Introduction to Biochemistry

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Bio Chemistry

- Bio= life
- Chemistry = how things interact
- Biochemistry= the branch of science in which you study the chemical and physical processes that occur in an organism.

Matter…

- ☐ All matter, whether living or nonliving, is made of the same type building blocks called **atoms**
- ☐ An **atom** is the smallest basic unit of matter
- ☐ All atoms have the same basic structure, composed of <u>three</u> smaller particles
  1. **Proton** – a positively charged particle in an atom's nucleus
  2. **Neutron** – a neutral (no charge) particle which has about the same mass as a proton and is also in the nucleus
  3. **Electron** – a negatively charged particle found outside the nucleus. Electrons are much, much smaller than proton and neutrons

Elements…

1. Different types of atoms are called **elements,** which cannot be broken down by ordinary chemical means
2. Which element an atom is depends on the <u>number of protons</u> in the atom's nucleus
    1. For example… all hydrogen atoms have 1proton and all oxygen atoms have 8 protons
3. Only about 25 different elements are found in organisms
    1. However, atoms of different elements can "link" or bond together to form compounds

Compounds…

- Atoms form compounds in two ways
  1. Ionic bonds – consists of ions and forms through the electrical force between oppositely charged ions
     - An ion is an atom that has lost or gained electrons
       - Cation – an ion that loses electrons so becomes positively charged
       - Anion – an ion that gains electrons so becomes negatively charged
  2. Covalent bonds – forms when atoms share one or more pairs of electrons
     - A molecule consists of two or more atoms held together by covalent bonds

Why elements bond the way they do…

- All atoms want 8 electrons in their outer most energy level (shell) This is called the **octet rule.**
- That is why they do what they do
  - Ionic bonds – gain or lose electrons
  - Covalent share electrons
- How do we identify each type
  - Ionic compound – metal + non-metal
  - Covalent compound – non-metal + non-metal

Atoms

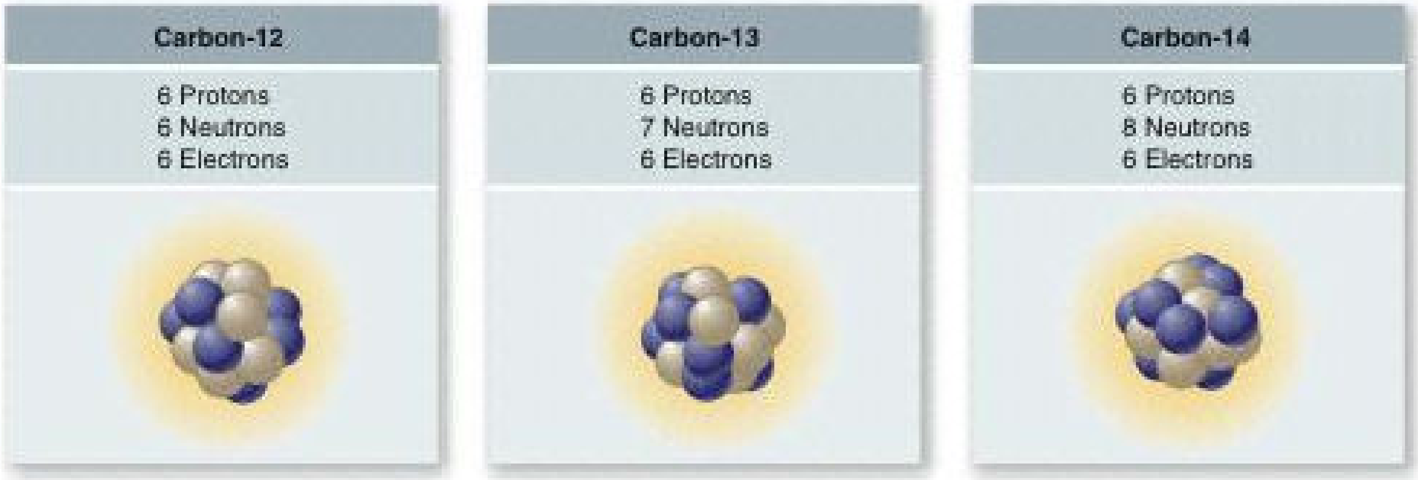
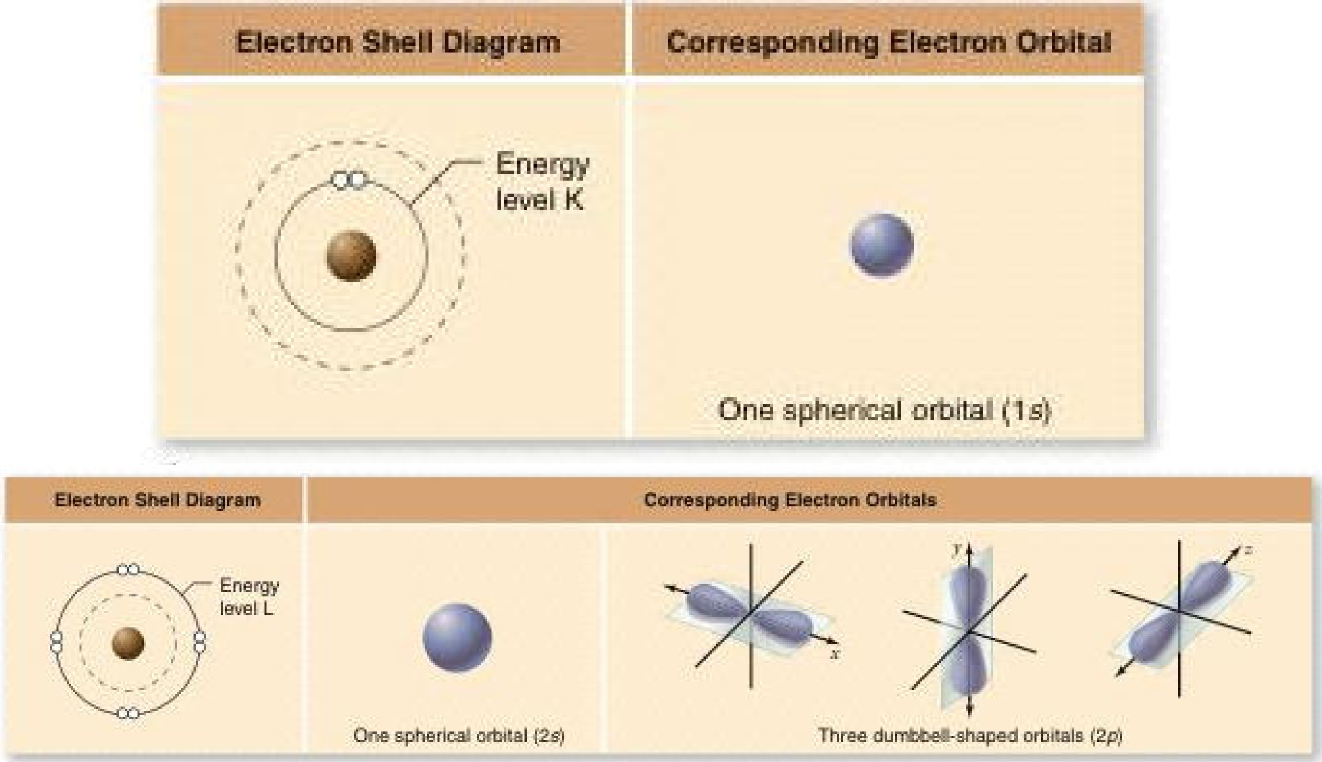
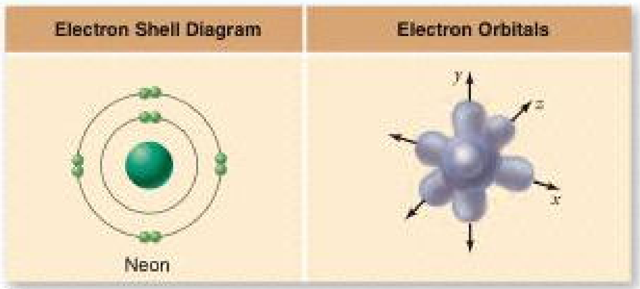


figure 2.3
THE THREE MOST ABUNDANT ISOTOPES OF CARBON. Isotopes of a particular element have different numbers of neutrons.

Electron orbitals



b.



c.

figure 2.4

ELECTRON ORBITALS. ***a.*** The lowest energy level or electron shell—the one nearest the nucleus—is level K. It is occupied by a single *s* orbital, referred to as 1*s*. ***b.*** The next highest energy level, L, is occupied by four orbitals: one *s* orbital (referred to as the 2*s* orbital) and three *p* orbitals (each referred to as a 2*p* orbital). Each orbital holds two paired electrons with opposite spin. Thus, the K level is populated by two electrons, and the L level is populated by a total of eight electrons. ***c.*** The neon atom shown has the L and K energy levels completely filled with electrons and is thus unreactive.

Energy Levels

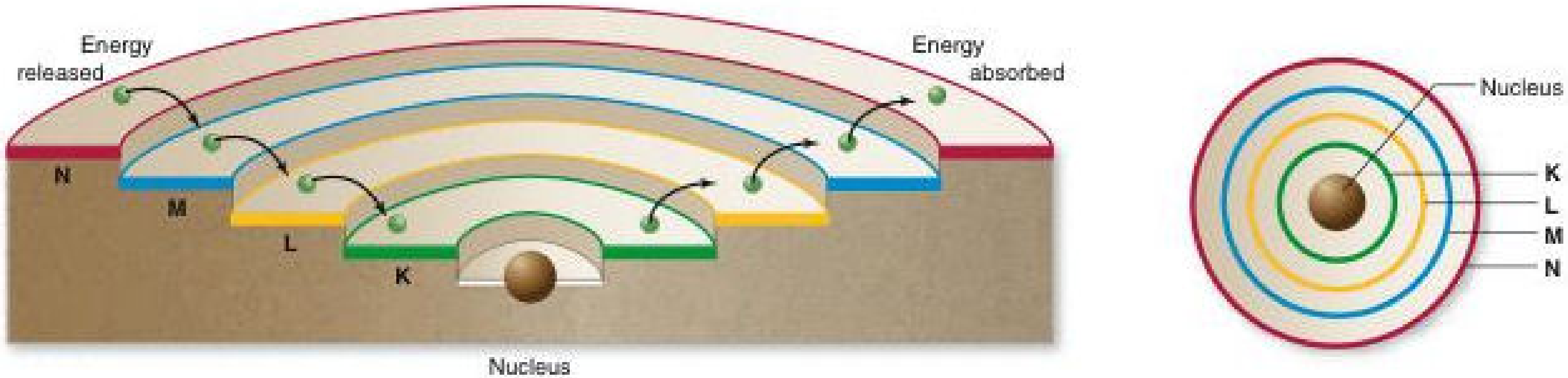


figure 2.5

ATOMIC ENERGY LEVELS. Electrons have energy of position. When an atom absorbs energy, an electron moves to a higher energy level, farther from the nucleus. When an electron falls to lower energy levels, closer to the nucleus, energy is released. The first two energy levels are the same as shown in the previous figure.

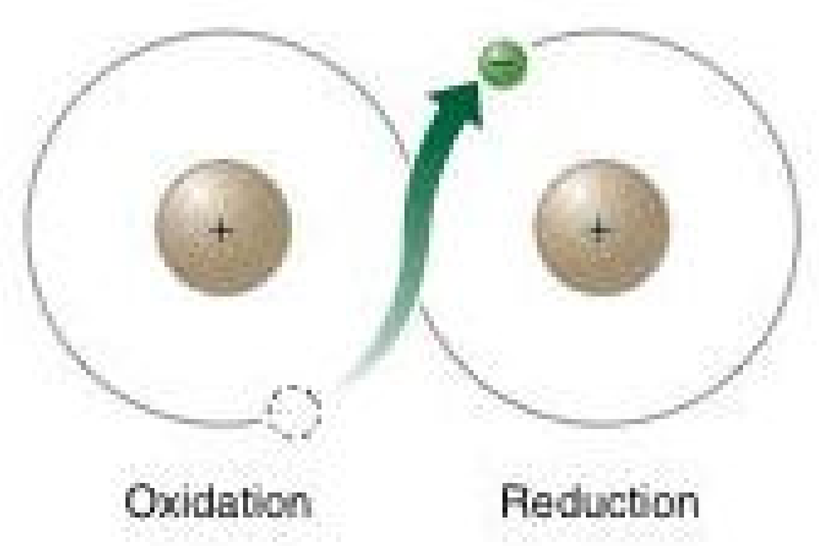
Redox Reactions

Redox can involve loss or gain of an electron or a hydrogen (contains an electron)

$C_6H_{12}O_6 + 6O_2$ ---> $6CO_2 + 6H_2O$

Carbon loses hydrogen therefore is oxidized.

Oxygen gains hydrogen therefore is reduced.



Electronegativities

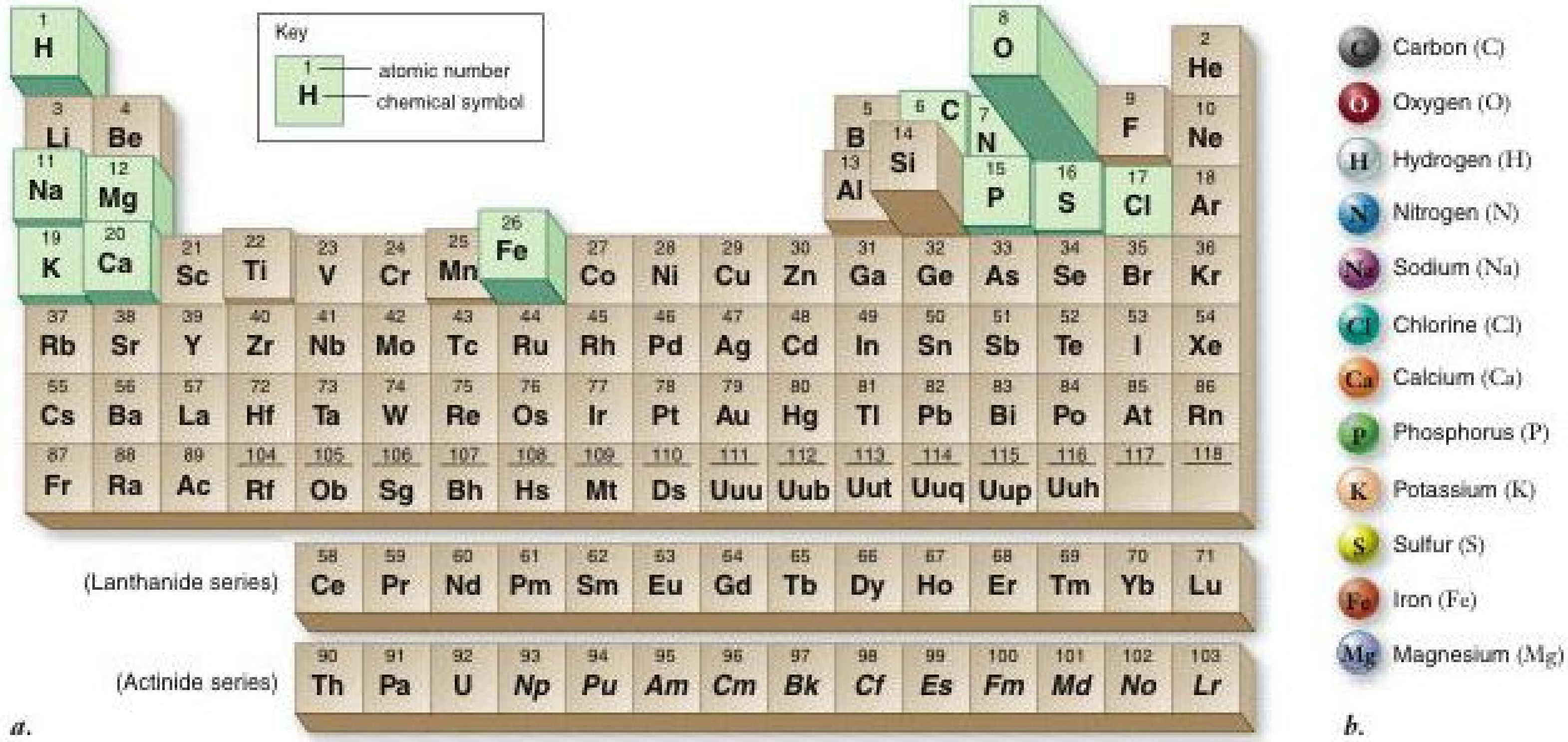


figure 2.6

PERIODIC TABLE OF THE ELEMENTS. ***a.*** In this representation, the frequency of elements that occur in the Earth's crust is indicated by the height of the block. Elements shaded in green are found in living systems in more than trace amounts. ***b.*** Common elements found in living systems are shown in colors that will be used throughout the text.

Biochemistry

- There are several different types of bonds that are impor… Biology.
- Covalent=
- Ionic = sw
- Polar Cov… etween.
- The realit… ve both ionic and covalent characteristics– polar.

TABLE 2.1 Bonds and Interactions

Name	Basis of interaction	Strength
Covalent bond	Sharing of electron pairs	Strong
Ionic bond	Attraction of opposite charges	↑
Hydrogen bond	Sharing of H atom	
Hydrophobic interaction	Forcing of hydrophobic portions of molecules together in presence of polar substances	↓
van der Waals attraction	Weak attractions between atoms due to oppositely polarized electron clouds	Weak

Ionic Bonds

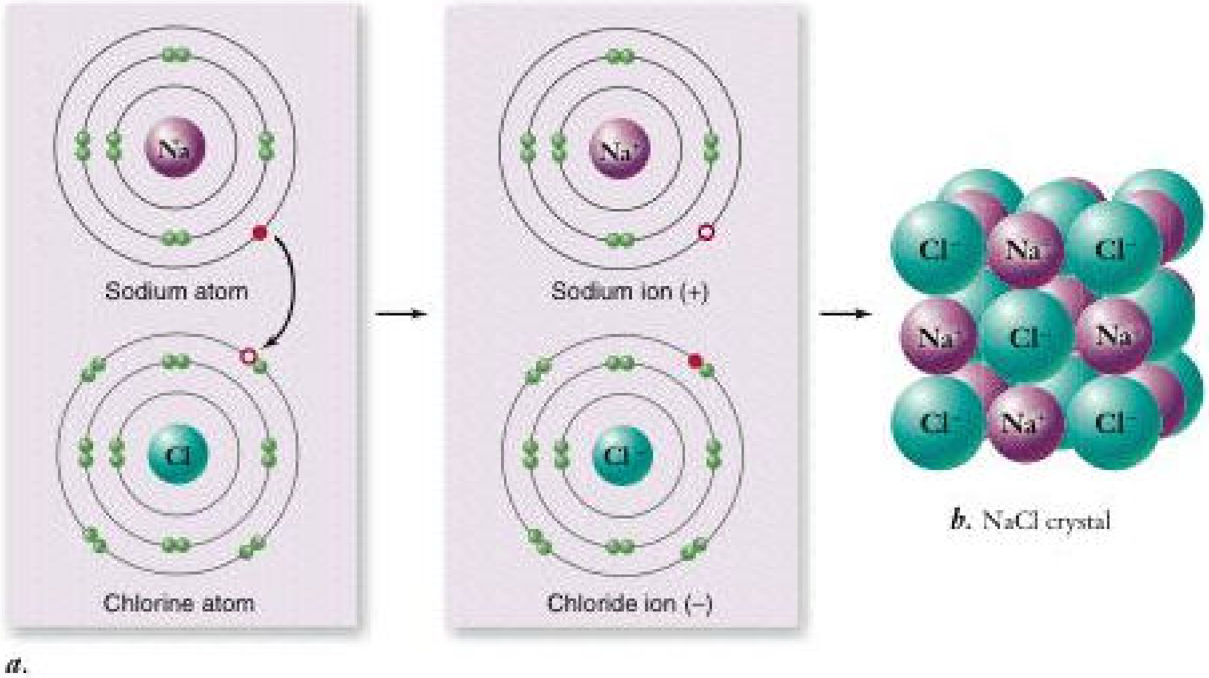
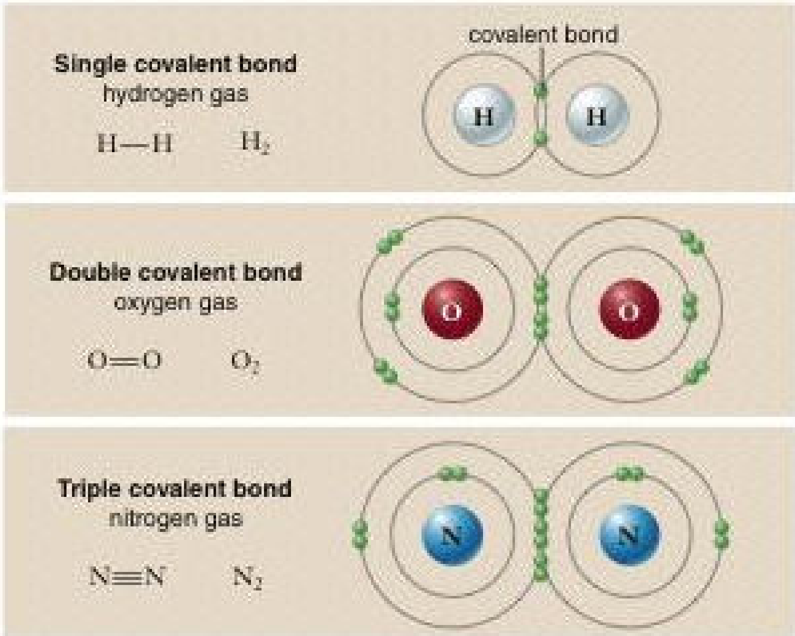


figure 2.8

THE FORMATION OF IONIC BONDS BY SODIUM CHLORIDE.

a. When a sodium atom donates an electron to a chlorine atom, the sodium atom becomes a positively charged sodium ion, and the chlorine atom becomes a negatively charged chloride ion. ***b.*** The electrostatic attraction of oppositely charged ions leads to the formation of a lattice of Na^+ and Cl^-.

Covalent Bonds



Covalent bonds are represented in chemical formulas as lines connecting atomic symbols, where each line between two bonded atoms represents the sharing of one pair of electrons. The *structural formulas* of hydrogen gas and oxygen gas are H—H and O=O, respectively, and their *molecular formulas* are H_2 and O_2. The structural formula for N_2 is N≡N.

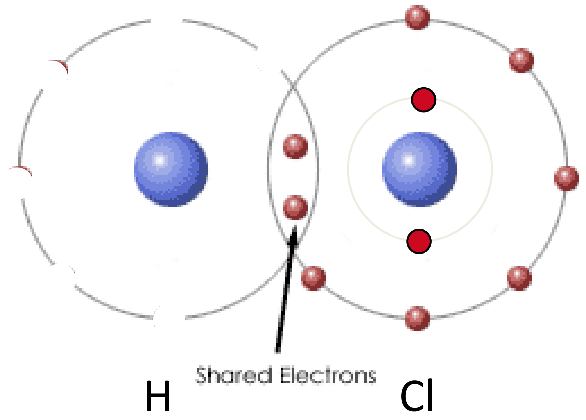
Electronegativity

Electronegativity, symbol χ, is the chemical property that describes the ability of an atom (or, more rarely, a functional group) to attract electrons (or electron density) towards itself in a covalent bond.

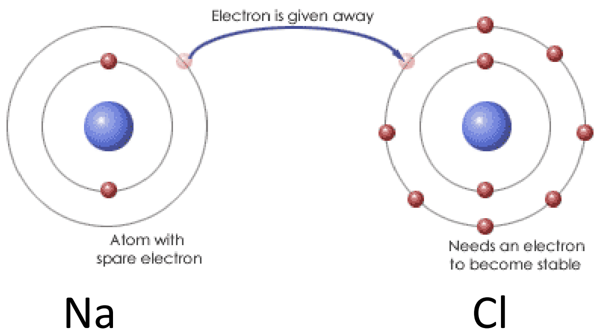
TABLE 2.2	Relative Electronegativities of Some Important Atoms
Atom	Electronegativity
O	3.5
N	3.0
C	2.5
H	2.1

Covalent and Ionic Bonds

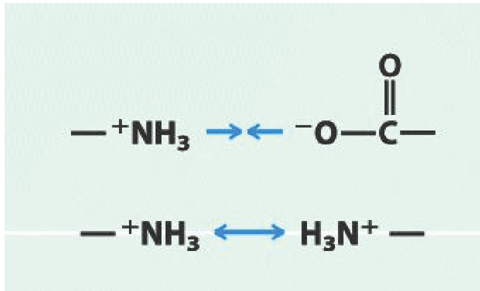
To convert kilocalories into kilojoules multiply by 4.184



Covalent (100-400 kcal/mol)



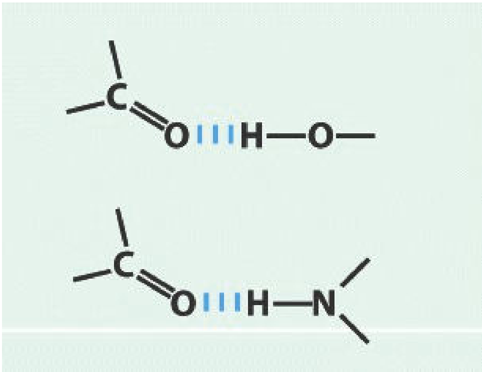
Ionic (100-300 kcal/mol)

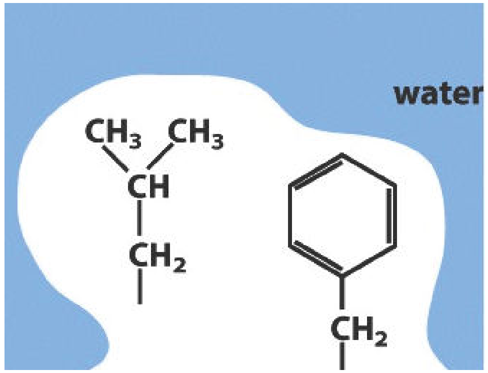


attraction

repulsion

Hydrogen and hydrophobic interactions





H2 (12-16 kcal/mol)
attraction between a hydrogen atom in one molecule and a atom of high electronegativity in another molecule. It is an <u>intermolecular</u> force, not an intramolecular force.

Hydrophobic Interactions

To convert kilocalories into kilojoules multiply by 4.184

Van der Waals

TABLE 2–4 van der Waals Radii and Covalent (Single-Bond) Radii of Some Elements

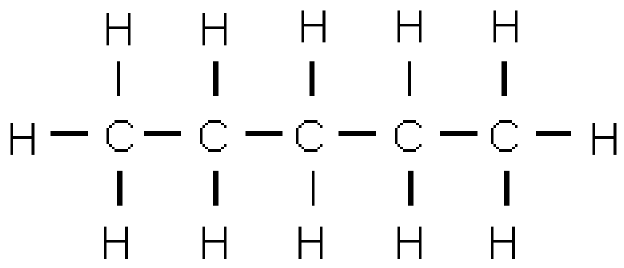
Element	van der Waals radius (nm)	Covalent radius for single bond (nm)
H	0.11	0.030
O	0.15	0.066
N	0.15	0.070
C	0.17	0.077
S	0.18	0.104
P	0.19	0.110
I	0.21	0.133

Sources: For van der Waals radii, Chauvin, R. (1992) Explicit periodic trend of van der Waals radii. *J. Phys. Chem.* 96, 9194–9197. For covalent radii, Pauling, L. (1960) *Nature of the Chemical Bond,* 3rd edn, Cornell University Press, Ithaca, NY.

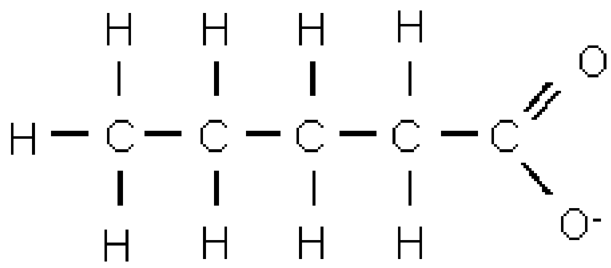
Note: van der Waals radii describe the space-filling dimensions of atoms. When two atoms are joined covalently, the atomic radii at the point of bonding are less than the van der Waals radii, because the joined atoms are pulled together by the shared electron pair. The distance between nuclei in a van der Waals interaction or a covalent bond is about equal to the sum of the van der Waals or covalent radii, respectively, for the two atoms. Thus the length of a carbon-carbon single bond is about 0.077 nm + 0.077 nm = 0.154 nm.

Table 2-4
Lehninger Principles of Biochemistry, Fifth Edition

Nonpolar molecules are ***hydrophobic*** (means "water fearing"). They do not dissolve in water.



Polar and **ionic** molecules have positive and negative charges and are therefore attracted to water molecules because water molecules are also polar. They are said to be ***hydrophilic*** because they interact with (dissolve in) water by forming hydrogen bonds.

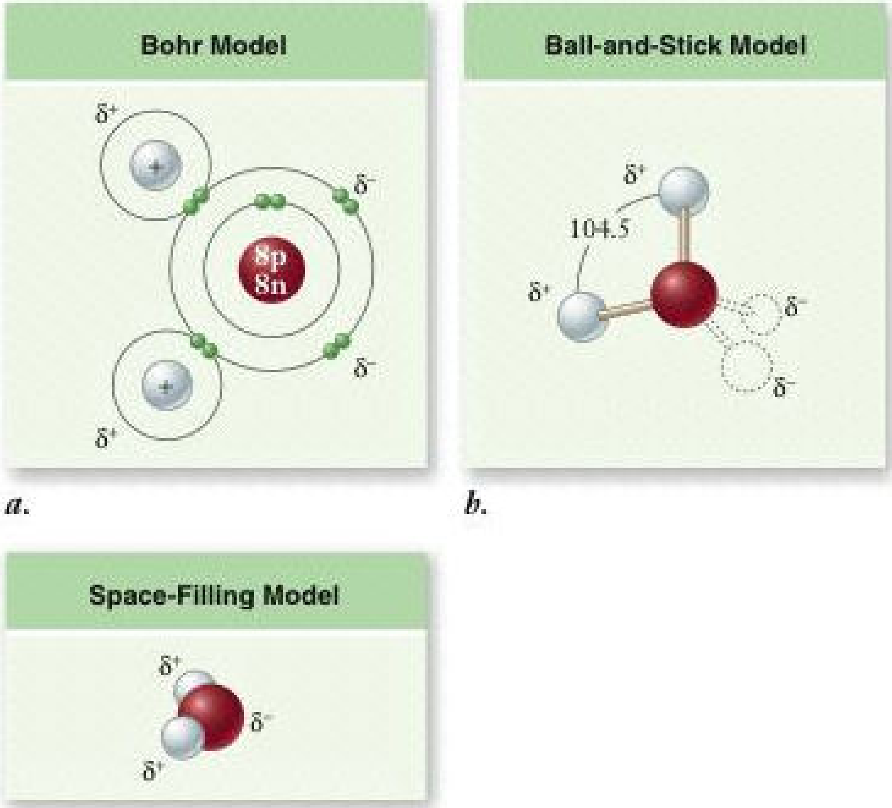


Bond Strength

- While it takes more energy to break ionic bonds in a dry environment, in living things molecules are in aqueous environments.
- Therefore in Biology: Covalent bonds are stronger than Ionic bonds, and H-bonds are weaker than both.
- Keep in mind that in large numbers H-bonds can be strong.

Polar Covalent Bonds

- Because (... tivity value of 3.44 ar ... f 2.1, the difference ... t at any given tim ... ikely to be found clo
- Oxygen is ... ef.
- While the ... either atom, we ... , δ^-



a. b. c.

Hydrogen Bonds

- Because I
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  somethin
  polarizati … the H to
  form a w … rge of
  another
- Which el … ill tend to
  form H-b

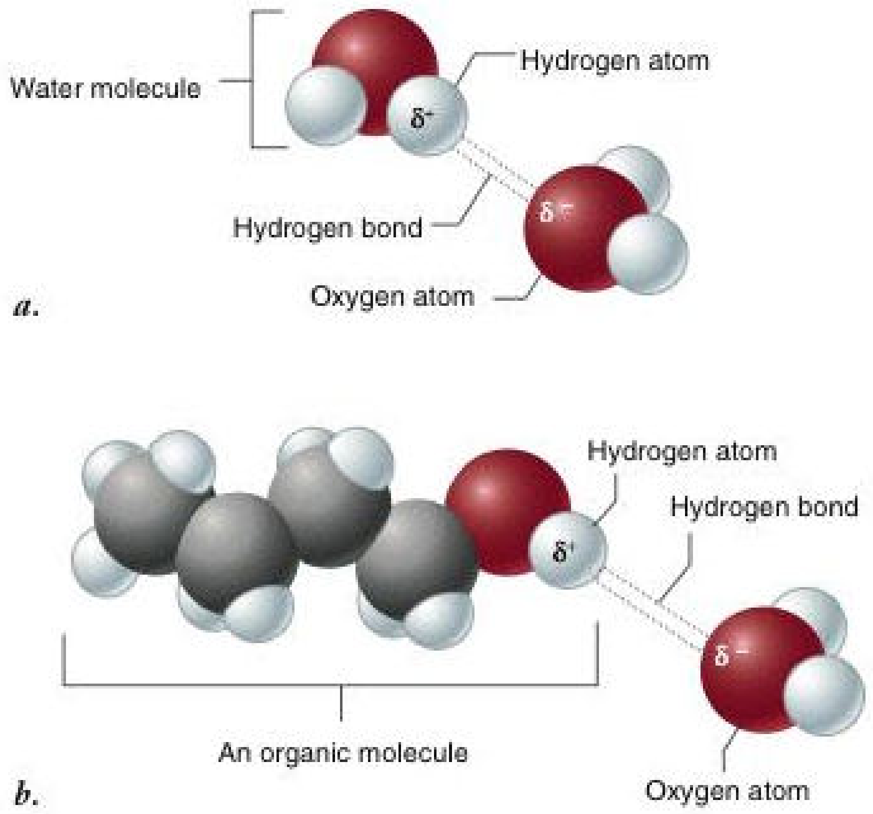

figure 2.11

STRUCTURE OF A HYDROGEN BOND. ***a.*** Hydrogen bond between two water molecules. ***b.*** Hydrogen bond between an organic molecule (*n*-butanol) and water. H in *n*-butanol forms a hydrogen bond with oxygen in water. This kind of hydrogen bond is possible any time H is bound to a more electronegative atom (see table 2.2).

- A Si … o 4 H-
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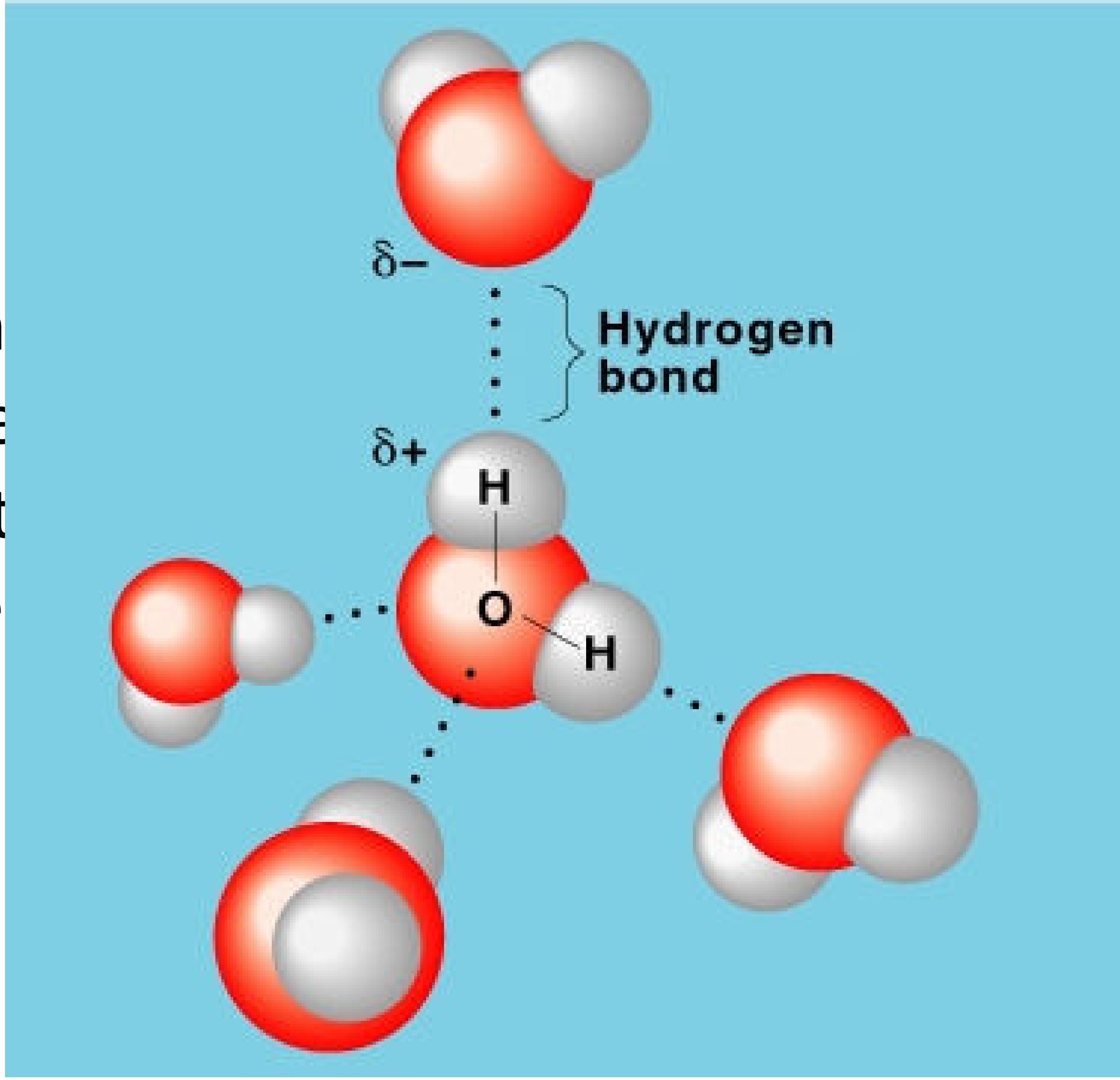
whe … ecules
that … the net
stre …



Water Phase Changes

- When going from a liquid to a gas, H-bonds have to be broken- it requires an increase in energy.
- When Water evaporates is takes energy from the environment, which in turn cools off the environment. (sweating cools us)
- When water freezes, it is releasing energy to the environment.

Solutions

- Ions Disso
- Covalent m nds with each othe and separate i (dissolving sugar in w ule gets surrounde molecules)

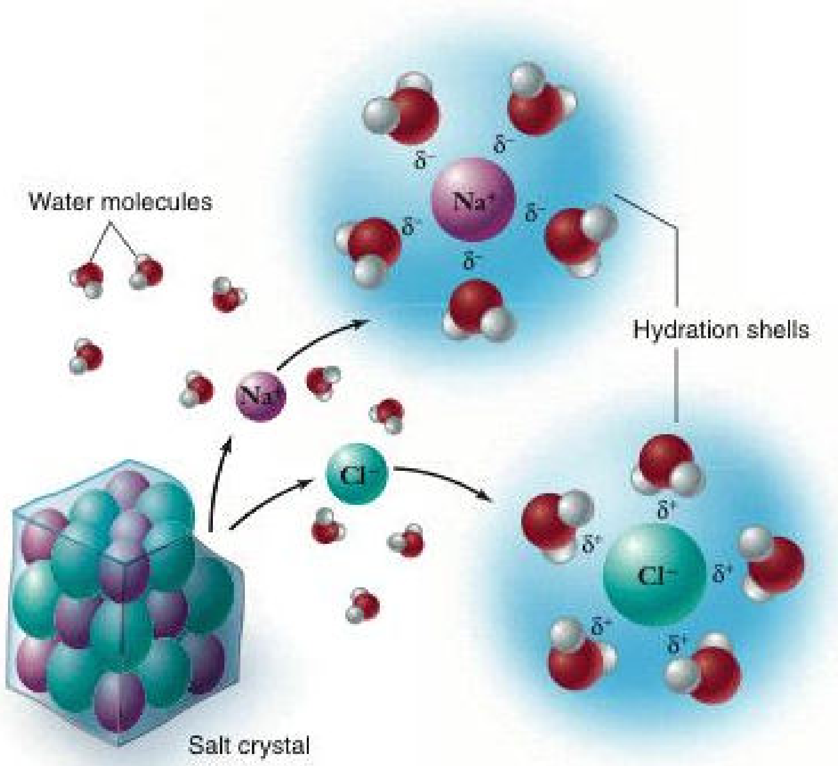


figure 2.14

WHY SALT DISSOLVES IN WATER. When a crystal of table salt dissolves in water, individual Na^+ and Cl^- ions break away from the salt lattice and become surrounded by water molecules. Water molecules orient around Cl^- ions so that their partial positive poles face toward the negative Cl^- ion; water molecules surrounding Na^+ ions orient in the opposite way, with their partial negative poles facing the positive Na^+ ion. Surrounded by hydration shells, Na^+ and Cl^- ions never reenter the salt lattice.