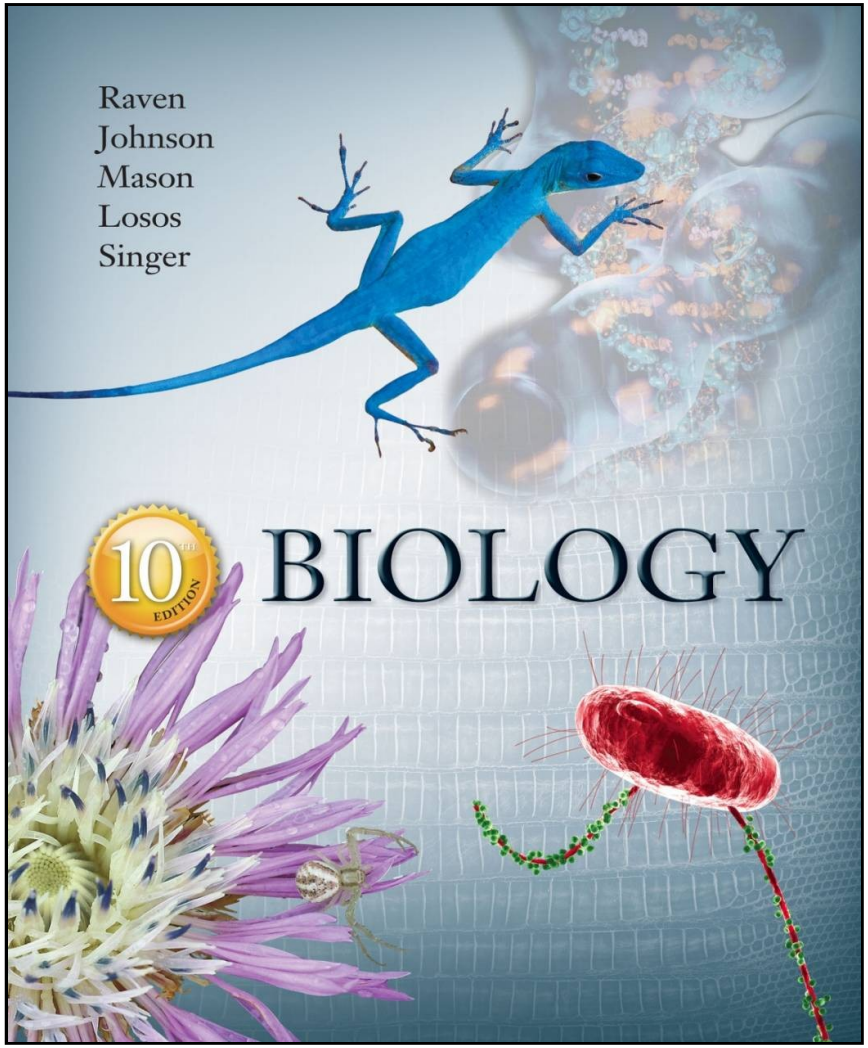


Chapter 02

Lecture and Animation Outline

To run the animations you must be in **Slideshow View**. Use the buttons on the animation to play, pause, and turn audio/text on or off.

Please Note: Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide's background before you can advance to the next slide.

The Nature of Molecules and the Properties of Water

Chapter 2

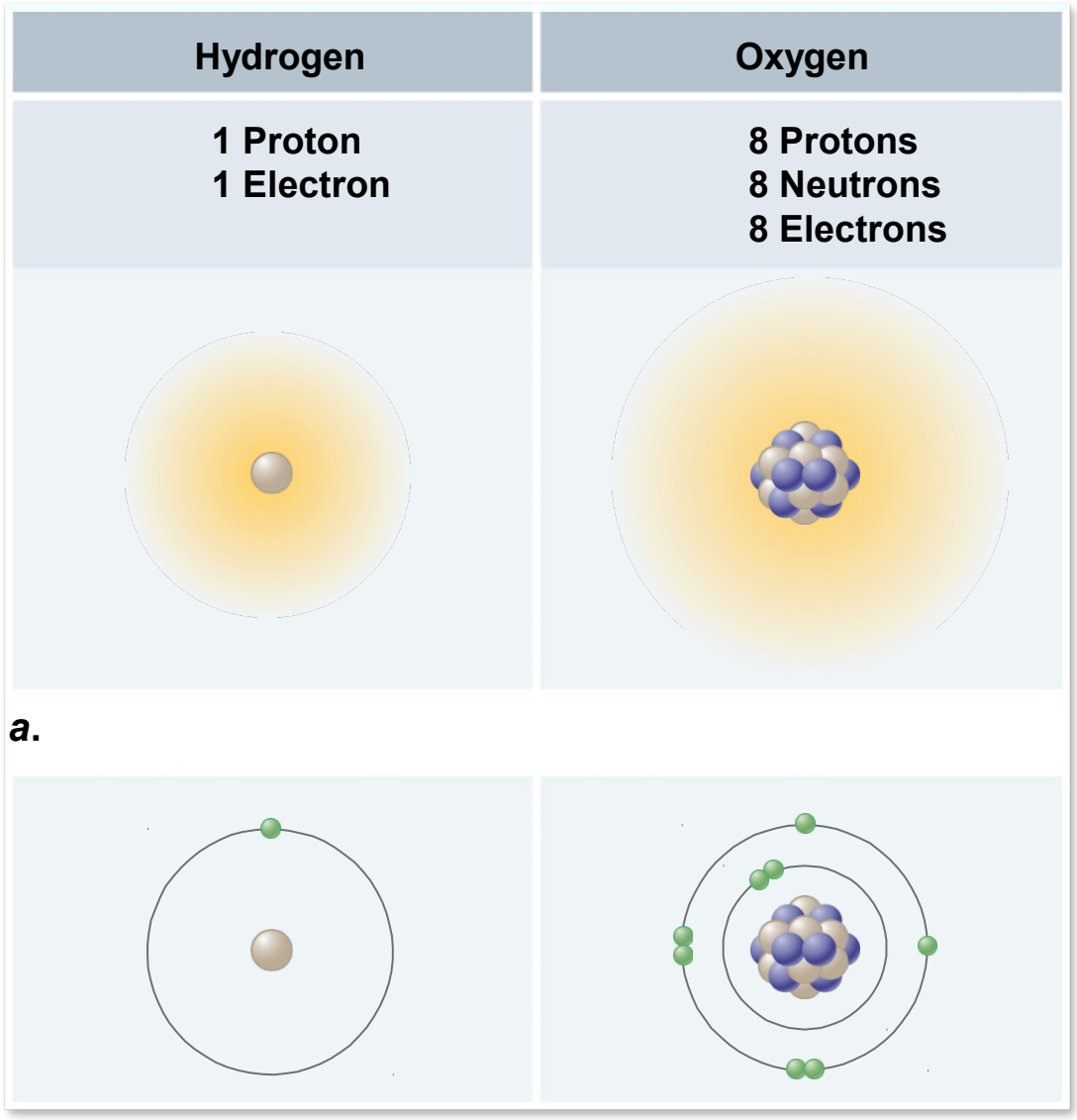
Nature of Atoms

- Matter has mass and occupies space
- 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
    - Located in the nucleus
  - Neutrons
    - Neutral particles
    - Located in the nucleus
  - Electrons
    - Negatively charged particles
    - Found in orbitals surrounding the nucleus



Atomic number

- Number of protons equals number of electrons
  - Atoms are electrically neutral
- Atomic number = number of protons
  - Every atom of a particular element has the same number of protons
- Element
  - Any substance that cannot be broken down to any other substance by ordinary chemical means

Atomic mass

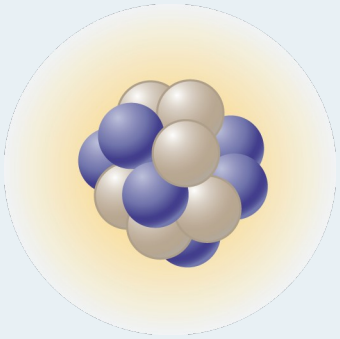
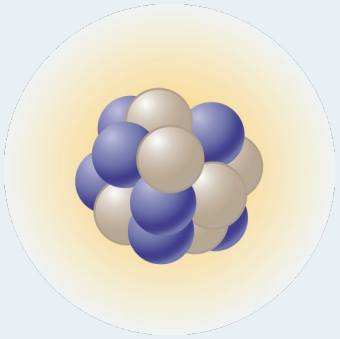
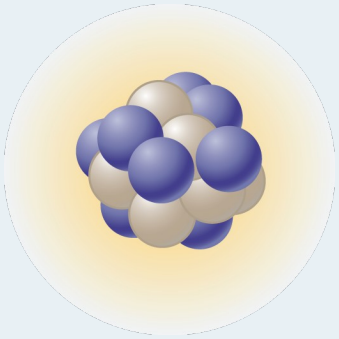
- Mass or weight?
  - Mass – refers to amount of substance
  - Weight – refers to force gravity exerts on substance
- Sum of protons and neutrons is the atom's atomic mass
- Each proton and neutron has a mass of approximately 1 Dalton

Electrons

- Negatively charged particles located in orbitals
- Neutral atoms have same number of electrons and protons
- Ions are charged particles – unbalanced
  - Cation – more protons than electrons = net positive charge
  - Anion – fewer protons than electrons = net negative charge

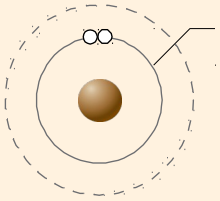
Isotopes

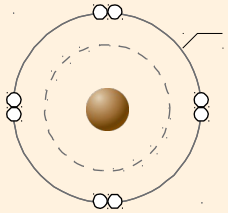
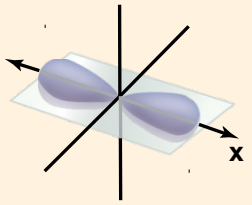
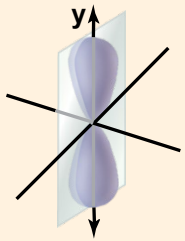
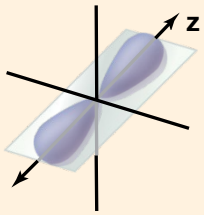
- Atoms of a single element that possess different numbers of neutrons
- Radioactive isotopes are unstable and emit radiation as the nucleus breaks up
  - Half-life – time it takes for one-half of the atoms in a sample to decay

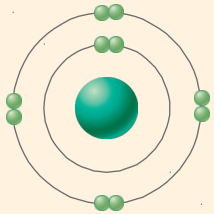
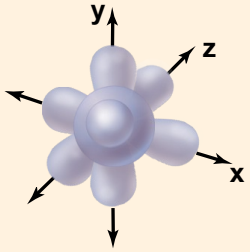
Carbon-12	Carbon-13	Carbon-14
6 Protons 6 Neutrons 6 Electrons	6 Protons 7 Neutrons 6 Electrons	6 Protons 8 Neutrons 6 Electrons
		

Electron arrangement

- Key to the chemical behavior of an atom lies in the number and arrangement of its electrons in their orbitals
- Bohr model – electrons in discrete orbits
- Modern physics defines orbital as area around a nucleus where an electron is most likely to be found
- No orbital can contain more than two electrons

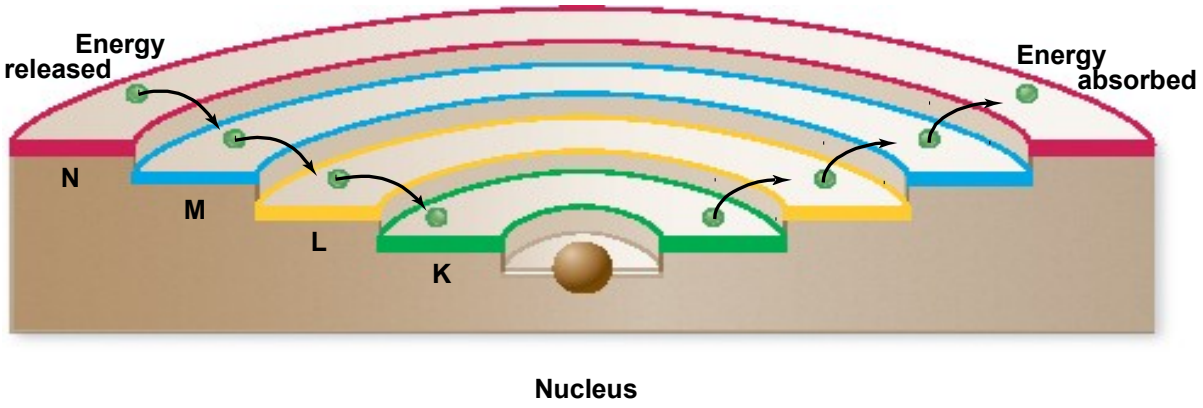
Electron Shell Diagram	Corresponding Electron Orbital
	 One spherical orbital (1s)

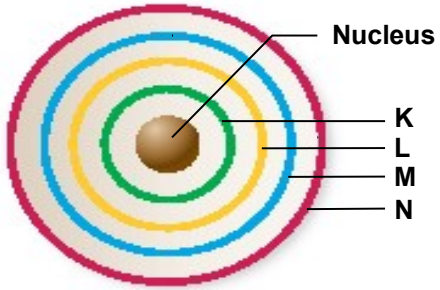
Electron Shell Diagram	Corresponding Electron Orbitals
	 One spherical orbital (2s)    Three dumbbell-shaped orbitals (2*kk*)

Electron Shell Diagram	Electron Orbitals
 Neon	

Energy levels

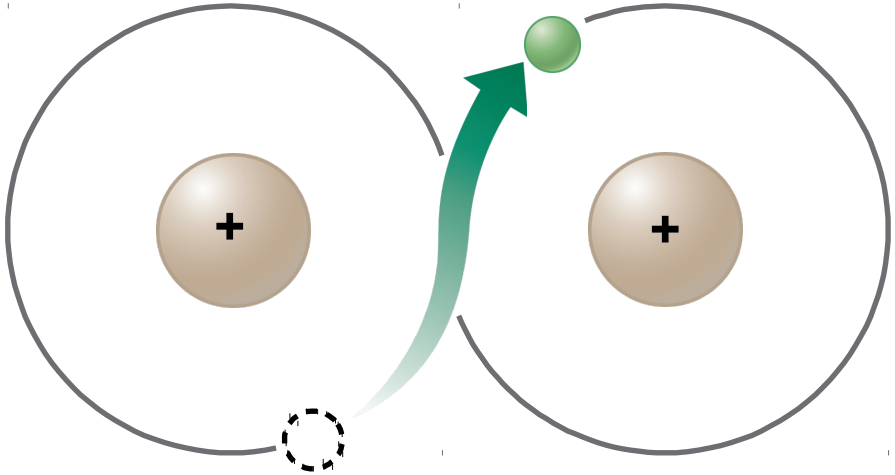
- Electrons have potential energy related to their position
  - Electrons farther from nucleus have more energy
- Be careful not to confuse energy levels, which are drawn as rings to indicate an electron's *energy, with orbitals, which have a variety of three-dimensional* shapes and indicate an electron's most likely *location*





Redox

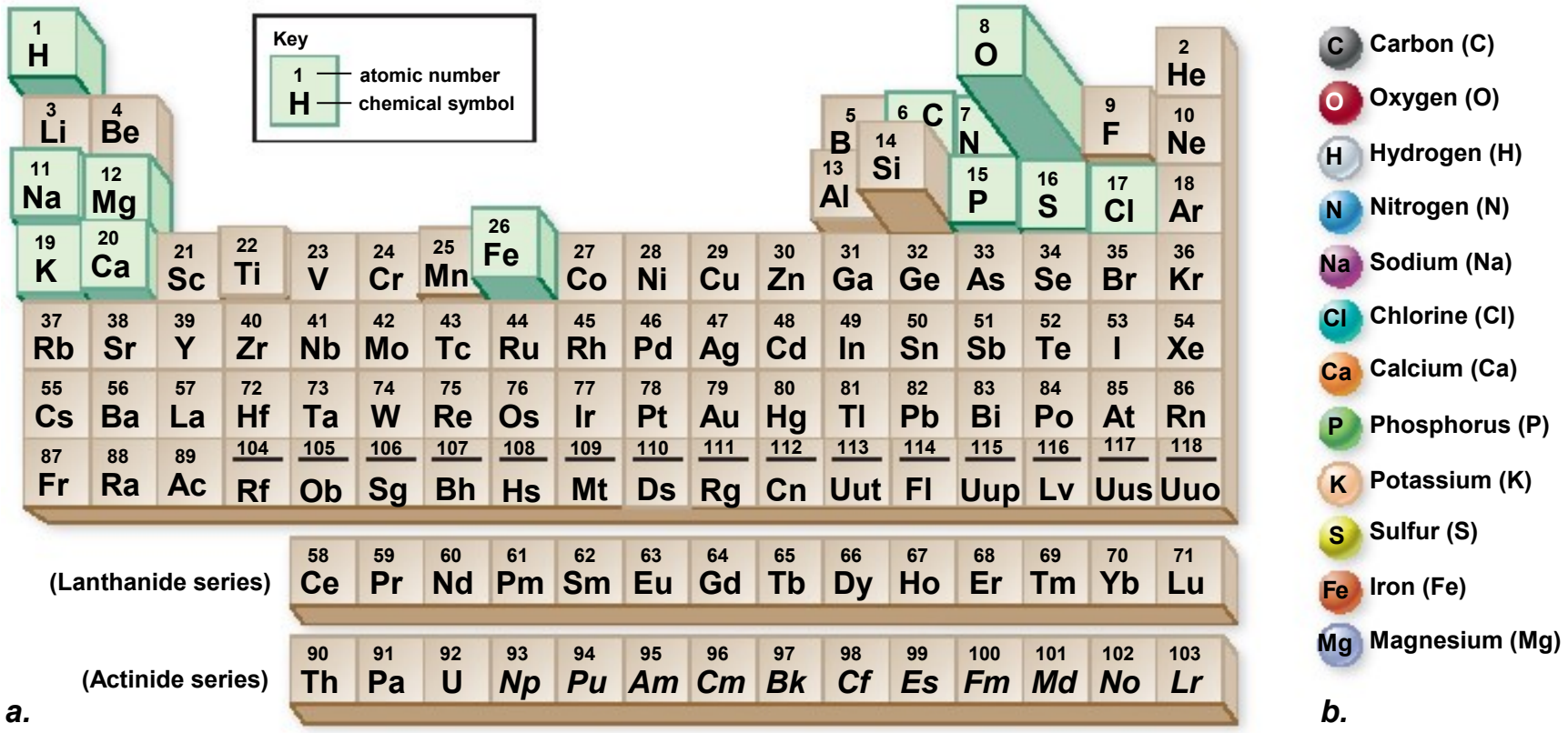
- During some chemical reactions, electrons can be transferred from one atom to another
  - Still retain the energy of their position in the atom
  - Oxidation = loss of an electron
  - Reduction = gain of an electron



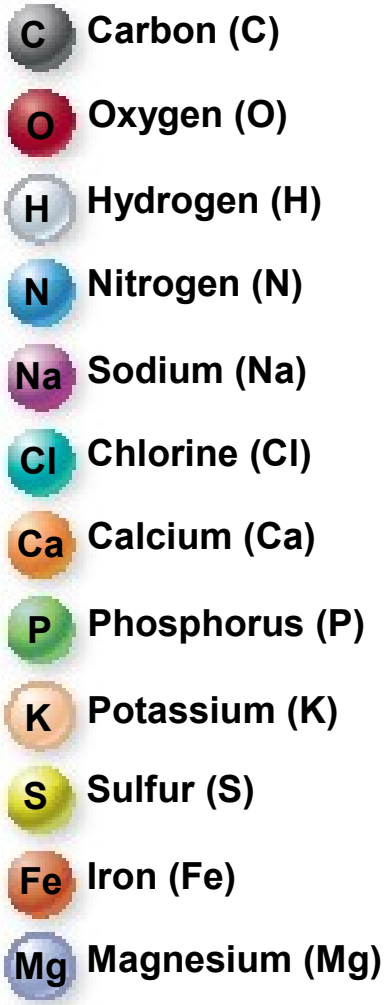
Elements

- Periodic table displays elements according to valence electrons
- Valence electrons – number of electrons in outermost energy level
- Inert (nonreactive) elements have all eight electrons
- Octet rule – atoms tend to establish completely full outer energy levels

Periodic Table of the Elements



- 90 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
- Organic molecules contain primarily CHON
- Some trace elements are very important



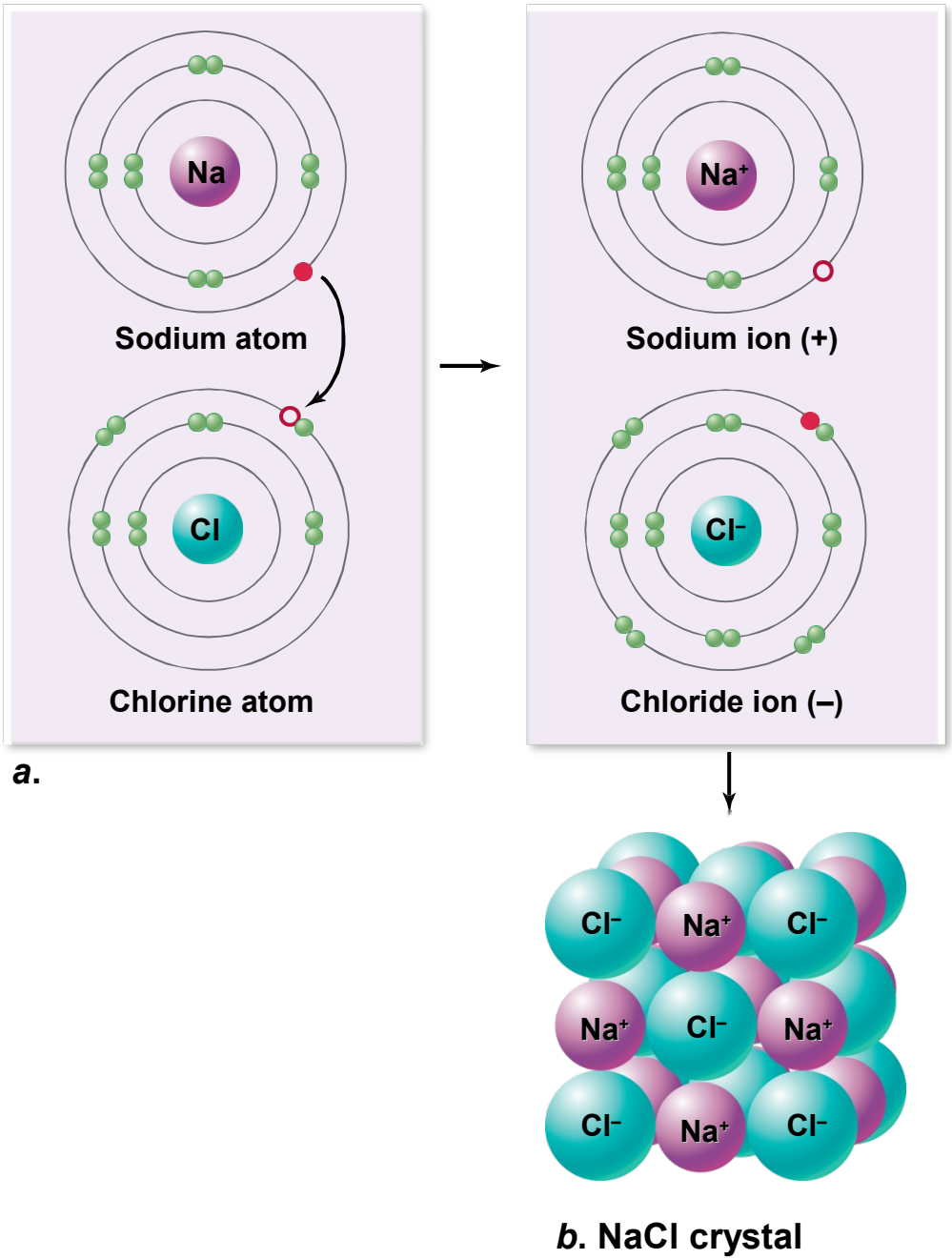
b.

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

Ionic bonds

- Formed by the attraction of oppositely charged ions
- Gain or loss of electrons forms ions
  - Na atom loses an electron to become Na^+
  - Cl atom gains an electron to become Cl^-
  - Opposite charges attract so that Na^+ and Cl^- remain associated as an ionic compound
- Electrical attraction of water molecules can disrupt forces holding ions together

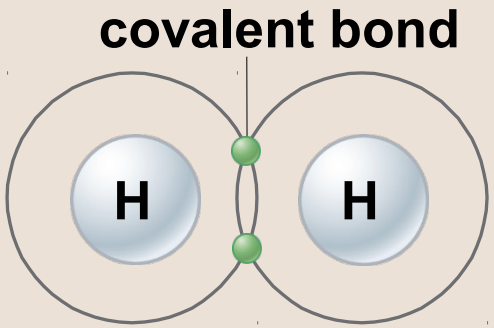


Covalent bonds

- Form when atoms share 2 or more valence electrons
- Results in no net charge, satisfies octet rule, no unpaired electrons
- Strength of covalent bond depends on the number of shared electrons
- Many biological compounds are composed of more than 2 atoms – may share electrons with 2 or more atoms

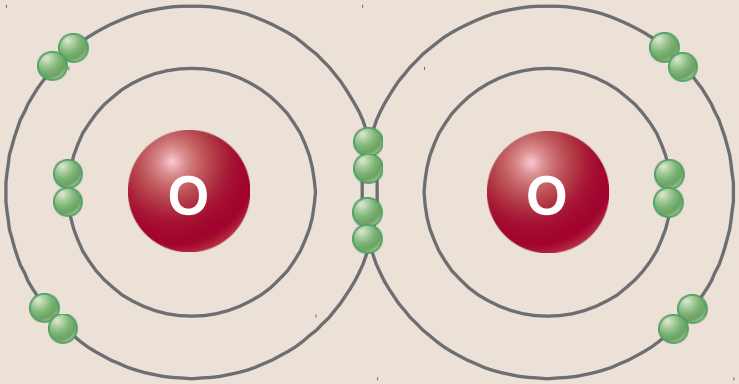
Single covalent bond
Hydrogen gas

H—H H_2



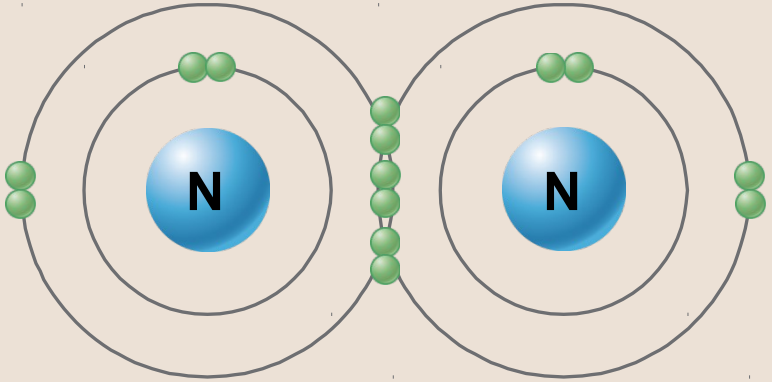
Double covalent bond
oxygen gas

O═O O_2



Triple covalent bond
Nitrogen gas

N≡N N_2



Electronegativity

- 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 reactions

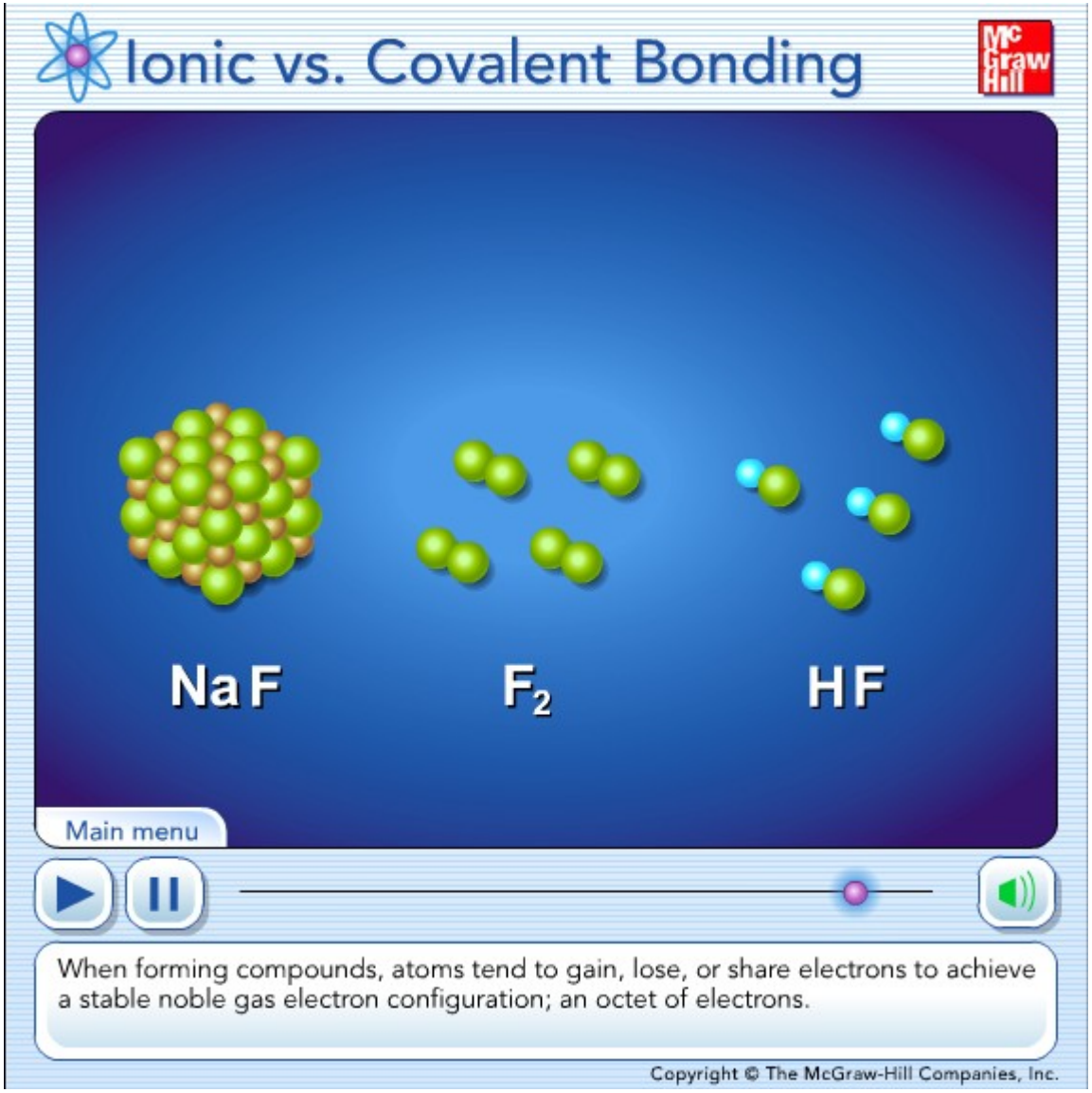
- Chemical reactions involve the formation or breaking of chemical bonds
- Atoms shift from one molecule to another without any change in number or identity of atoms
- Reactants = original molecules
- Products = molecules resulting from reaction

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

reactants products

- Extent of chemical reaction influenced by
  1. Temperature
  2. Concentration of reactants and products
  3. Catalysts

- Many reactions are reversible


Ionic vs. Covalent Bonding
NaF
F2
HF
Main menu
When forming compounds, atoms tend to gain, lose, or share electrons to achieve a stable noble gas electron configuration; an octet of electrons.
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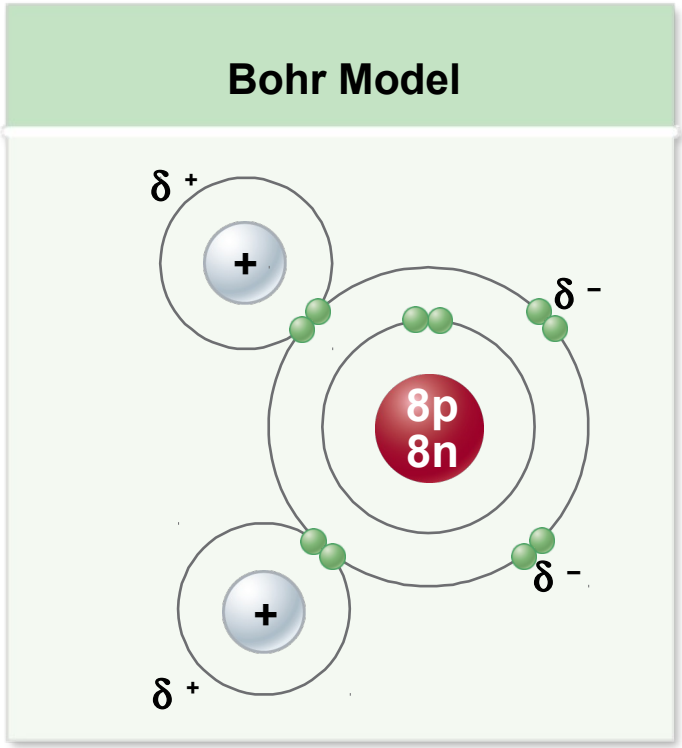
Water

- Life is inextricably tied to water
- Single most outstanding chemical property of water is its ability to form hydrogen bonds
  - Weak chemical associations that form between the partially negative O atoms and the partially positive H atoms of two water molecules

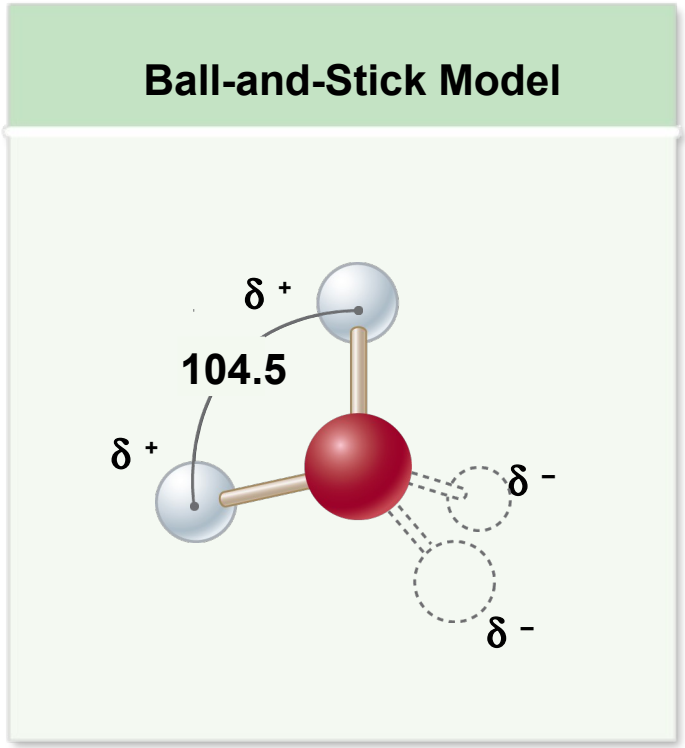
a. **Solid** ***b.*** **Liquid** ***c.*** **Gas**

Polarity of water

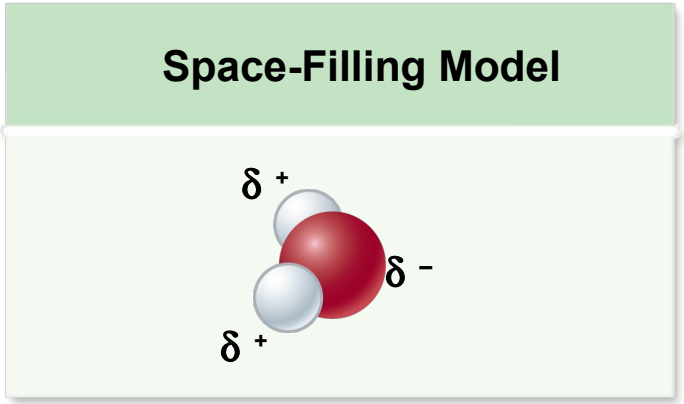
- Within a water molecule, the bonds between oxygen and hydrogen are highly polar
  - Oxygen is much more electronegative than Hydrogen
- Partial electrical charges develop
  - Oxygen is partially negative δ^+
  - Hydrogen is partially positive δ^-



a.



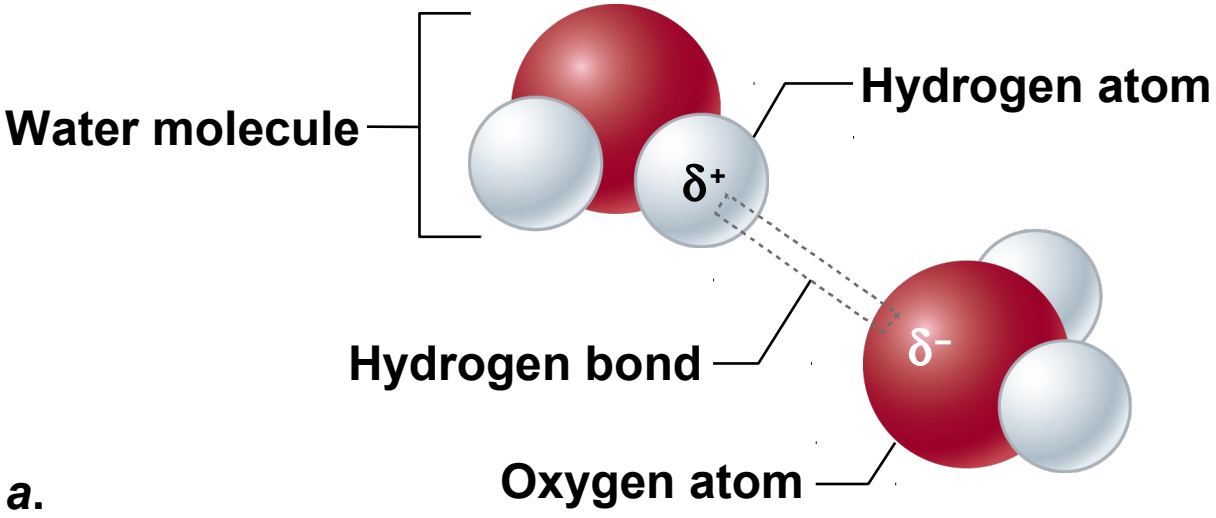
b.



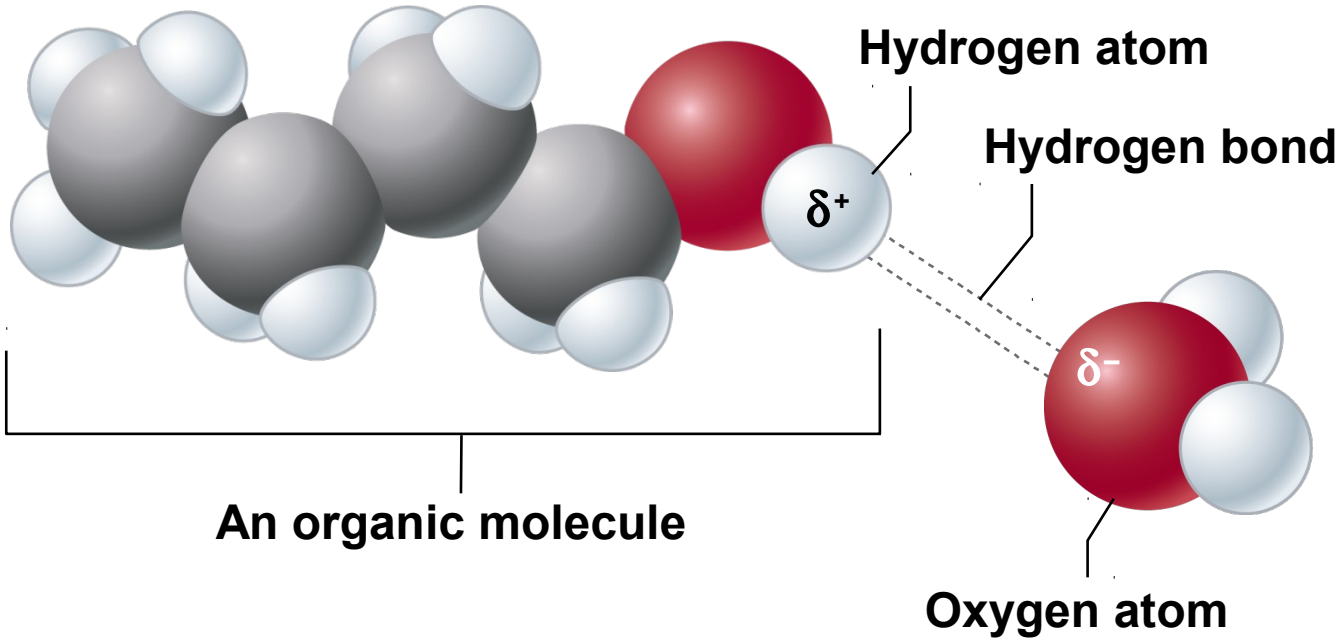
c.

Hydrogen bonds

- Cohesion – polarity of water allows water molecules to be attracted to one another
- Attraction produces hydrogen bonds
- Each individual bond is weak and transitory
- Cumulative effects are enormous
- Responsible for many of water's important physical properties



a.



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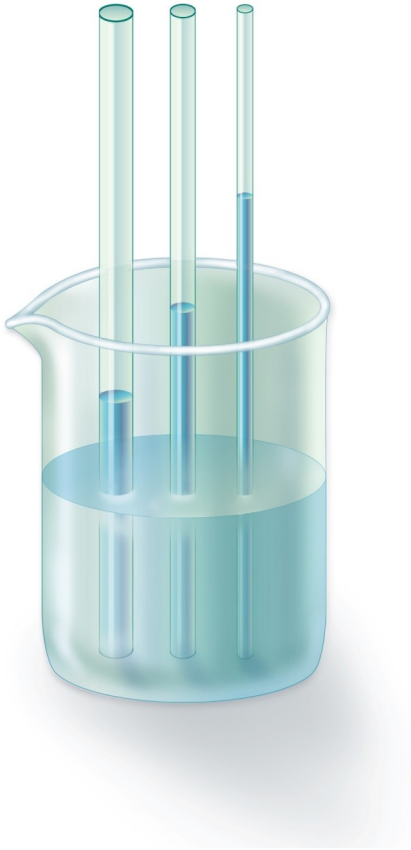
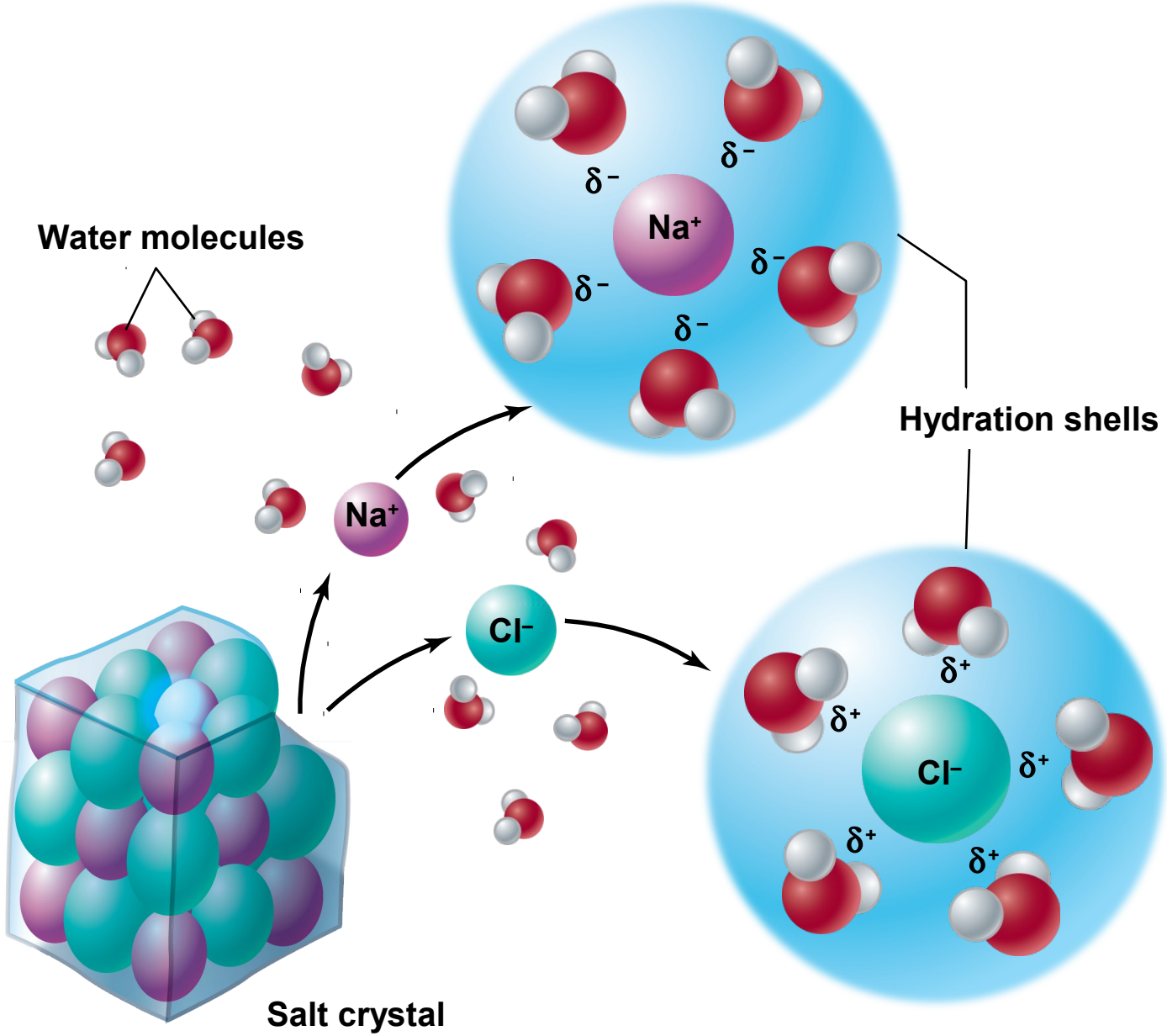


- Cohesion – water molecules stick to other water molecules by hydrogen bonding
- Adhesion – water molecules stick to other polar molecules by hydrogen bonding

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
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
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

$$H_2O \rightarrow OH^- + H^+$$

hydroxide ion

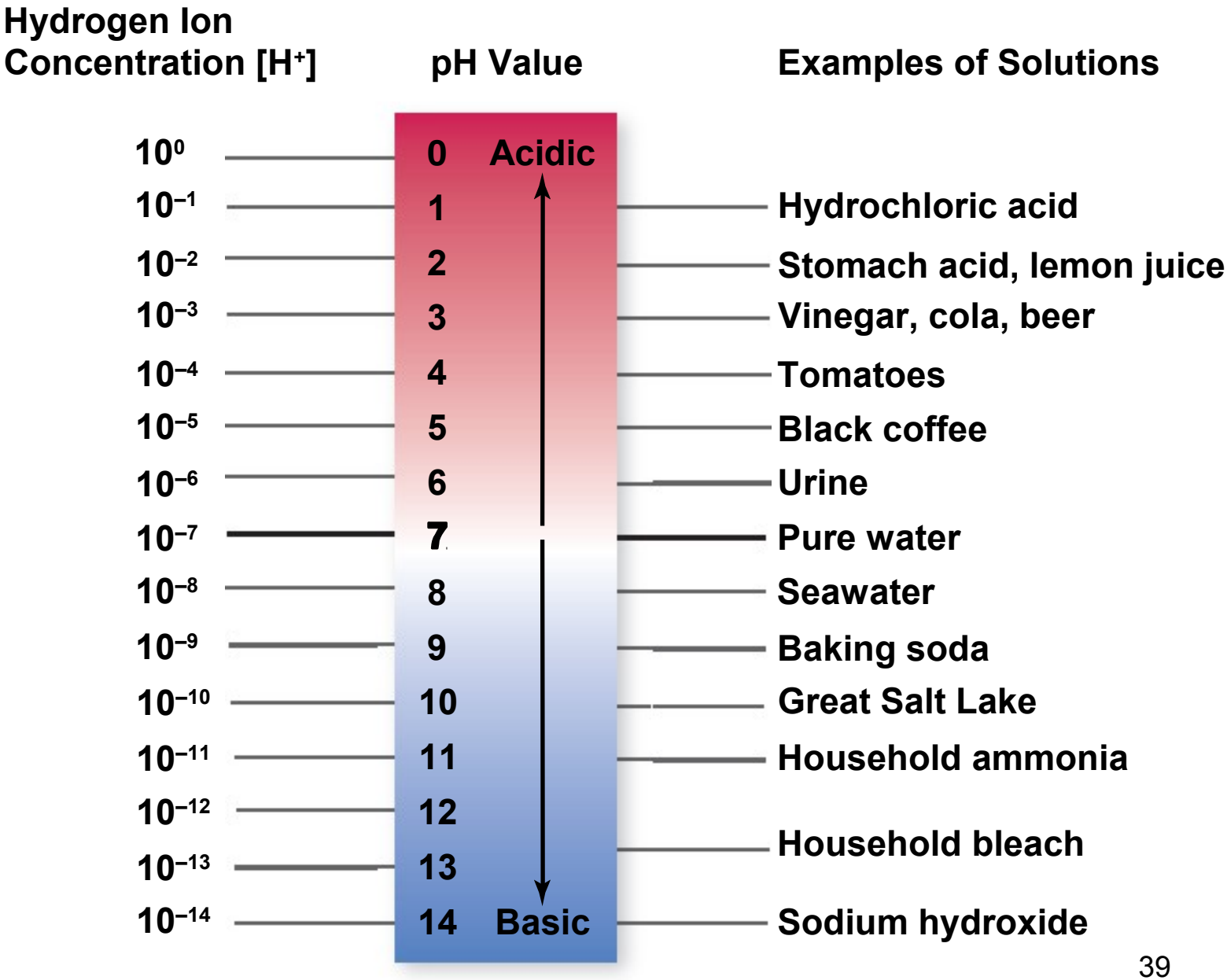
hydrogen ion

Acids and bases

- Pure water
  - $[H^+]$ of 10^{-7} mol/L
  - Considered to be neutral
  - Neither acidic nor basic
- pH is the negative logarithm of hydrogen ion concentration of solution

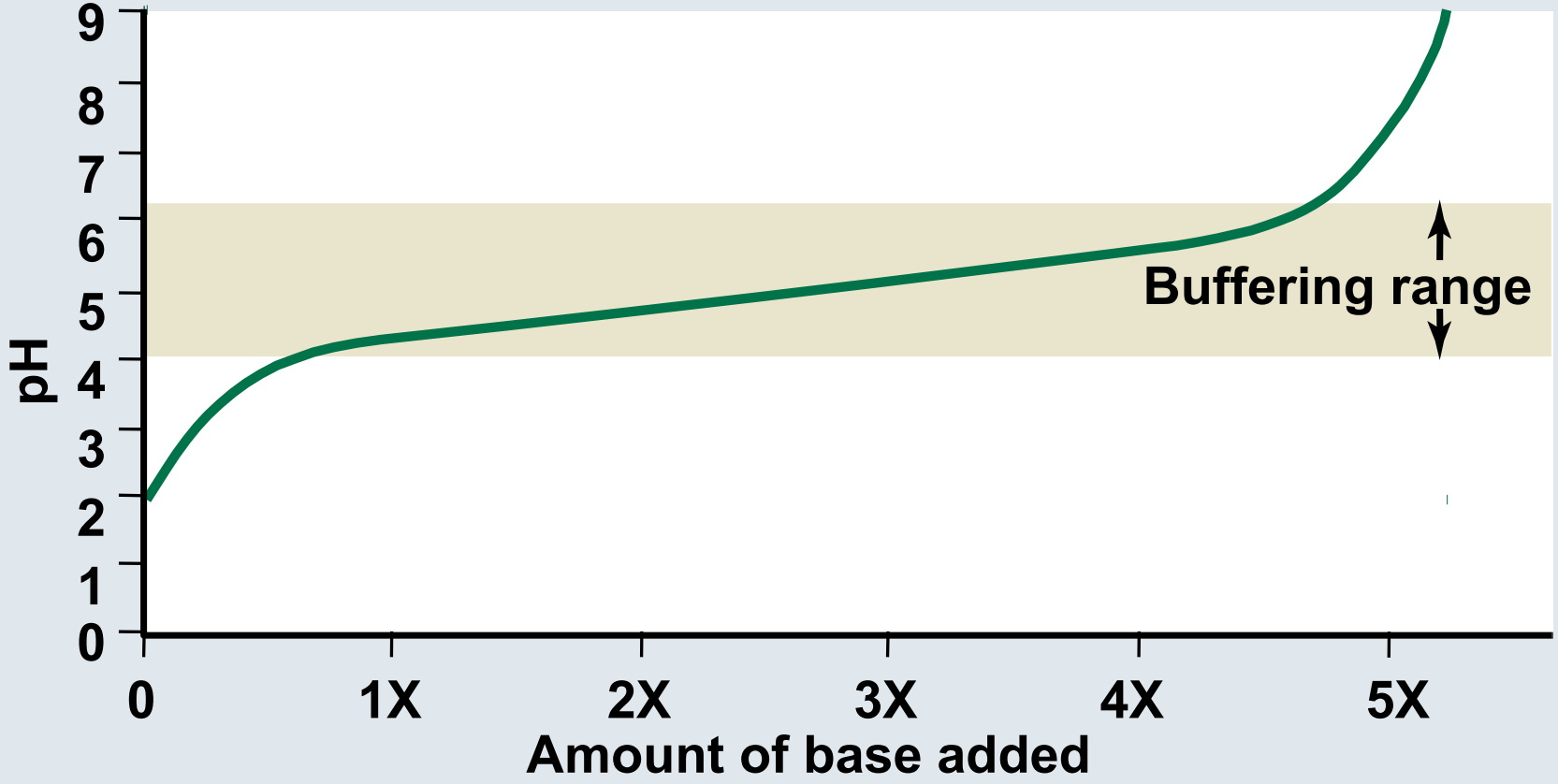
Acids and Bases - pH

- Acid
  - Any substance that dissociates in water to increase the [H^+] (and lower the pH)
  - The stronger an acid is, the more hydrogen ions it produces and the lower its pH
- Base
  - Substance that combines with H^+ dissolved in water, and thus lowers the [H^+]

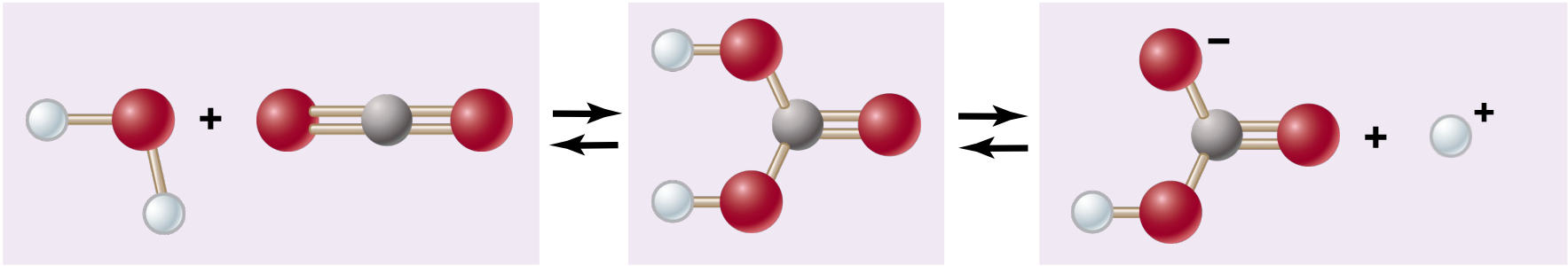


Buffers

- Substance that resists changes in pH
- Act by
  - Releasing hydrogen ions when a base is added
  - Absorbing hydrogen ions when acid is added
- Overall effect of keeping [H+] relatively constant



- 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^+)