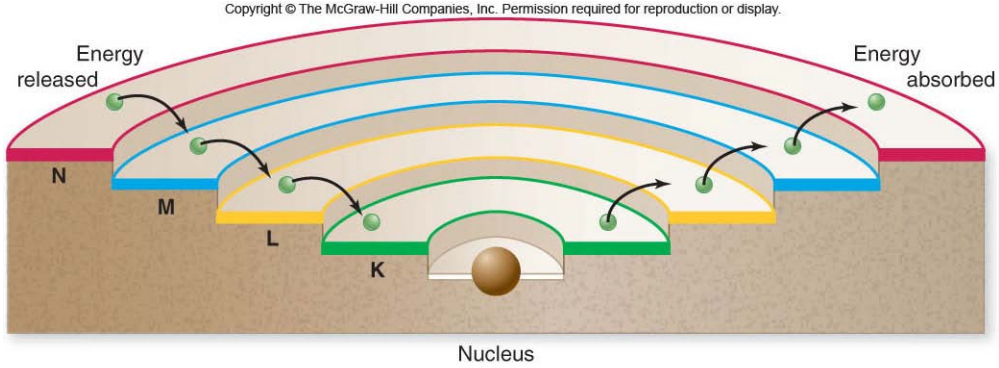
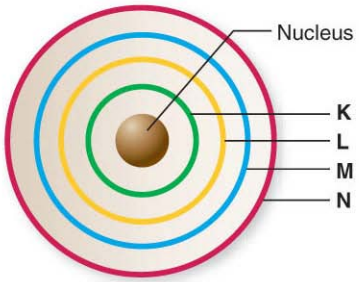


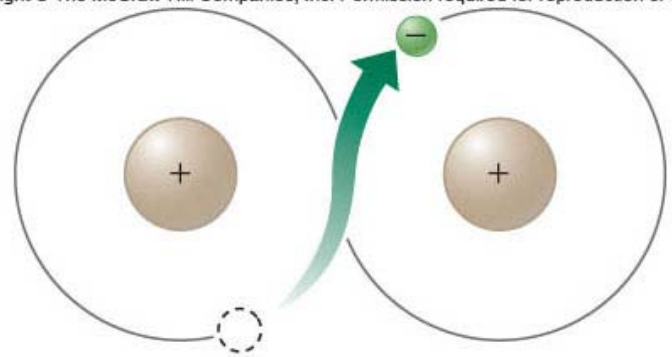


Atomic Structure

Electrons can be transferred from one atom to another, while still retaining the energy of their position in the atom.

-**oxidation** = loss of an electron

-**reduction** = gain of an electron



Elements

Valence electrons are the electrons in the outermost energy level of an atom.

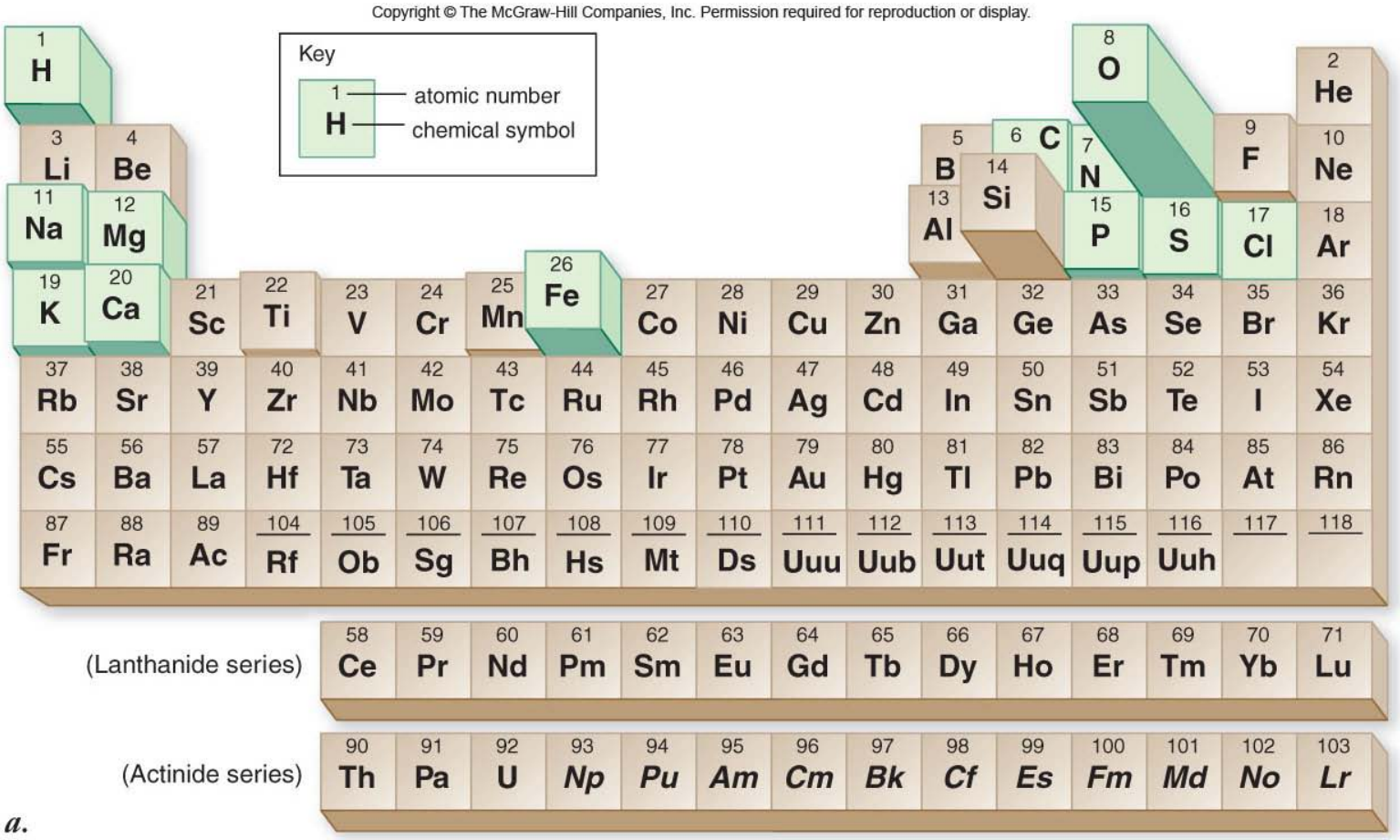
An element's chemical properties depend on interactions between valence electrons of different atoms.

Elements

The **Periodic Table** arranges all elements according to their atomic number.

The table identifies elements with similar chemical properties.

Periodic Table of the Elements



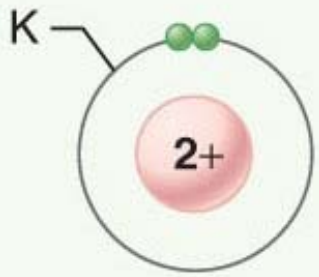
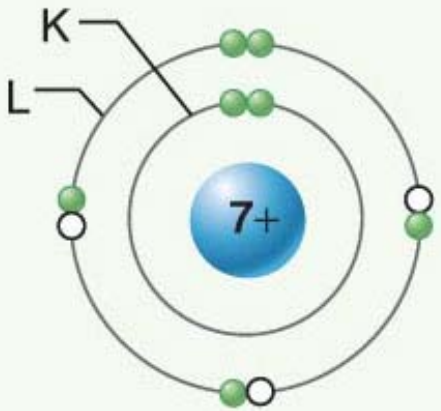
a.

Elements

Octet rule: Atoms tend to establish completely-full outer energy levels.

Atoms with full energy levels are less reactive than atoms with unfilled energy levels.

Elements

Nonreactive	Reactive
2 protons 2 neutrons 2 electrons	7 protons 7 neutrons 7 electrons
 Helium	 Nitrogen

Elements

There are 92 naturally occurring elements.

Only 12 elements are found in living organisms in substantial amounts.

Four elements make up 96.3% of human body weight:

- carbon, hydrogen, oxygen, nitrogen

Chemical Bonds

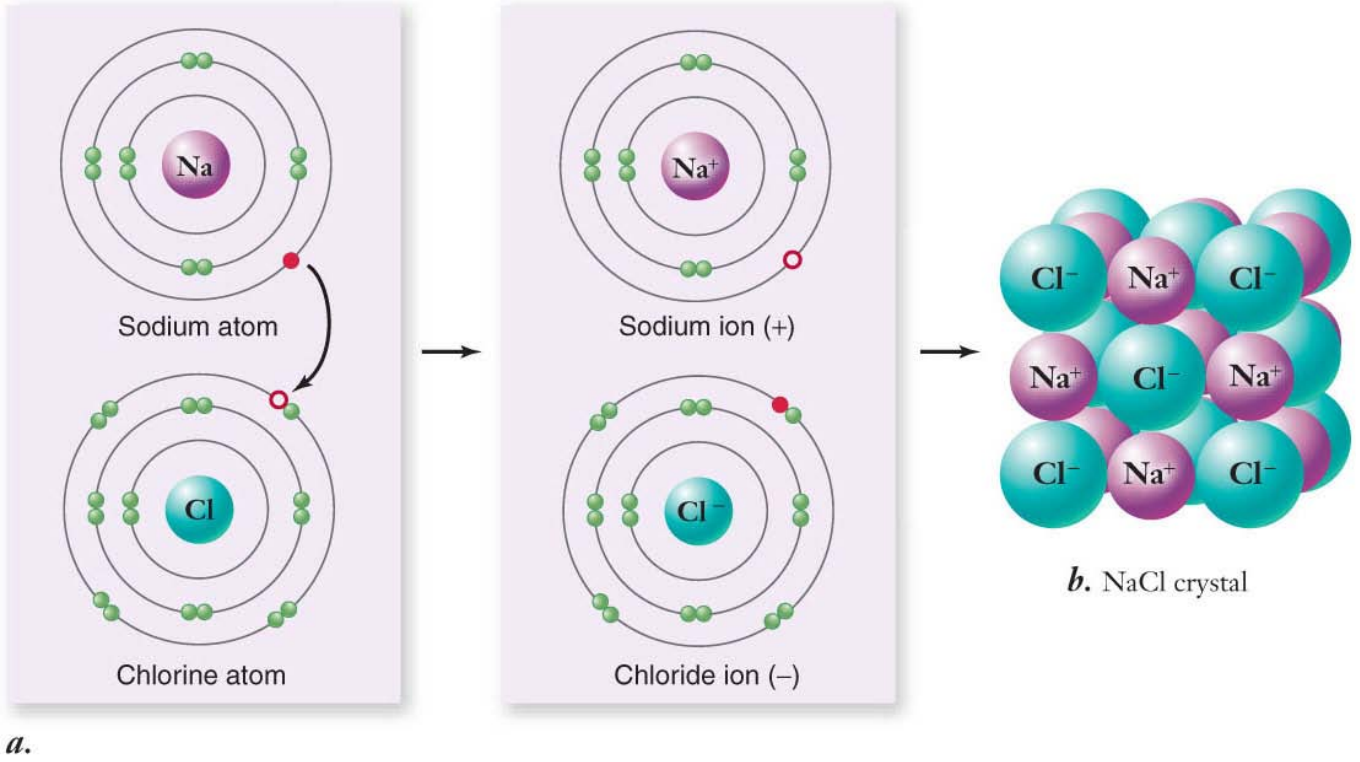
Molecules are groups of atoms held together in a stable association.

Compounds are molecules containing more than one type of element.

Atoms are held together in molecules or compounds by **chemical bonds**.

Chemical Bonds

Ionic bonds are formed by the attraction of oppositely charged ions.



a.

b. NaCl crystal

Chemical Bonds

Covalent bonds form when atoms share 2 or more valence electrons.

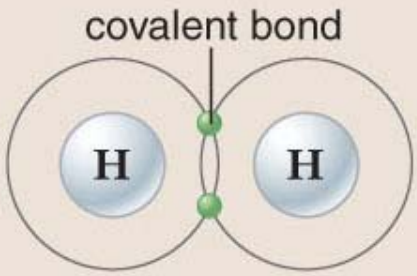
Covalent bond strength depends on the number of electron pairs shared by the atoms.

single bond < double bond < triple bond

Chemical Bonds

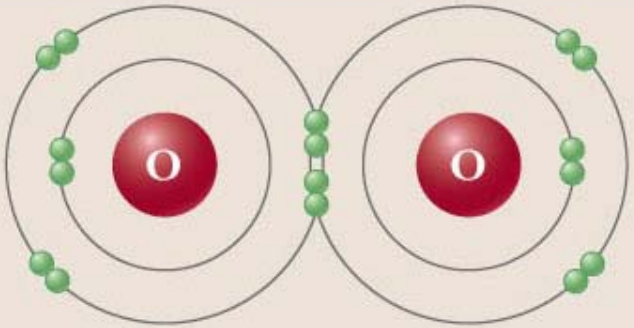
Single covalent bond
hydrogen gas

H—H H_2



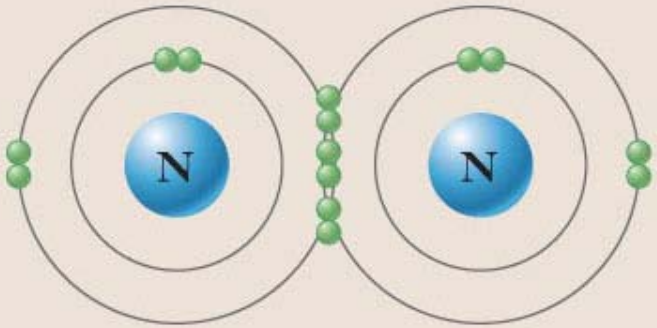
Double covalent bond
oxygen gas

O=O O_2



Triple covalent bond
nitrogen gas

N≡N N_2



Chemical Bonds

Electronegativity is an atom's affinity for electrons.

Differences in electronegativity dictate how electrons are distributed in covalent bonds.

- **nonpolar covalent bonds** = equal sharing of electrons
- **polar covalent bonds** = unequal sharing of electrons

Chemical Bonds

Chemical reactions involve the formation or breaking of chemical bonds.

Whether a chemical reaction occurs is influenced by

-temperature

-concentration of reactants and products

-availability of a catalyst

Chemical Bonds

Chemical reactions are written with the reactants first, followed by the products.

$$6H_2O + 6CO_2 \longrightarrow C_6H_{12}O_6 + 6O_2$$

reactants → products

Chemical reactions are often reversible.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2$$

Water Chemistry

All living organisms are dependent on water.

The structure of water is the basis for its unique properties.

The most important property of water is the ability to form **hydrogen bonds**.

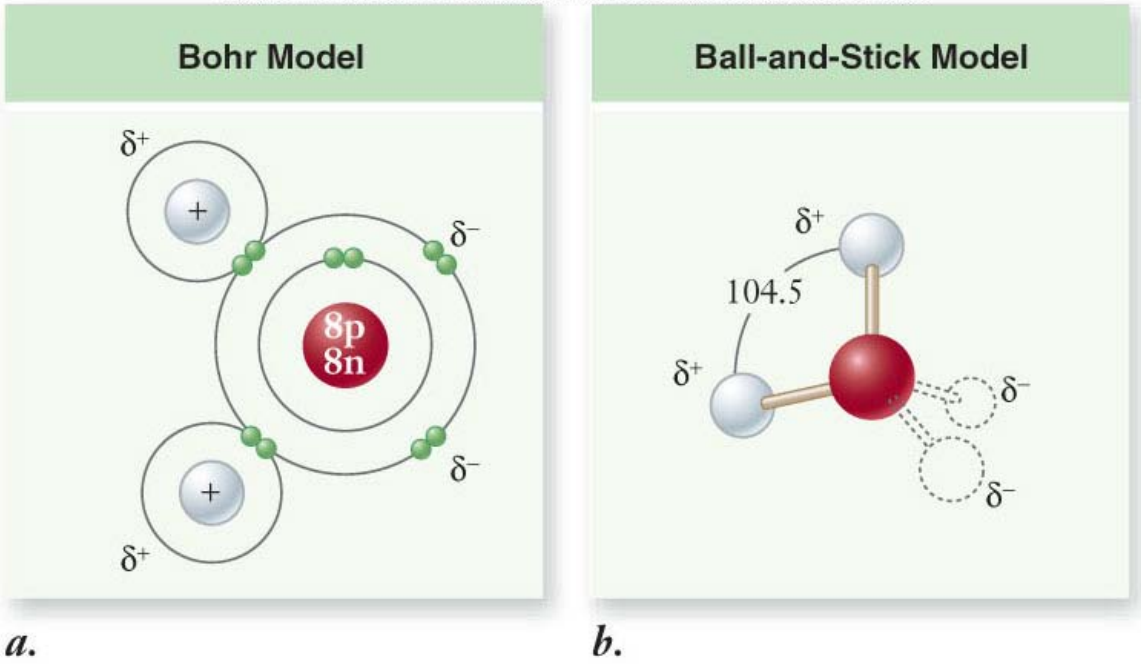
Water Chemistry

Within a water molecule, the bonds between oxygen and hydrogen are highly polar.

Partial electrical charges develop:

- oxygen is partially negative
- hydrogen is partially positive

Water Chemistry

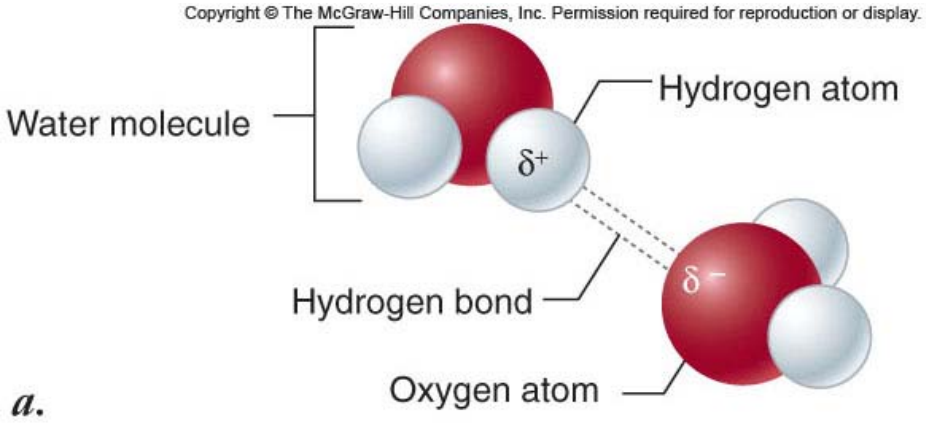


Water Chemistry

Hydrogen bonds are weak attractions between the partially negative oxygen of one water molecule and the partially positive hydrogen of a *different* water molecule.

Hydrogen bonds can form between water molecules or between water and another charged molecule.

Water Chemistry



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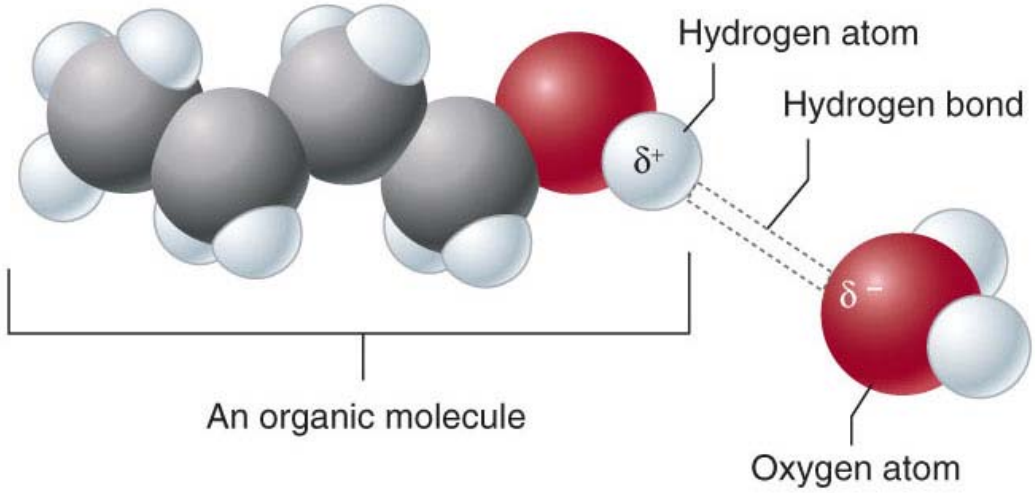

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Water Chemistry

The polarity of water causes it to be cohesive and adhesive.

cohesion: water molecules stick to other water molecules by hydrogen bonding

adhesion: water molecules stick to other polar molecules by hydrogen bonding

Water Chemistry

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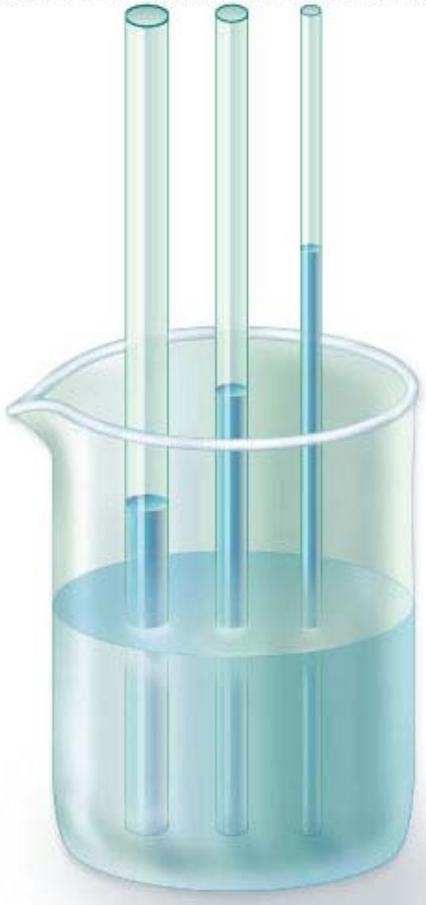
Water Chemistry



Properties of Water

1. Water has a high specific heat.

   - A large amount of energy is required to change the temperature of water.

2. Water has a high heat of vaporization.

   - The evaporation of water from a surface causes cooling of that surface.

Properties of Water

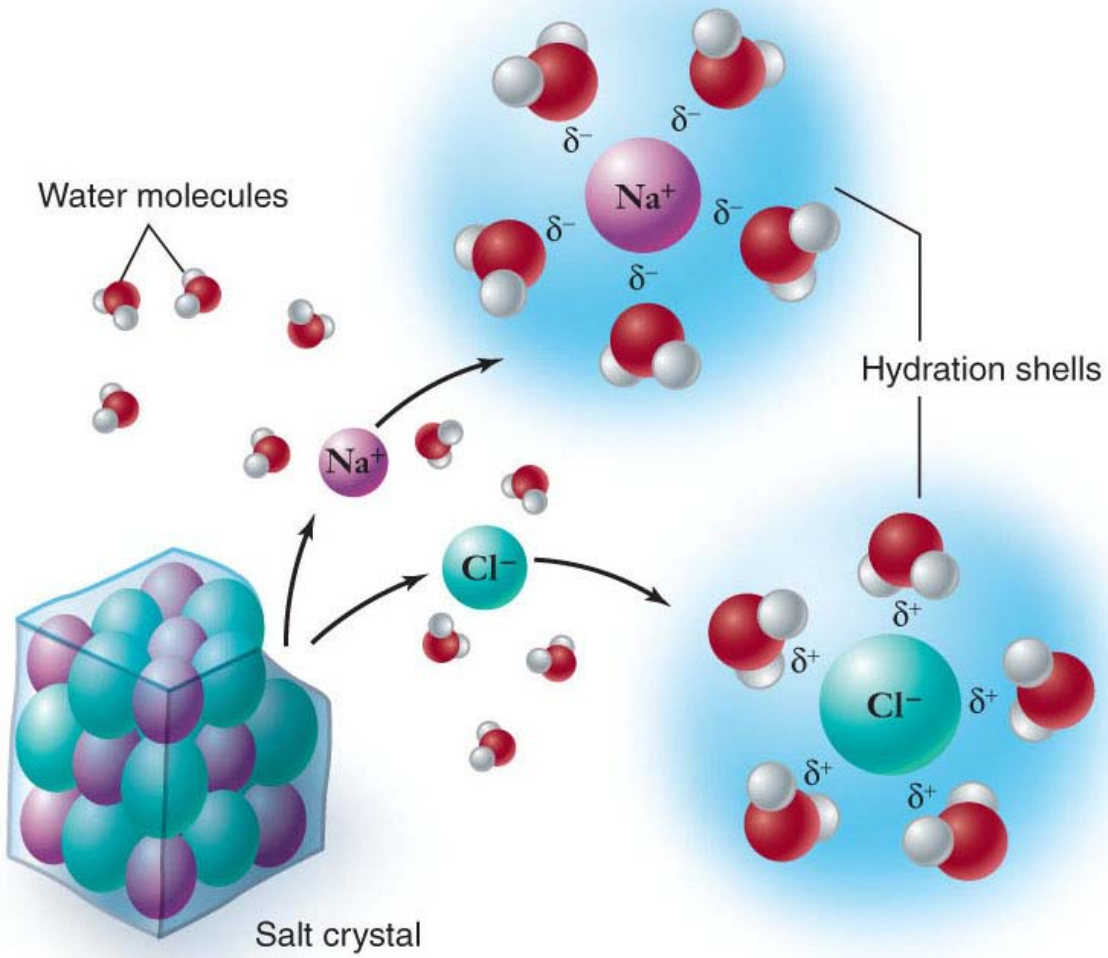
3. Solid water is less dense than liquid water.

   - Bodies of water freeze from the top down.

4. Water is a good solvent.

   - Water dissolves polar molecules and ions.

Properties of Water



Properties of Water

5. Water organizes nonpolar molecules.
   - **hydrophilic**: “water-loving”
   -**hydrophobic**: “water-fearing”
   - Water causes hydrophobic molecules to aggregate or assume specific shapes.

6. Water can form ions.

$H_2O \rightarrow OH^{-1} + H^{+1}$

hydroxide ion hydrogen ion

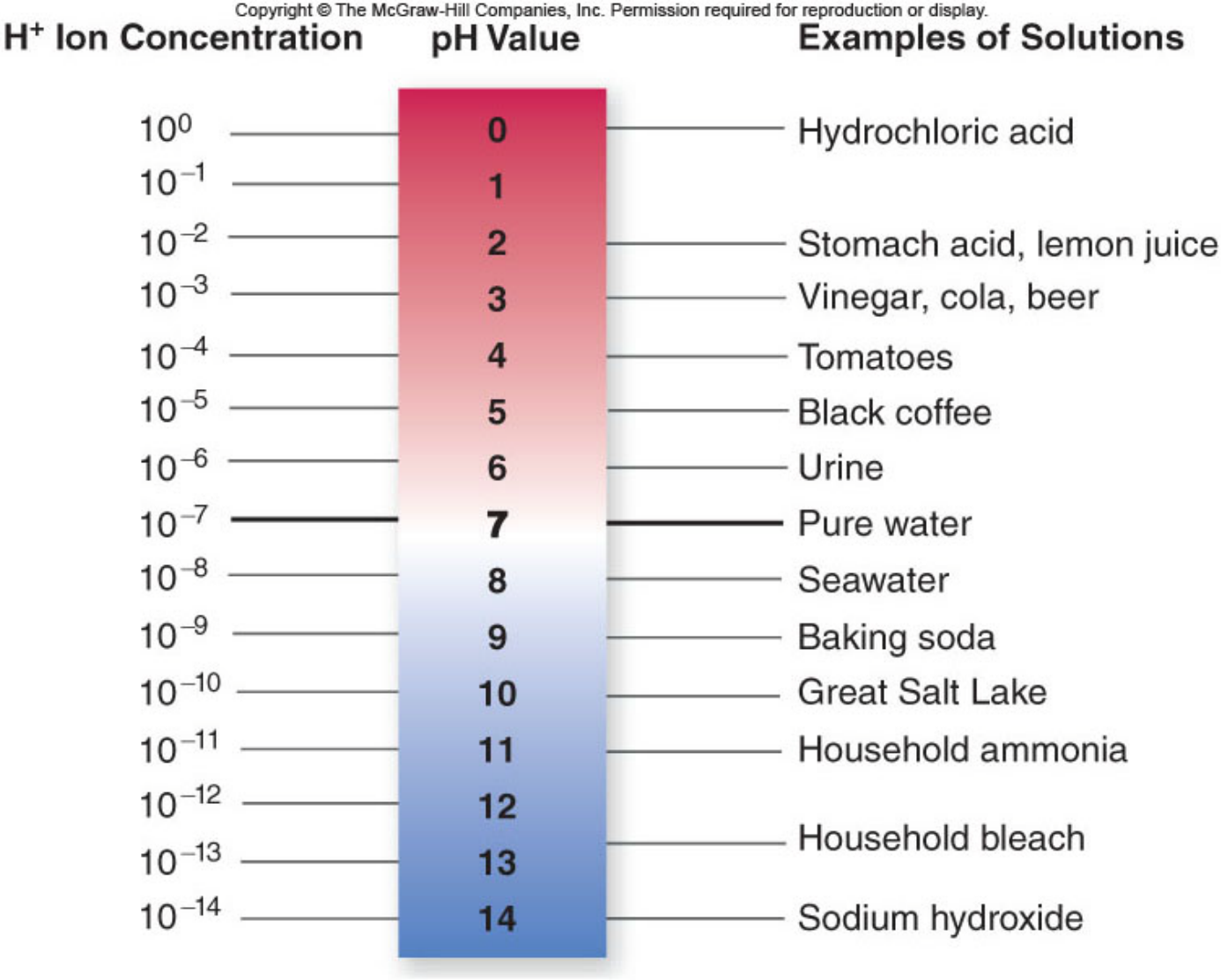
Acids and Bases

Hydrogen ion (H^{+1}) is the basis of the pH scale.

Greater H^{+1} concentration --- lower pH (acidic)

Lower H^{+1} concentration --- higher pH (basic)

Acids and Bases



Acids and Bases

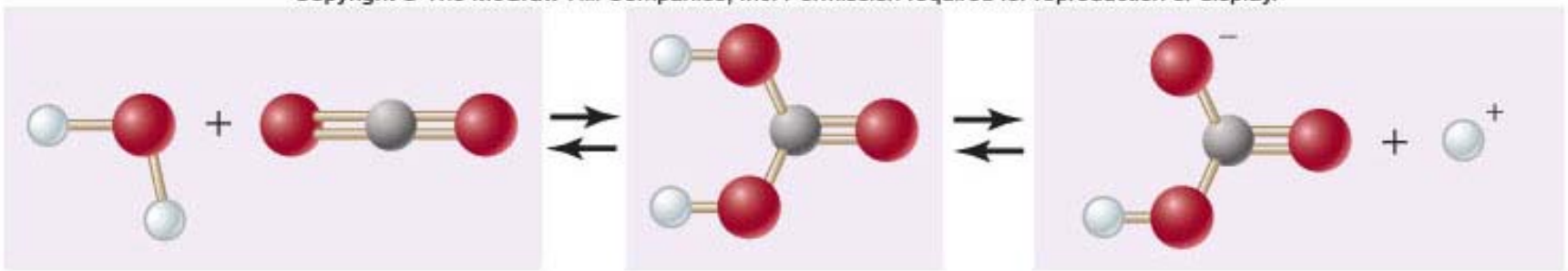
Acid: a chemical that releases H^{+1} ions.

Base: a chemical that accepts H^{+1} ions.

Buffer: a chemical that accepts/releases H^{+1} as necessary to keep pH constant

Acids and Bases

Most biological buffers consist of a pair of molecules, one an acid and one a base.



Water (H_2O) + Carbon dioxide (CO_2) ⇌ Carbonic acid (H_2CO_3) ⇌ Bicarbonate ion (HCO_3^-) + Hydrogen ion (H^+)

Acids and Bases