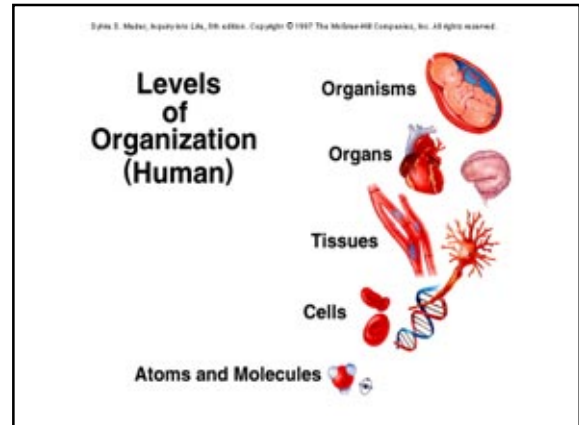


# Chemical Foundations of Life



## Atom, element, compound, and Mixture

Atom (element)	Oxygen (O)	Smallest unit that still has the properties of an element
Molecule (element)	Oxygen (O <sub>2</sub> )	Stable assembly of two or more atoms
Compound	Water (H <sub>2</sub> O) Carbon dioxide (CO <sub>2</sub> )	Substances forged in chemical reactions from two or more different elements
Mixture	Carbonated water	Different compounds combined together

## Atomic Structure

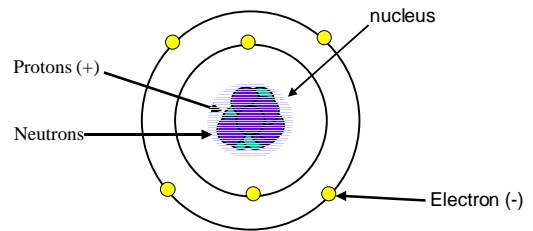


Fig. 2.2 Basic Structure of Atoms

	Hydrogen 1 Proton 1 Electron	
	Oxygen 8 Protons 8 Neutrons 8 Electrons	

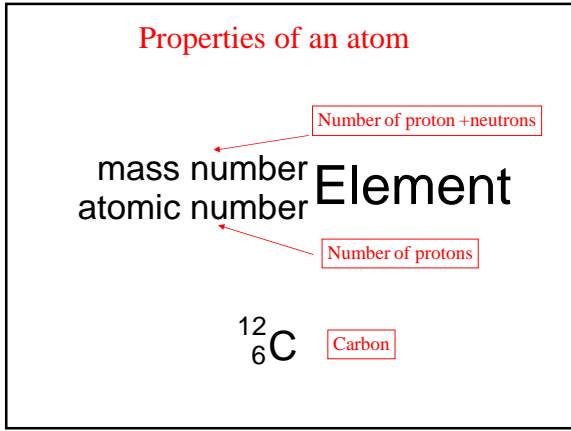
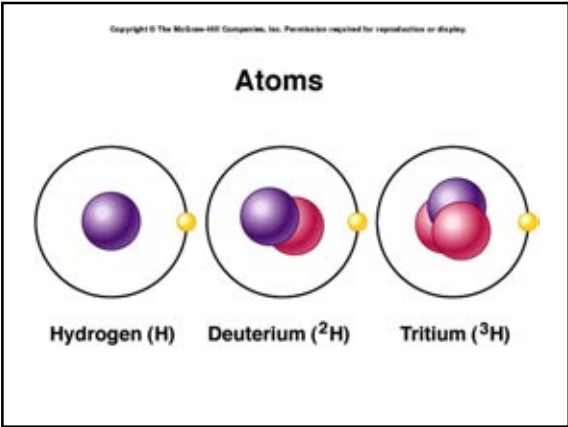
● Proton (Positive charge)    ● Neutron (No charge)    ● Electron (Negative charge)

	Charge	Mass
Protons	+	1
Electrons	-	0
Neutrons	0	1

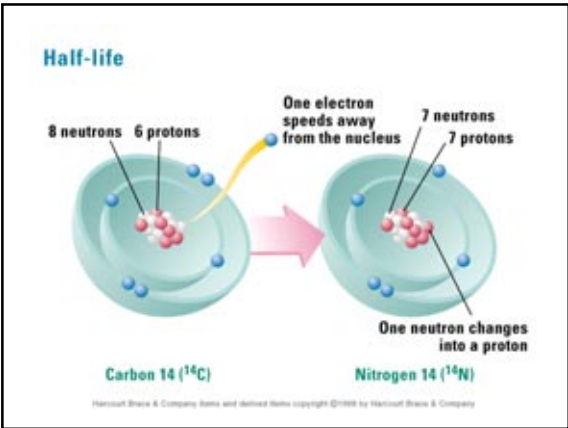
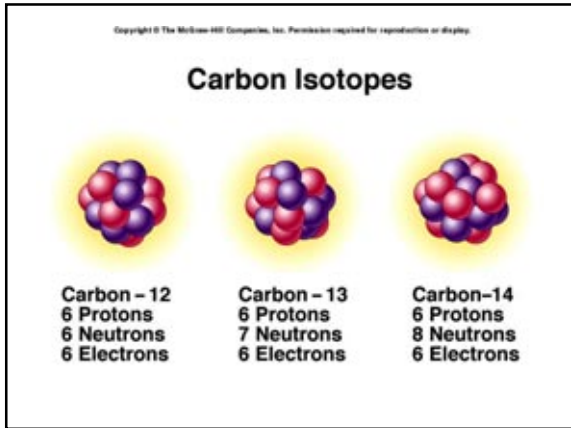
Question: What is the mass of Hydrogen?

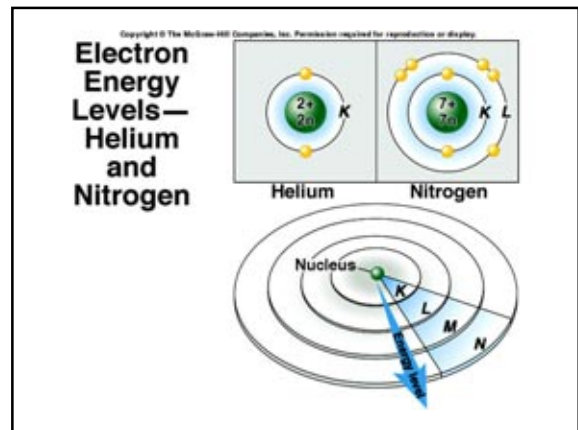
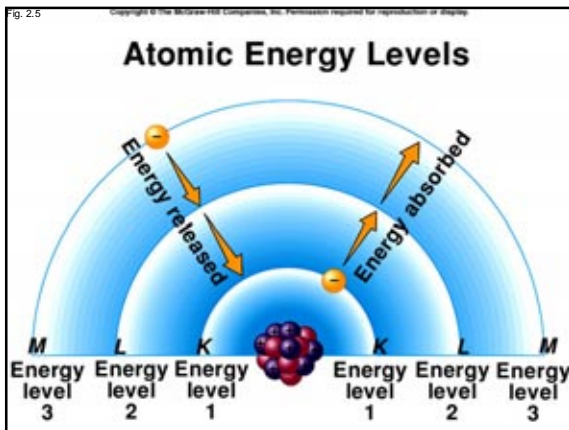
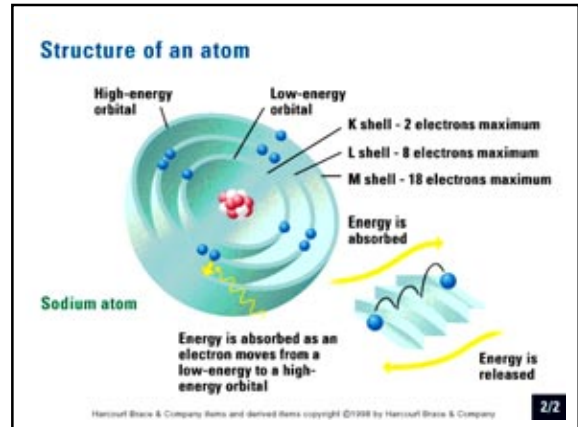
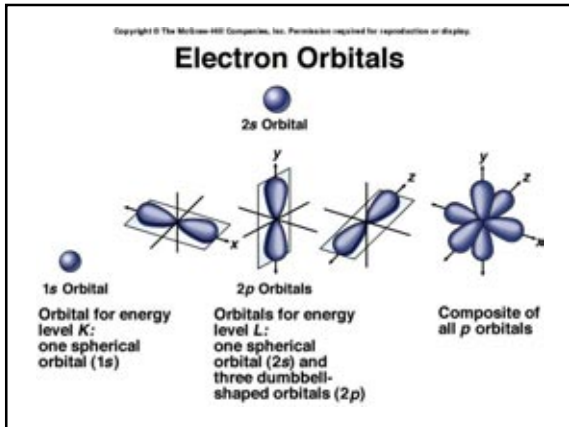
**First three periods of the Periodic Table**

Chemical symbol	Hydrogen H																Helium He			
First shell																				
Atomic number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Second shell																				
Third shell																				



- Isotopes**
- Atoms that have the same number of protons but a different number of neutrons.
  - All of these are isotopes of the element carbon.  $^{12}_6\text{C}$   $^{13}_6\text{C}$   $^{14}_6\text{C}$

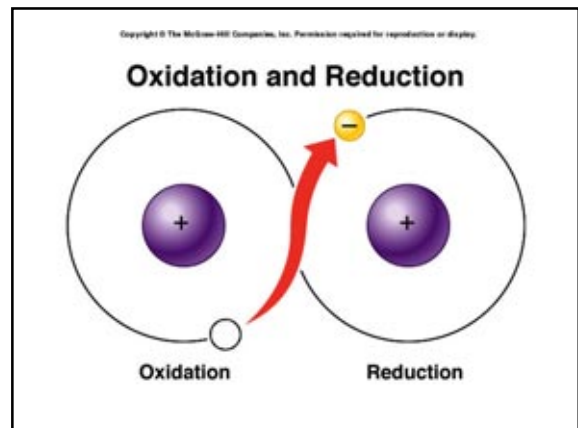




### Molecular weight

- The molecular weight of a substance is the sum of the atomic mass units of atoms in the molecule.
- Water ( $H_2O$ ) has *two* molecules of hydrogen ( $amu = 1$ ) and *one* atom of oxygen ( $amu = 16$ ).  
 $2(1) + 1(16) = 18$ ;

So, **18** is the molecular weight of water



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## Periodic Table

(Lanthanide series) Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

(Actinide series) Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

**Table 3.3 The Most Common Elements on Earth and Their Distribution in the Human Body**

Element	Symbol	Atomic Number	Approximate Percent of Earth's Crust by Weight	Percent of Human Body by Weight	Significance or Function
Oxygen	O	8	46.6	65.0	Required for cellular respiration; component of water
Silicon	Si	14	27.7	Trace	
Aluminum	Al	13	8.3	Trace	
Iron	Fe	26	5.0	Trace	
Calcium	Ca	20	5.6	1.7	Component of bones and teeth; supports muscle contraction
Sodium	Na	11	2.8	0.2	Principal positive ion outside cells; important in nerve function
Potassium	K	19	2.4	0.4	Principal positive ion inside cells; important in nerve function
Magnesium	Mg	12	2.2	0.1	Crucial component of many energy-transferring reactions
Hydrogen	H	1	0.14	9.1	Essential organic component of water and most organic molecules
Manganese	Mn	25	0.1	Trace	
Phosphorus	P	15	0.07	Trace	
Fluorine	F	9	0.07	Trace	
Phosphorus	P	15	0.07	1.0	Building of nucleic acids; important in energy transfer
Carbon	C	6	0.02	18.1	Building of organic molecules
Sulfur	S	16	0.03	0.1	Component of most proteins
Chlorine	Cl	17	0.02	0.2	Principal negative ion outside cells
Vanadium	V	23	0.01	Trace	
Chromium	Cr	24	0.01	Trace	
Copper	Cu	29	0.01	Trace	Key component of many enzymes
Nitrogen	N	7	Trace	3.3	Component of all proteins and nucleic acids
Boron	B	5	Trace	Trace	
Calcium	Ca	20	Trace	Trace	
Zinc	Zn	30	Trace	Trace	Key component of many enzymes
Selenium	Se	34	Trace	Trace	
Molybdenum	Mo	42	Trace	Trace	Key component of many enzymes
Tin	Sn	50	Trace	Trace	
Silver	Ag	47	Trace	Trace	Component of thyroid hormones

Chemical symbol  
Atomic number  
Atomic mass (average of all isotopes)

Lanthanide series  
Actinide series

## Octet Rule

- Atoms need to fill the outer shell with a maximum of 8 electrons to attain and maintain stability.

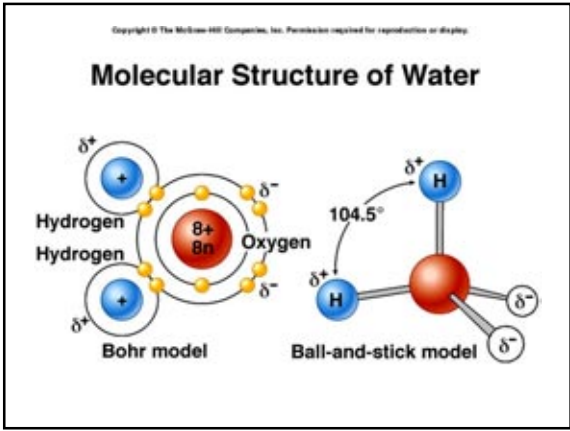
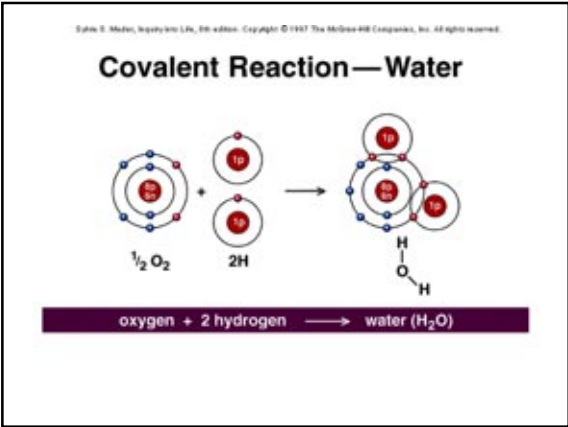
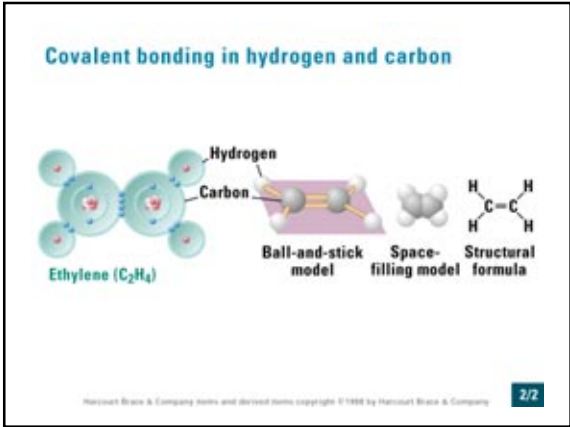
## How are molecules held together (Chemical Bonds)?

- Atoms try to have full octet of electrons in the outer shell.
  - Strong bonds
    - Covalent bonds
      - Sharing of electrons.
    - Ionic bonds
      - Donating/accepting of electrons between two atoms
  - Weak bonds
    1. Hydrogen bonds - an attraction between molecules due to partial charges
    2. van der Waals - attraction between close molecules - very weak

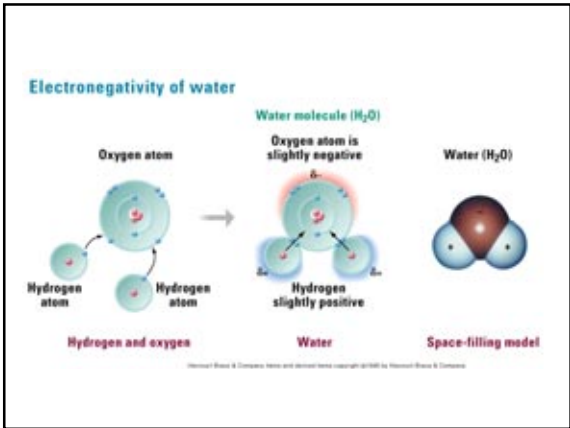
## Ionic Bond

- Formed by the donating and accepting of electrons by two atoms.
- Strong bond.
- Atoms that have nearly full or nearly empty shells tend to form ions.
  - Positively-charged ions are called cations.
  - Negatively-charged ions are called anions.



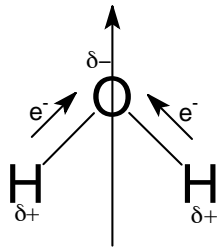


- ### Electronegativity
- Tendency to gain electrons
    - Most electronegative
      - Oxygen
      - Chlorine
  - Tendency to lose electrons
    - Least electronegative
      - Sodium
      - Potassium
      - lithium

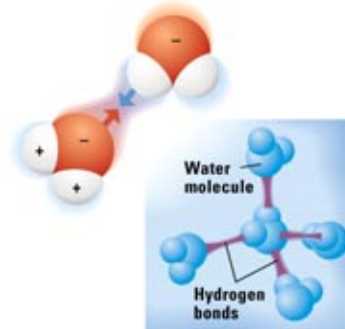


- ### Hydrogen Bond
- Formed by partial positive ( $\delta^+$ ) and partial negative ( $\delta^-$ ) charges formed by electronegative atoms in two molecules
  - Weak bond.

## Polarity

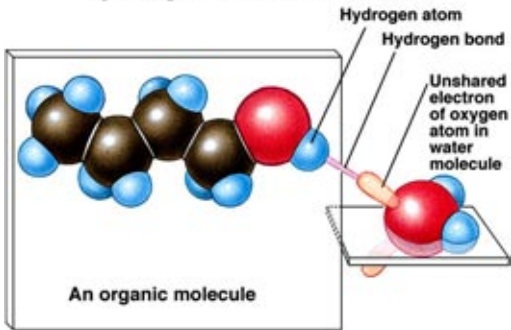


## Hydrogen bonds between water molecules



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## Hydrogen Bond Structure



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## Hydrogen Bonding in Water Molecules

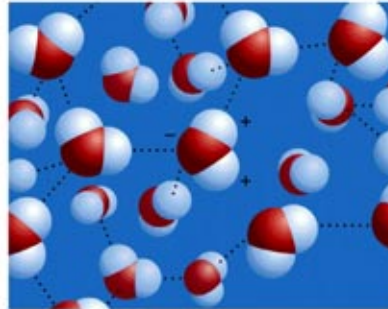


Fig. 2.11

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## Forms of Water



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Table 2.2 The Properties of Water

Property	Explanation	Example of Benefit to Life
cohesion	Hydrogen bonds hold water molecules together	Layers pull water upward from the roots, seeds swell and germinate
High specific heat	Hydrogen bonds absorb heat when they break, and release heat when they form, minimizing temperature changes	Water stabilizes the temperature of organisms and the environment
High heat of vaporization	Many hydrogen bonds must be broken for water to evaporate	Evaporation of water cools body surfaces
Lower density of ice	Water molecules in an ice crystal are spaced relatively far apart because of hydrogen bonding	Because ice is less dense than water, lakes do not freeze solid
High polarity	Polar water molecules are attracted to ions and polar compounds, making them soluble	Many kinds of molecules can move freely in cells, permitting a diverse array of chemical reactions

## Properties of Water

- Denser as liquid than a solid (ice formation)
- High heat capacity
  - High boiling point
  - Good evaporative coolant
- Surface tension and cohesion
- Adhesion--sticks to everything
  - Capillary action
- Good solvent (polar medium)
  - Solutes (NaCl, sugars, etc.)

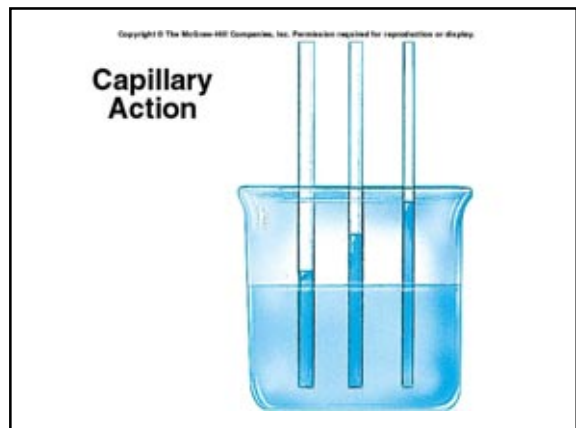
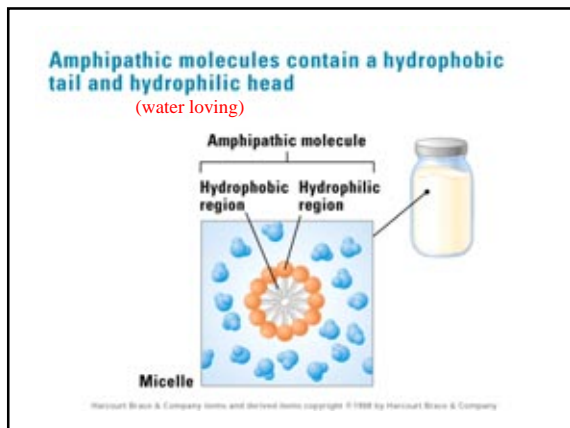
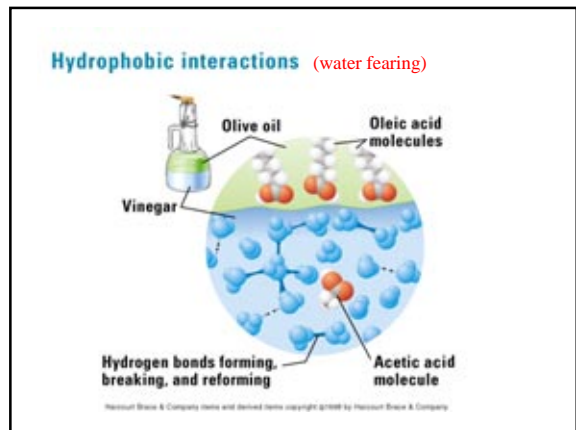
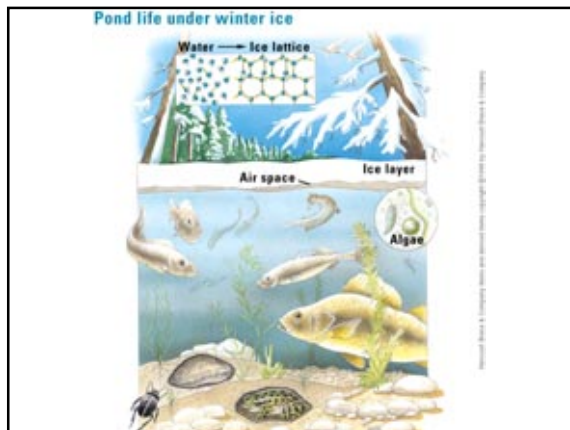
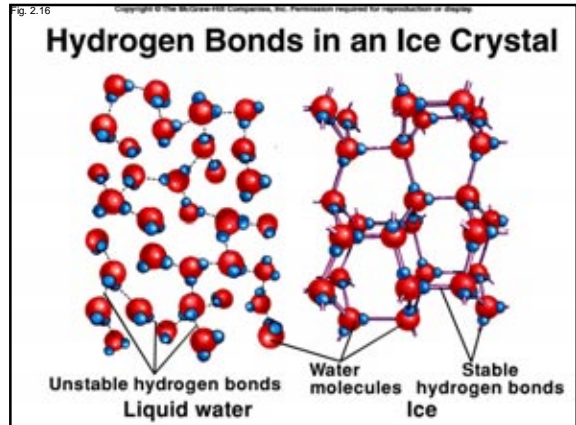


Fig. 2.14

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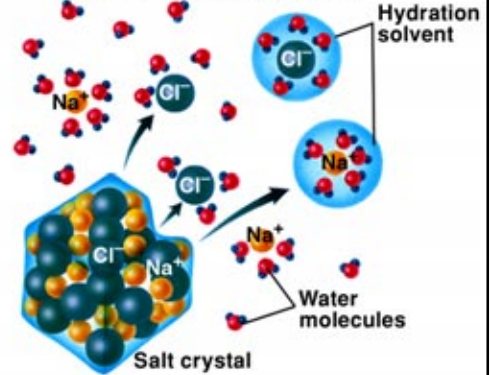
### Cohesion



Fig. 2.17

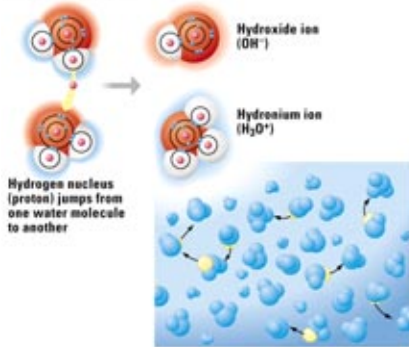
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### Water as a Solvent



### Juggling protons

Two water molecules



Acid-donates  $\text{H}^+$   
Base-accepts  $\text{H}^+$

pH is a measure of the hydrogen ion concentration

### pH Scale

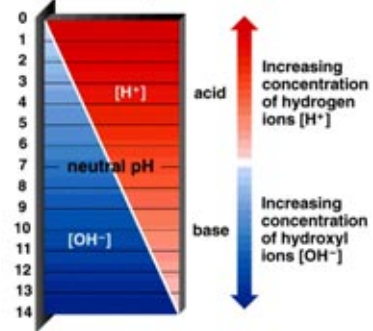
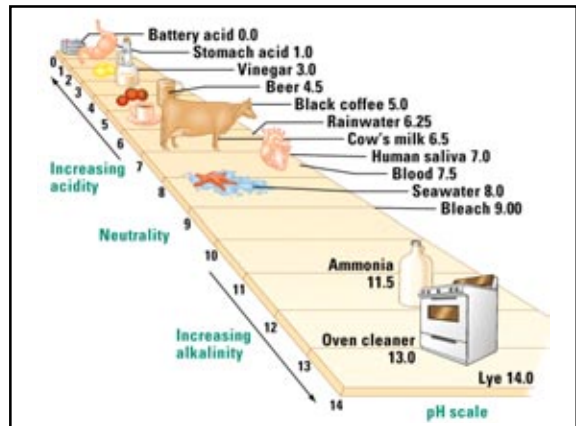
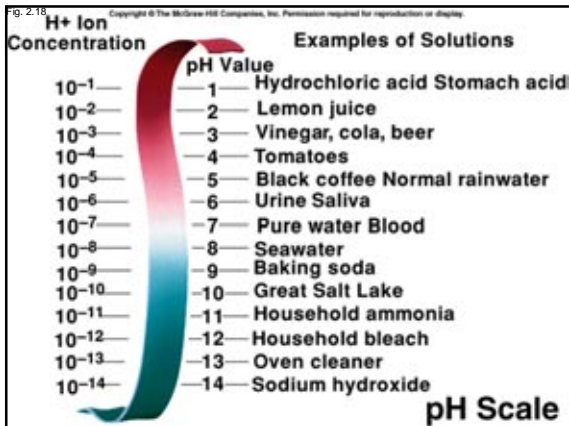
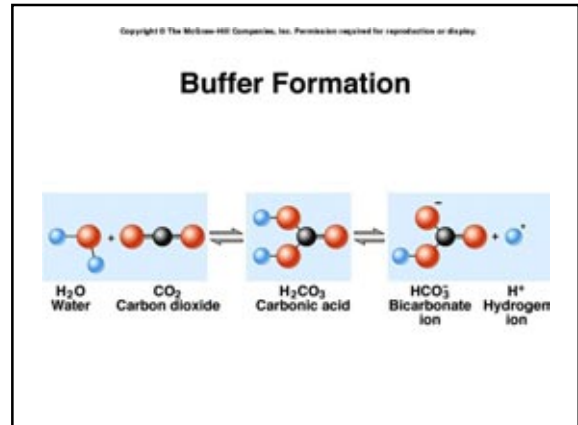
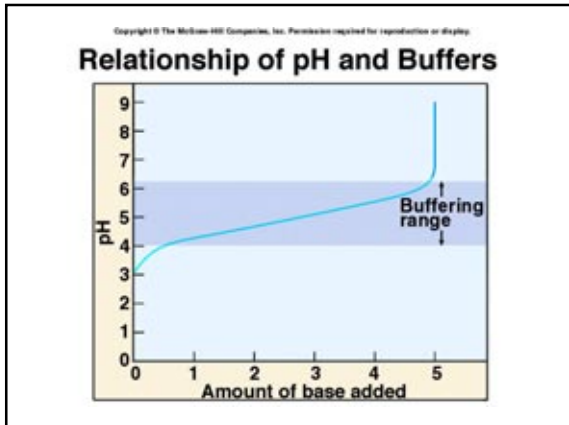


Fig. 2.18

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### Buffers

- ✓ Molecules that easily converts between acid and base forms
- ✓ Ex. Carbonic acid and bicarbonate in the blood

**Blood**  $\Rightarrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-$

**Lungs**  $\Rightarrow \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

