

# Nature of Molecules

## Chapter 2



### Atomic Structure

All **matter**: composed of **atoms**

Understanding structure of atoms critical to  
understanding nature of biological molecules

## Atomic Structure

**Atoms** composed of

- protons** – positively charged particles
- neutrons** – neutral particles
- electrons** – negatively charged particles



Protons & neutrons: in **nucleus**

Electrons: in orbitals surrounding nucleus

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## Atomic Structure

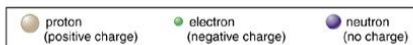
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Hydrogen	Oxygen
1 Proton 1 Electron	8 Protons 8 Neutrons 8 Electrons
	

*a.*



*b.*



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Every different atom has a characteristic number of protons in nucleus

**atomic number** = number of protons

Atoms with same atomic number have same chemical properties & belong to same **element**

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Each proton & neutron has a mass of ~1 dalton

Sum of protons & neutrons = **atomic mass**

**Isotopes** – atoms of same element having different atomic mass numbers due to different numbers of neutrons—nucleus unstable & releases energy (radiation)

**$^2\text{H}$  deuterium**

**$^3\text{H}$  tritium**




**$^{14}\text{C}$  carbon 14 dating**

**$^{238}\text{U}$**

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## Atomic Structure

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

## Atomic Structure

**Neutral atoms** have same number of protons & electrons

**Ions:** charged atoms

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

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

## Atomic Structure

Electrons: in orbitals surrounding nucleus

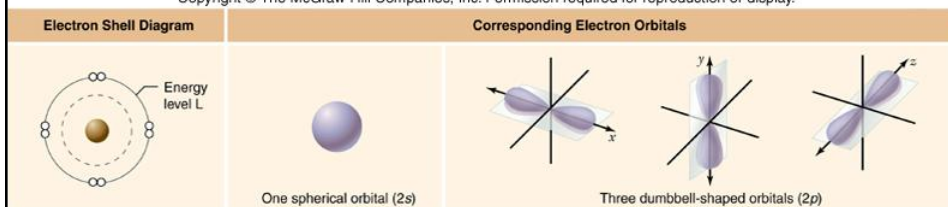
Each orbital can contain only 2 electrons

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

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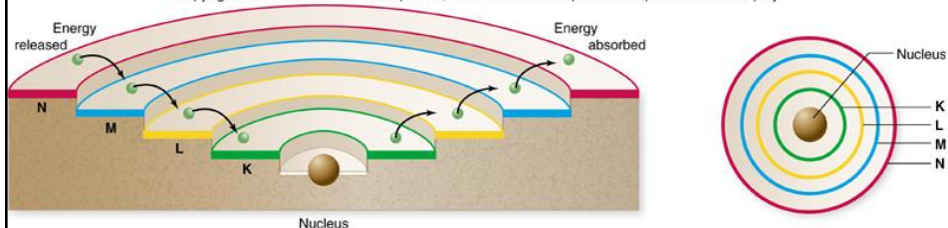
## Atomic Structure

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h.

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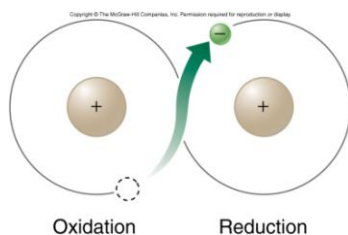
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## Atomic Structure

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

**-oxidation** = loss of an electron

**-reduction** = gain of an electron



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## Elements

**Valence electrons:** electrons in outermost energy level of an atom

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

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## Elements

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

Table identifies elements with similar chemical properties

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# of Elemen ts

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Key  
 1 — atomic number  
 H — chemical symbol

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	
		(Lanthanide series)															
		(Actinide series)															

*a.*

- Carbon (C)
- Oxygen (O)
- Hydrogen (H)
- Nitrogen (N)
- Sodium (Na)
- Chlorine (Cl)
- Calcium (Ca)
- Phosphorus (P)
- Potassium (K)
- Sulfur (S)
- Iron (Fe)
- Magnesium (Mg)

*b.*

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Elements

**Octet rule:**

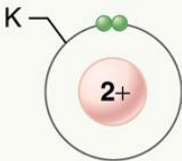
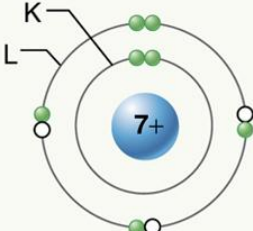
Atoms tend to establish completely-full outer energy levels

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

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Elements

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Nonreactive	Reactive
2 protons 2 neutrons 2 electrons	7 protons 7 neutrons 7 electrons
 <p data-bbox="458 1624 544 1653">Helium</p>	 <p data-bbox="891 1624 991 1653">Nitrogen</p>

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## Elements

**90** naturally occurring elements

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

**4 elements** make up **96.3%** of human body weight:  
- **carbon, hydrogen, oxygen, nitrogen**

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## Atoms &amp; Elements

**Molecules:**

-groups of **atoms** held together in a stable association

**Compounds:**

-molecules containing more than one type of **element**

**Atoms:**

-held together in molecules or compounds by **chemical bonds**

-**basic unit of chemistry**

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## Chemical Bonds \*

- 1) co-valent    sharing of electrons
  
- 2) ionic        transfer of electrons
  
- 3) hydrogen    weak attractions between partially negative oxygen of one water molecule partially positive hydrogen of a *different* water molecule

\* **chemical bonds where energy stored**

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### Chemical Bonds

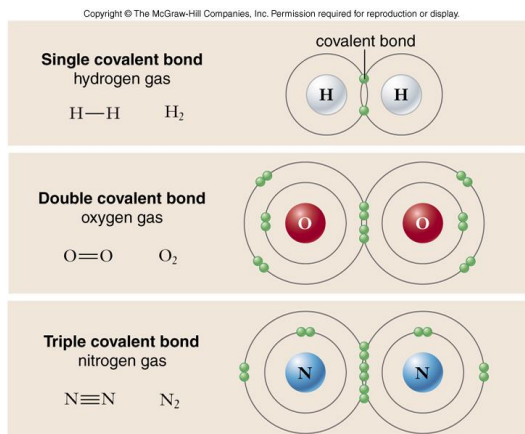
**1) Covalent bonds** form when atoms share 2 or more valence electrons

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

single bond < double bond < triple bond

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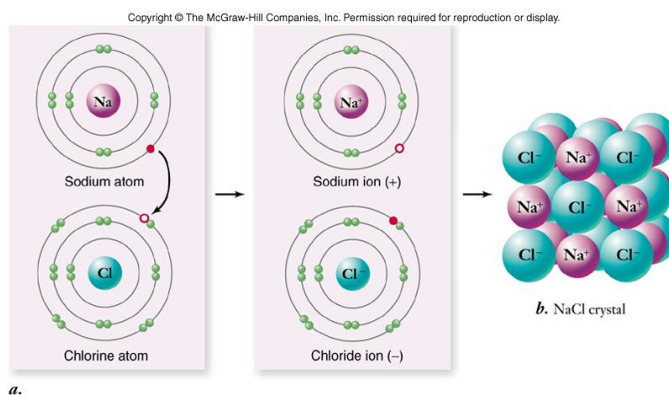
## Chemical Bonds



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## Chemical Bonds

**2) Ionic bonds:** formed by the attraction of oppositely charged ions.



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## 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

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## Chemical Bonds

Chemical reactions involve formation or breaking of chemical bonds

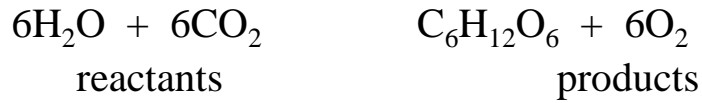
Whether a chemical reaction occurs is influenced by

- temperature
- concentration of reactants & products
- availability of a catalyst

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## Chemical Bonds

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



Chemical reactions are often reversible.



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## Water Chemistry

All living organisms are dependent on **water**

Structure of water: basis for its unique properties

Most important property of water:

its ability to form **hydrogen bonds**

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## Water Chemistry

Within a water molecule, bonds between oxygen & hydrogen are highly polar

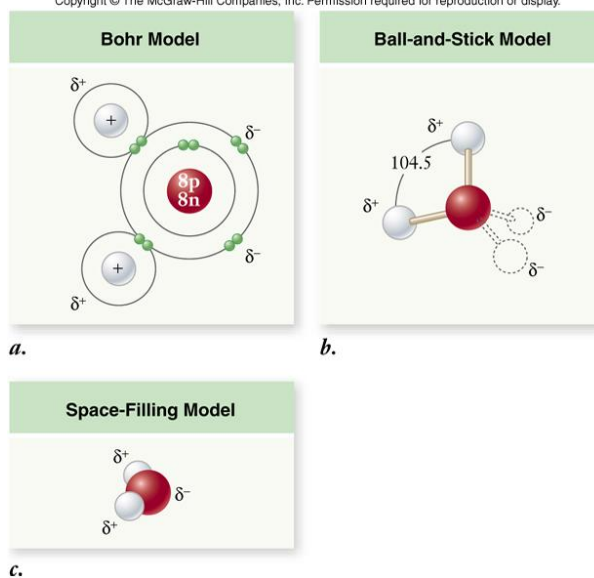
Partial electrical charges develop:

- oxygen partially **negative**
- hydrogen partially **positive**

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## Water Chemistry

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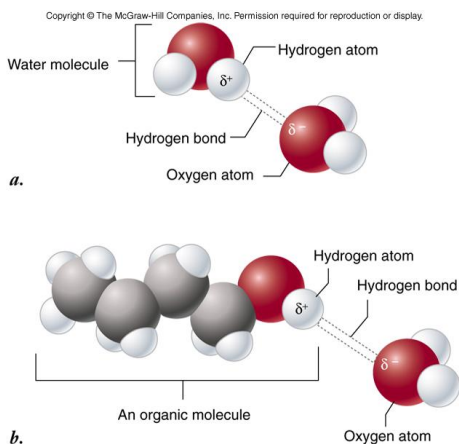
## Water Chemistry

**3) Hydrogen bonds:** weak attractions between partially negative oxygen of one water molecule partially positive hydrogen of a *different* water molecule

Hydrogen bonds can form between water molecules or between water & another charged molecule

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## Water Chemistry



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## Water Chemistry

Polarity of water: be cohesive & adhesive

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

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

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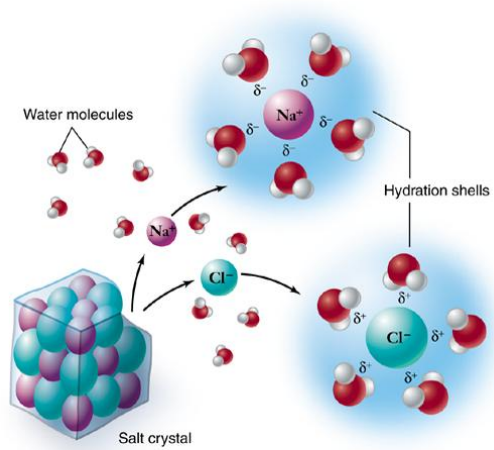
## Properties of Water

1. Water: high specific heat
  - Large amount of energy required to change temperature of water
2. Water: high heat of vaporization
  - Evaporation of water from a surface causes cooling of that surface
3. Solid water: less dense than liquid water.
  - Bodies of water freeze from top down
4. Water: a good solvent
  - Water dissolves polar molecules & ions

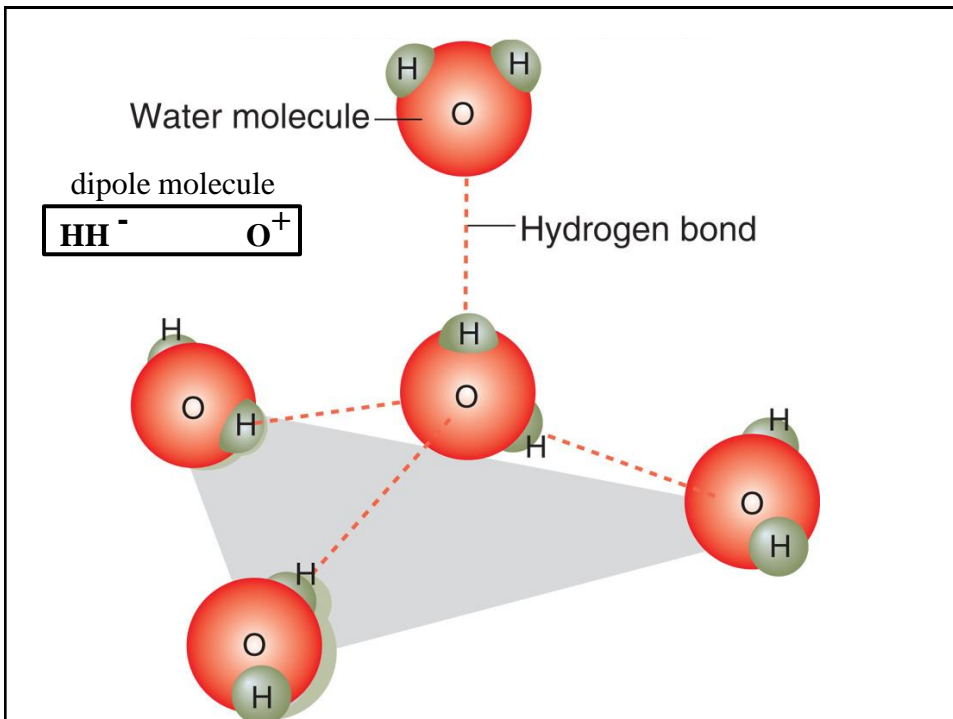
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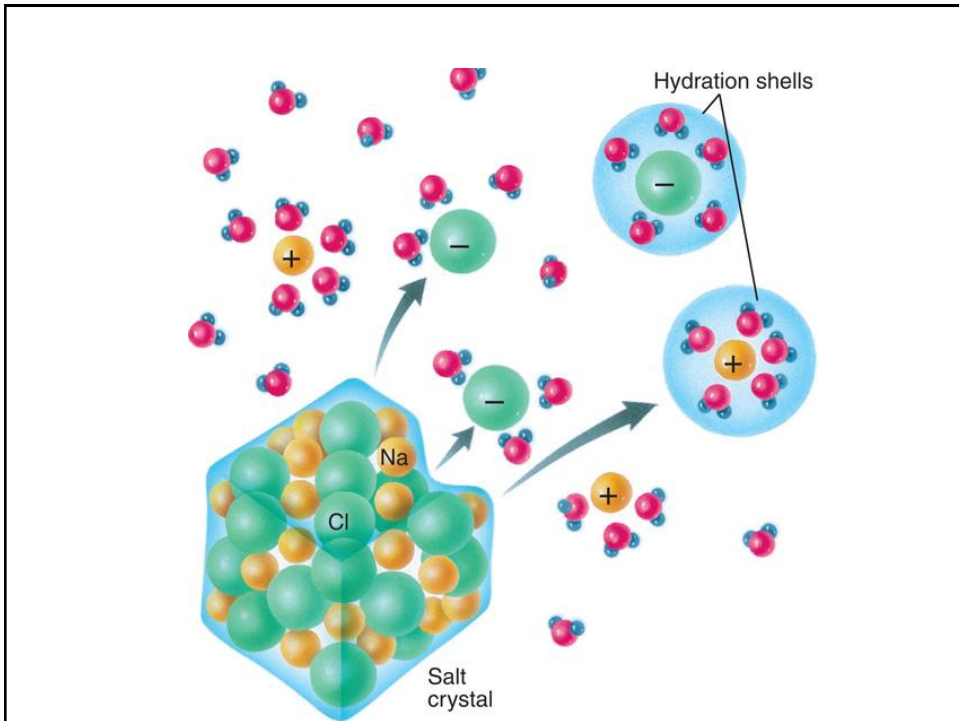
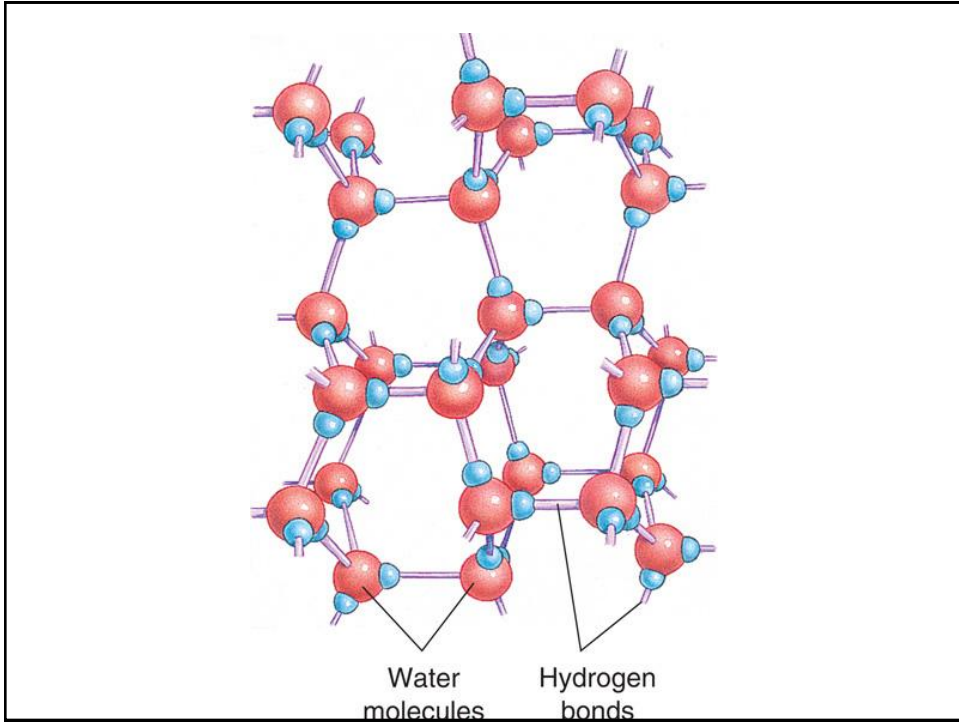
Properties of Water

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## Properties of Water

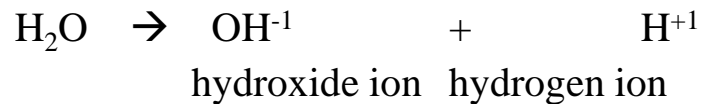
5. Water organizes nonpolar molecules.

- **hydrophilic**: “water-loving”

- **hydrophobic**: “water-fearing”

- Water causes hydrophobic molecules to aggregate or assume specific shapes

6. Water can form ions



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## Acids &amp; Bases

Hydrogen ion ( $\text{H}^{+1}$ ): basis of the pH scale

Greater  $\text{H}^{+1}$  concentration --- lower pH (**acidic**)

Lower  $\text{H}^{+1}$  concentration --- higher pH (**basic**)

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## Acids &amp; Bases

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H <sup>+</sup> Ion Concentration	pH Value	Examples of Solutions
10 <sup>0</sup>	0	Hydrochloric acid
10 <sup>-1</sup>	1	
10 <sup>-2</sup>	2	Stomach acid, lemon juice
10 <sup>-3</sup>	3	Vinegar, cola, beer
10 <sup>-4</sup>	4	Tomatoes
10 <sup>-5</sup>	5	Black coffee
10 <sup>-6</sup>	6	Urine
10 <sup>-7</sup>	7	Pure water
10 <sup>-8</sup>	8	Seawater
10 <sup>-9</sup>	9	Baking soda
10 <sup>-10</sup>	10	Great Salt Lake
10 <sup>-11</sup>	11	Household ammonia
10 <sup>-12</sup>	12	Household bleach
10 <sup>-13</sup>	13	
10 <sup>-14</sup>	14	Sodium hydroxide

## Acids &amp; Bases

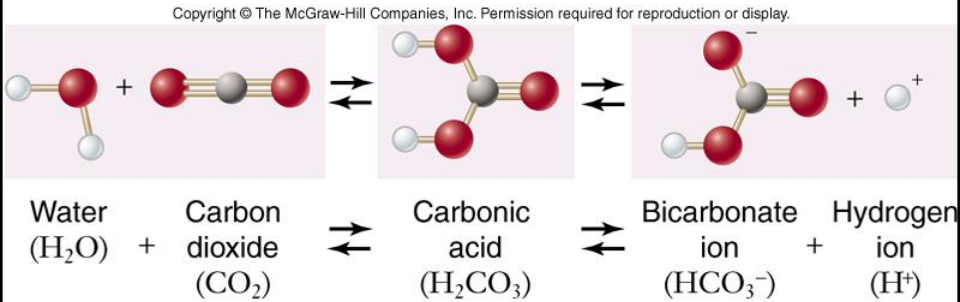
**Acid:** chemical that releases H<sup>+</sup> ions

**Base:** chemical that accepts H<sup>+</sup> ions

**Buffer:** chemical that accepts/releases H<sup>+</sup> as necessary to keep pH constant

## Acids &amp; Bases

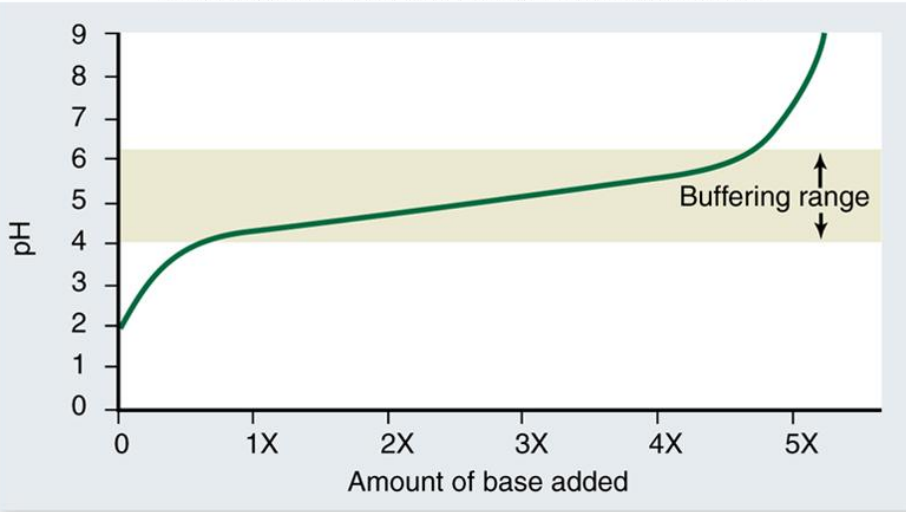
Most biological buffers consist of a pair of molecules,  
one an acid & one a base



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## Acids &amp; Bases

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