Chapter 2

The Chemical Context of Life

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PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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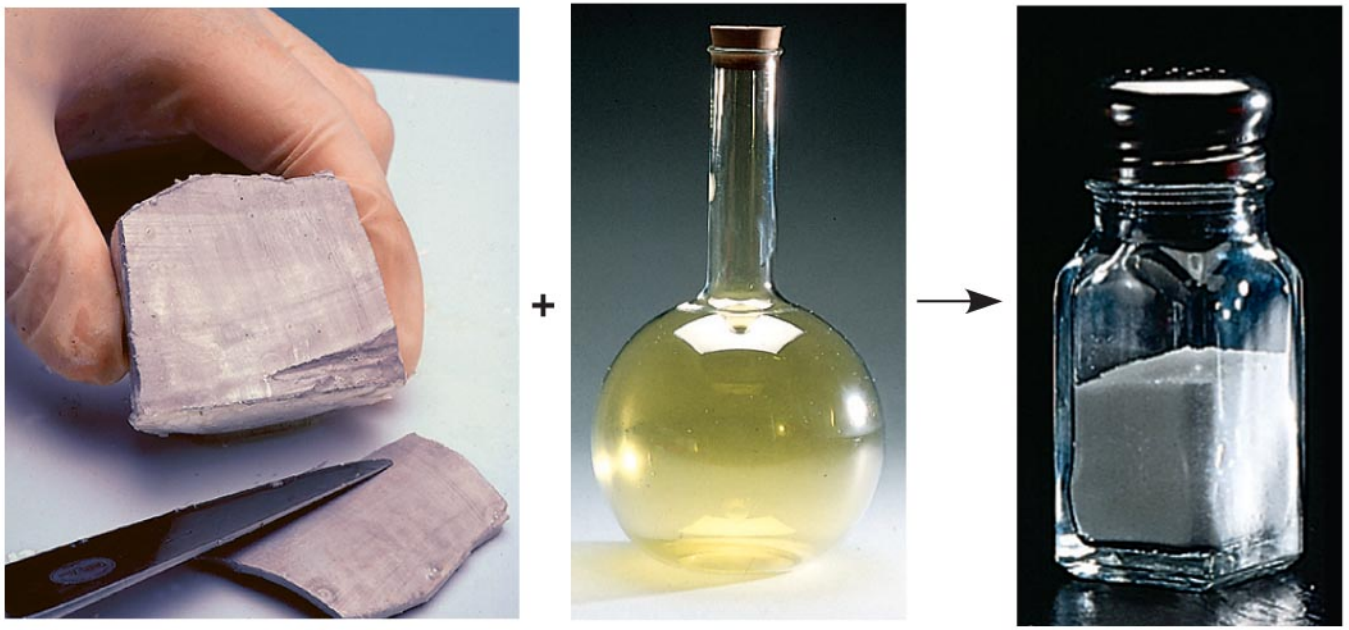
Learning objectives:

1. Identify the four major elements
2. Distinguish between the following pairs of terms: neutron and proton, atomic number and mass number, atomic weight and mass number
3. Distinguish between and discuss the biological importance of the following: nonpolar covalent bonds, polar covalent bonds, ionic bonds, hydrogen bonds, and van der Waals interactions

Concept 2.1: Matter consists of chemical elements in pure form and in combinations called compounds

- Organisms are composed of **matter**
- Matter is anything that takes up space and has mass



Elements -fundamental forms of matter

- cannot be broken down into anything smaller and still retain the properties of that element

- 92 naturally occurring elements

- many other synthesized elements; typically unstable and short-lived

- living organisms are comprised almost entirely of only 4 elements: oxygen, carbon, hydrogen and nitrogen (>95% of mass)

- many elements are necessary to maintain life; those that are required but occur in minute amounts = trace elements

Essential Elements of Life

Table 2.1 Naturally Occurring Elements in the Human Body

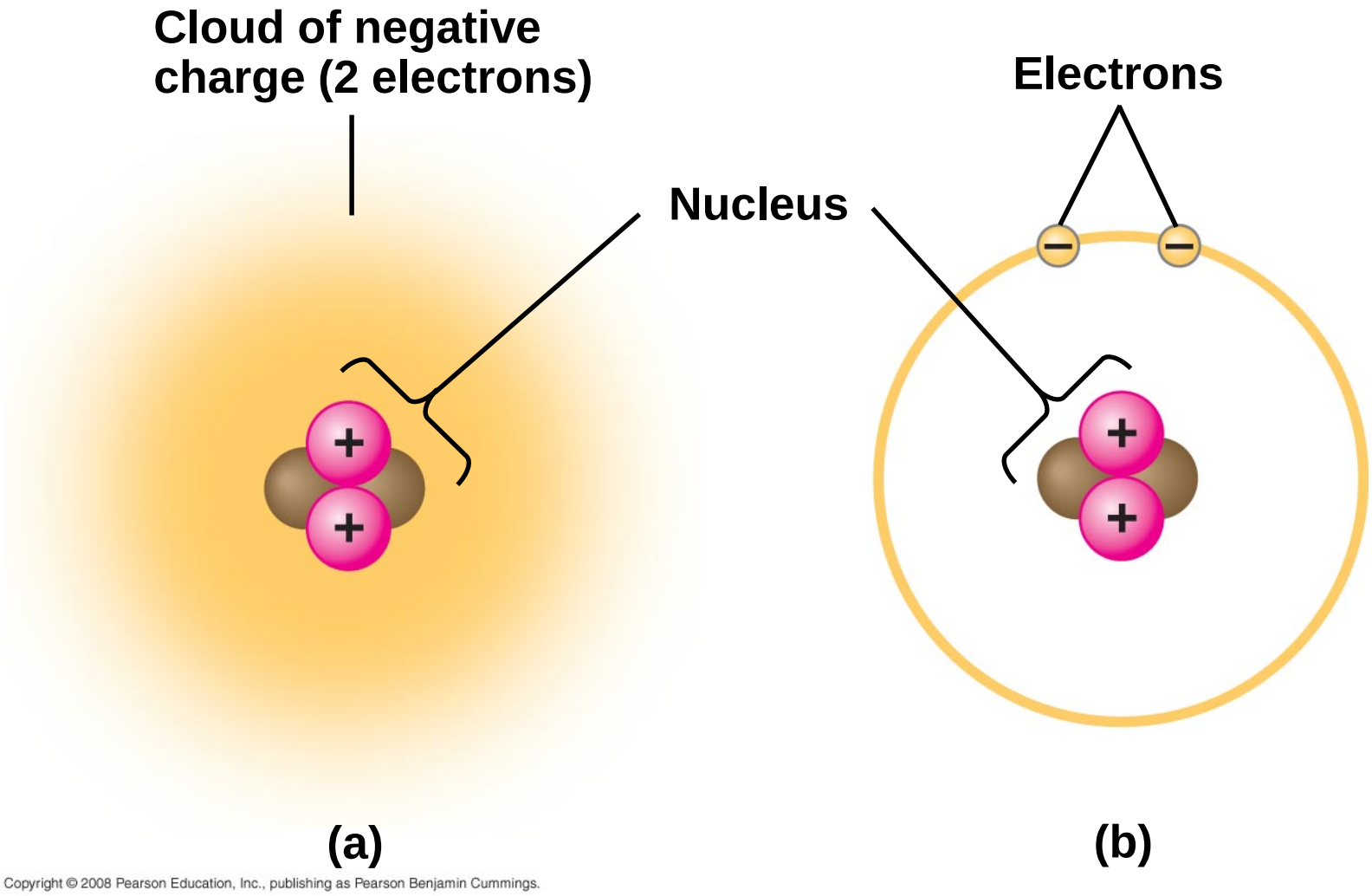
Symbol	Element	Atomic Number (see p. 33)	Percentage of Human Body Weight
Elements making up about 96% of human body weight			
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Elements making up about 4% of human body weight			
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1
Elements making up less than 0.01% of human body weight (trace elements)			
Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)			

Fig. 2-4

(a) Nitrogen deficiency – stunted plant growth

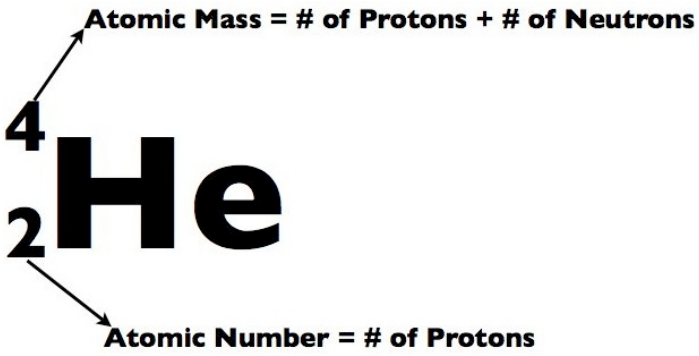
(b) Iodine deficiency – enlarged thyroid gland (goiter)

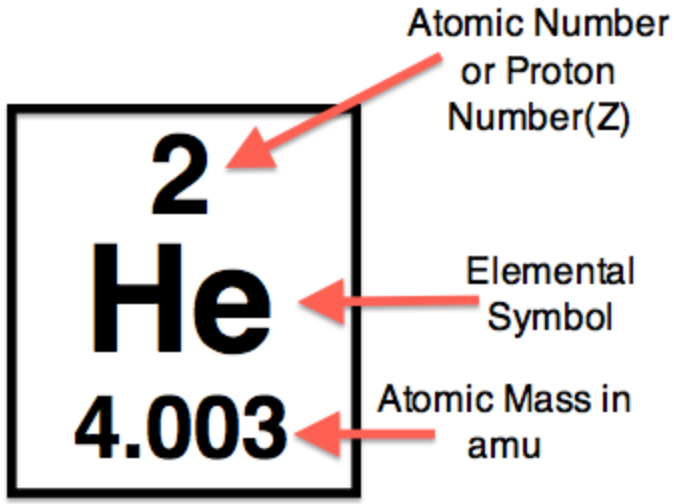
Concept 2.2: An element's properties depend on the structure of its atoms

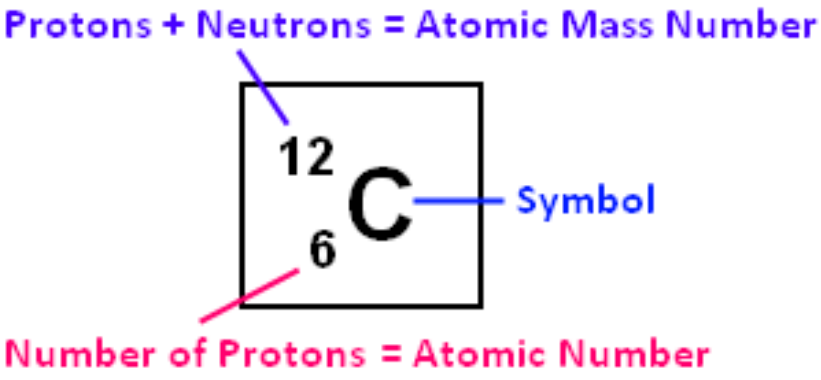


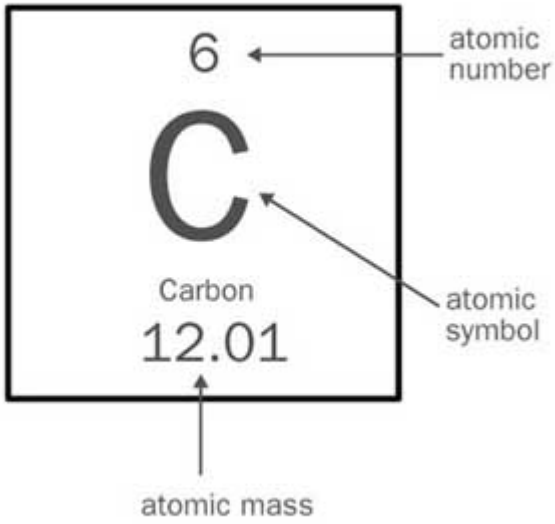
Atomic Number and Atomic Mass

- Atoms of the various elements differ in number of subatomic particles
- An element's **atomic number** is the number of protons in its nucleus (e.g., H = 1, C = 6, O = 8)
- An element's **mass number** is the sum of protons plus neutrons in the nucleus (e.g., H = 1, C = 12, O = 16)
- **Atomic mass**, the atom's total mass (average mass of all isotopes), can be approximated by the mass number


Atomic Mass = # of Protons + # of Neutrons
4
2He
Atomic Number = # of Protons

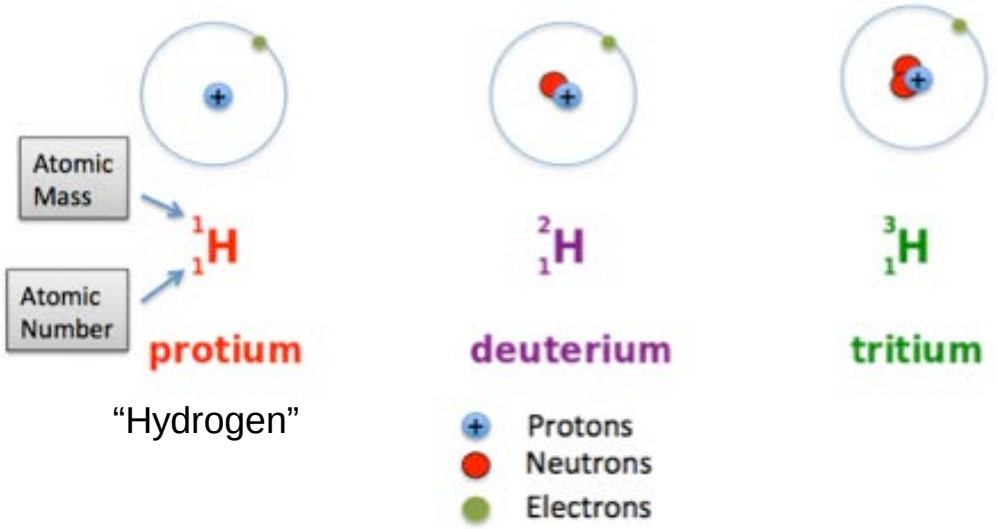

Atomic Number or Proton Number(Z)
2
He
4.003
Elemental Symbol
Atomic Mass in amu


Protons + Neutrons = Atomic Mass Number
12
C
6
Symbol
Number of Protons = Atomic Number


6
atomic number
C
Carbon
12.01
atomic symbol
atomic mass

Isotopes

- All atoms of an element have the same number of protons but may differ in number of neutrons
- **Isotopes** are two atoms of an element that differ in number of neutrons (e.g., ^{14}C has 6 protons and 8 neutrons)

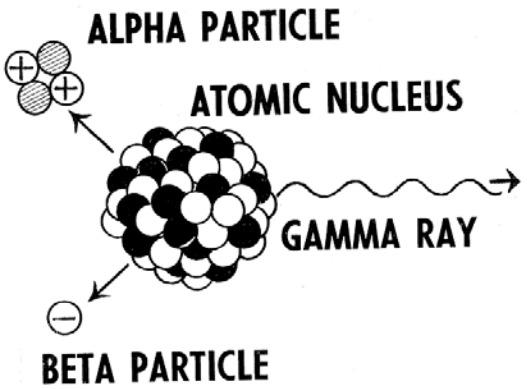


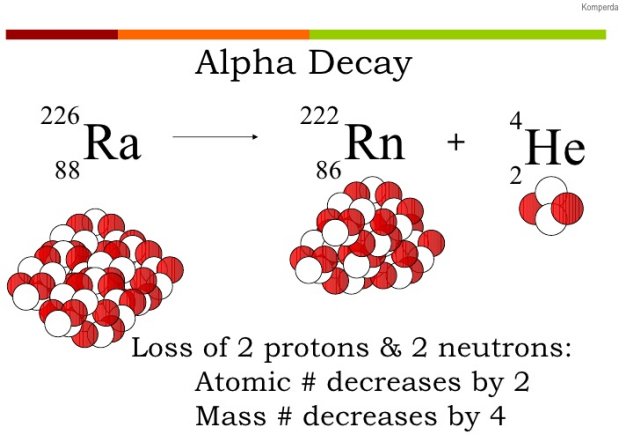
"Hydrogen"

Isotopes

Radioactive isotopes decay spontaneously, giving off particles and energy

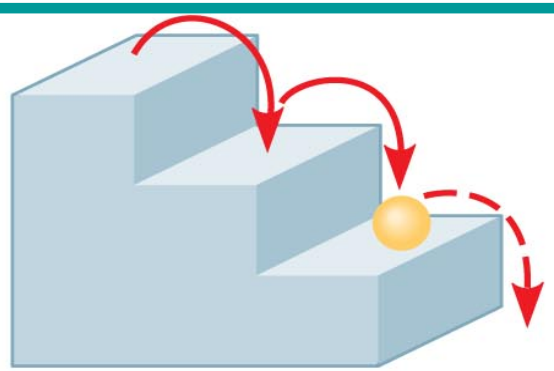
- alpha particle (helium nucleus, no electrons)
- beta particle (high energy electrons)
- gamma rays (high energy EM radiation)

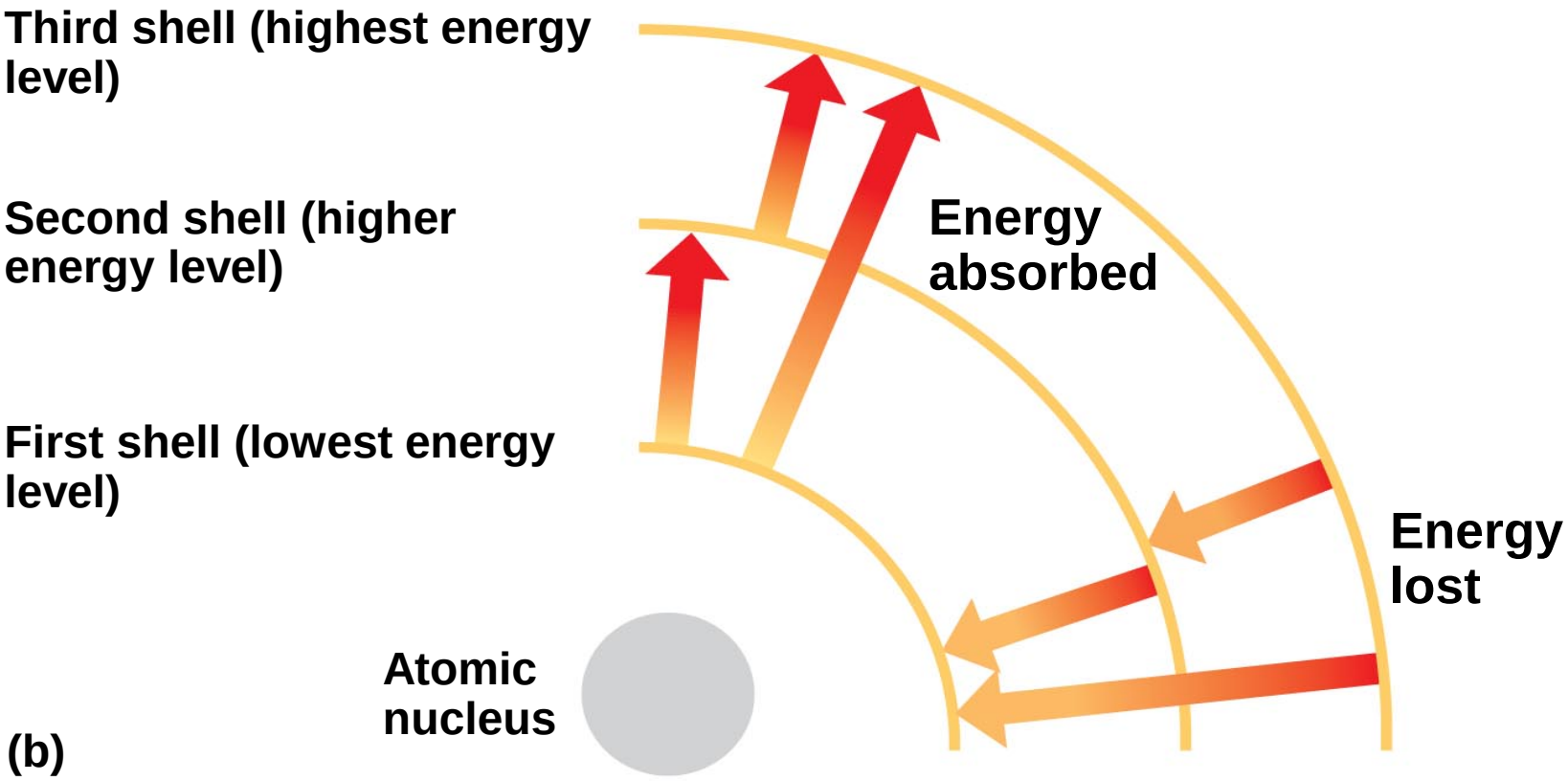




The Energy Levels of Electrons

(a) A ball bouncing down a flight of stairs provides an analogy for energy levels of electrons





- - electrons circle the atomic nucleus (protons + neutrons) in regions called orbitals
- - orbital - region of space around the nucleus where the probability of finding and electron is high
- - no more than 2 electrons can occupy any given orbital
- - orbitals are arranged in “shells” around the atomic nucleus
  - - if there is more than one orbital in a shell, the orbitals are divided within subshells
- - each successive shell has a higher energy level than the previous shell
- - an electron “vacancy” in the outermost shell means that a atom may lose, gain or share electrons to form a chemical bond

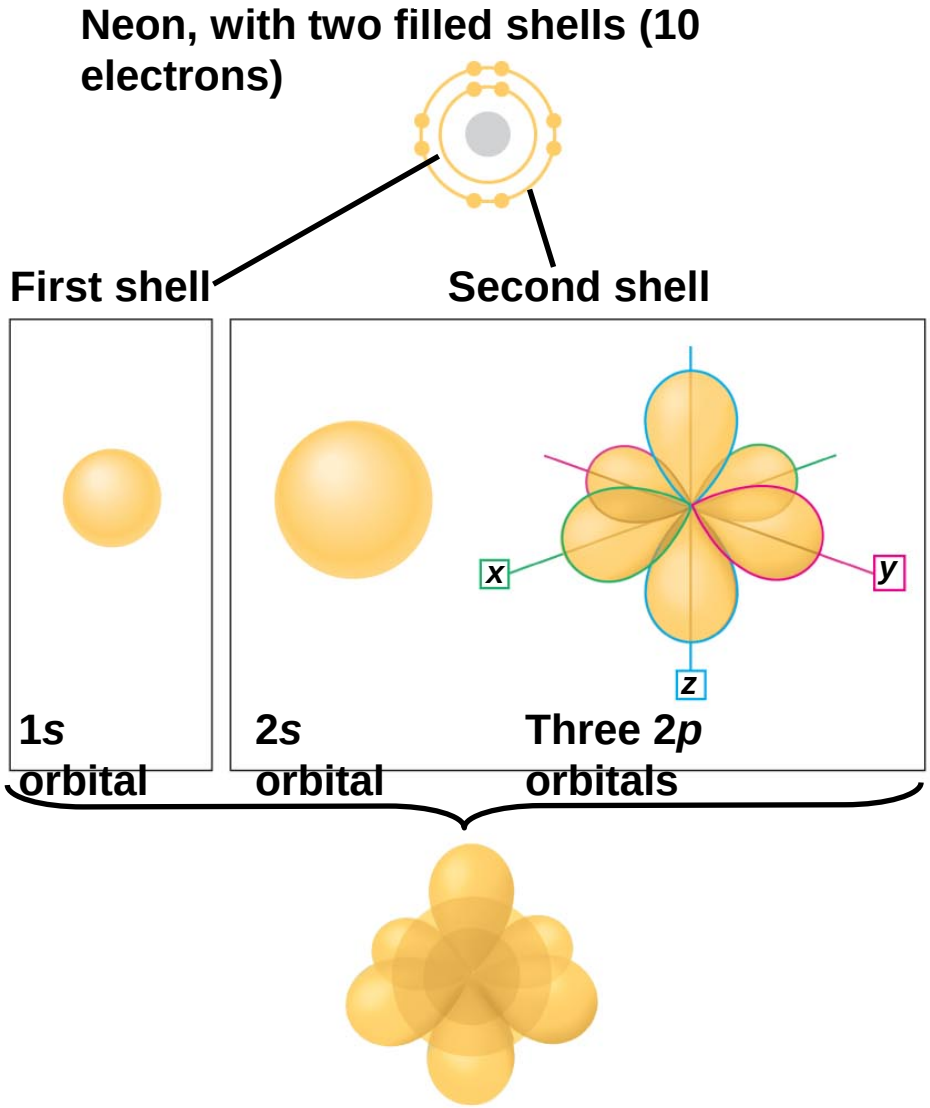
Electron Orbitals

Subshells	Maximum number of Electrons
s	2
p	6
d	10
f	14

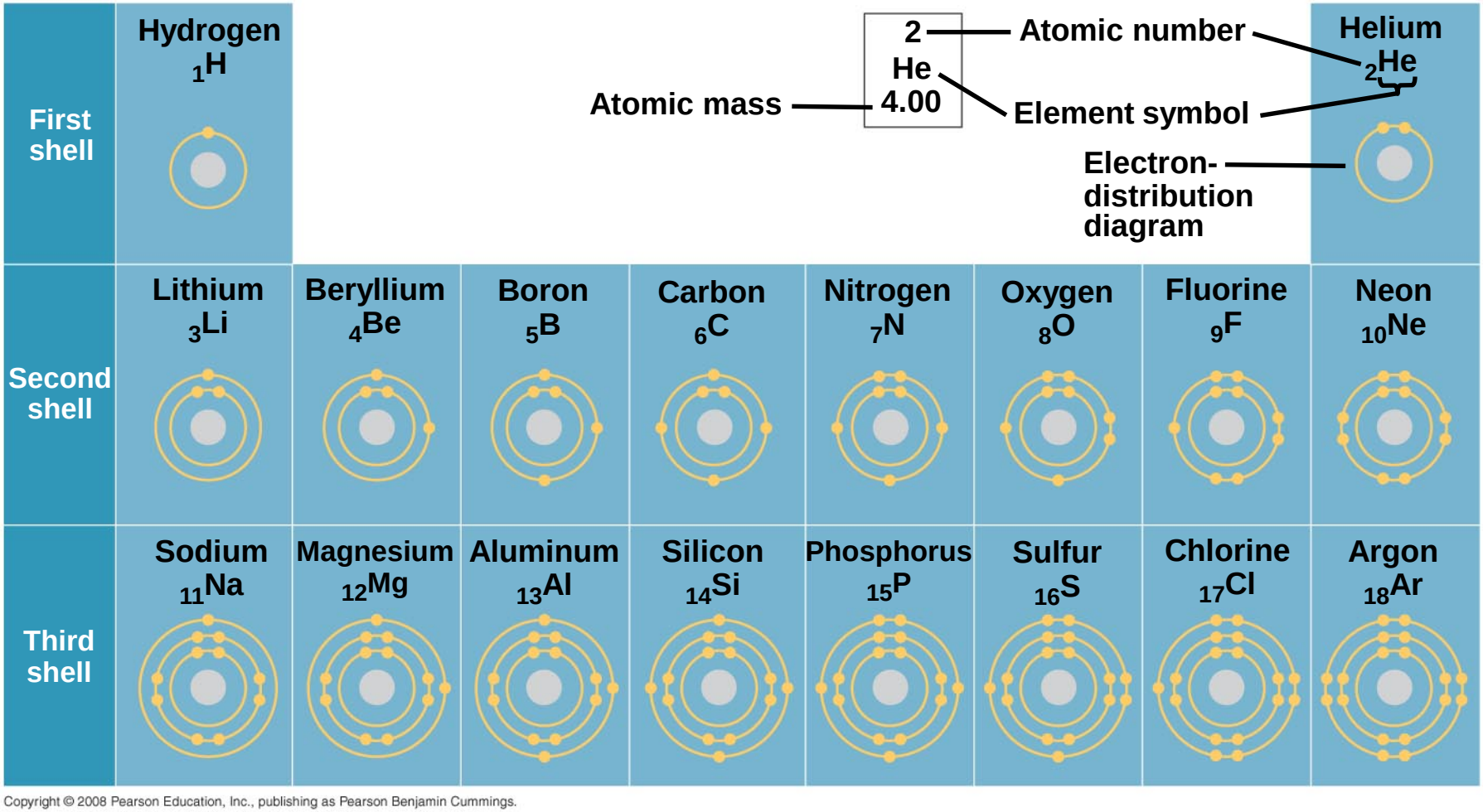
(a) Electron-distribution diagram

(b) Separate electron orbitals

(c) Superimposed electron orbitals



Electron Distribution and Chemical Properties



How can you tell how many electrons an atom has?

What do elements with atomic numbers 6 and 14 have in common?

A. same number of electrons

B. same atomic mass

C. same valence (outermost electrons)

D. will form the same number of bonds

How many chemicals bonds are possible for Be and Mg?

a. 2 b. 4 c. 10 d. 12

Concept 2.3: The formation and function of molecules depend on chemical bonding between atoms

- Atoms with incomplete valence shells (outermost) can share or transfer valence electrons with certain other atoms
- These interactions usually result in atoms staying close together, held by attractions called **chemical bonds**

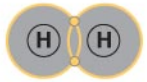
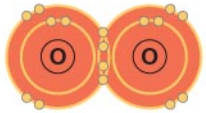
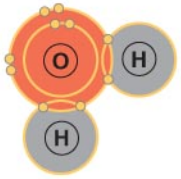
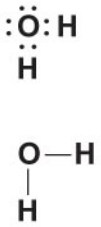
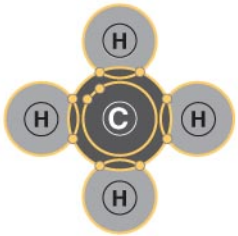
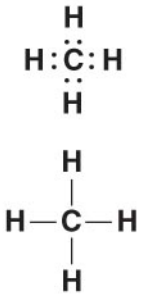
Chemical Bonds

- - a sharing of electrons between two or more atoms or ions
- - molecule - two or more atoms bonded together
- - compound - a molecule of two or more atoms bonded together that never changes its proportions (e.g., water, sucrose, amino acids)
- - mixture - two or more element (molecules, compounds) that intermingle in varying proportions (e.g., sucrose and water; the ocean; the atmosphere)

Types of Chemical Bonds
- ionic, covalent, hydrogen

- Covalent Bonds
- - two atoms with unpaired electrons in their outermost orbitals will attract each other
- - atoms share two or more **pairs** of electrons
- - strongest of the 3 types of bonds
- - single, double or triple covalent bonds

Covalent Bonds

Name and Molecular Formula	Electron-distribution Diagram	Lewis Dot Structure and Structural Formula	Space-filling Model
(a) Hydrogen (H_2)			
(b) Oxygen (O_2)			
(c) Water (H_2O)			
(d) Methane (CH_4)			

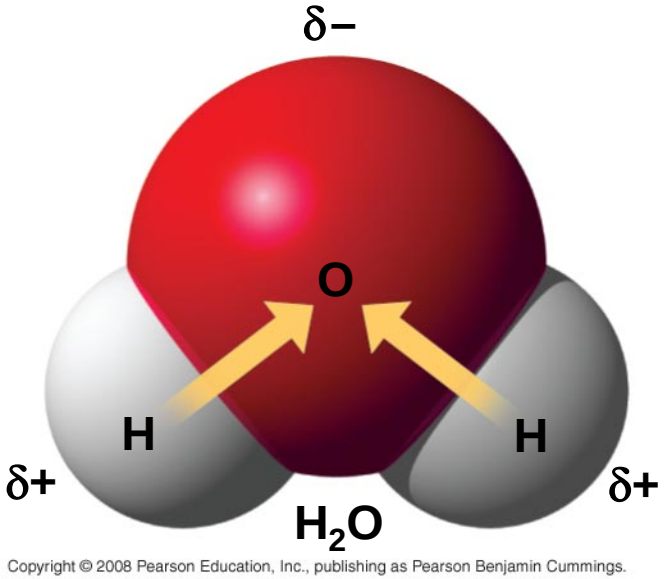
Octet Rule

Types of Chemical Bonds
- ionic, covalent, hydrogen

- Polarity
- - when electrons are shared equally by the atoms, the bond is nonpolar
- - when electrons are shared unequally, the bond is polar
- - atoms of a molecule with a polar covalent bond have partial positive and negative charges; the molecule is neutral in charge

Electronegativity

Fig. 2-13

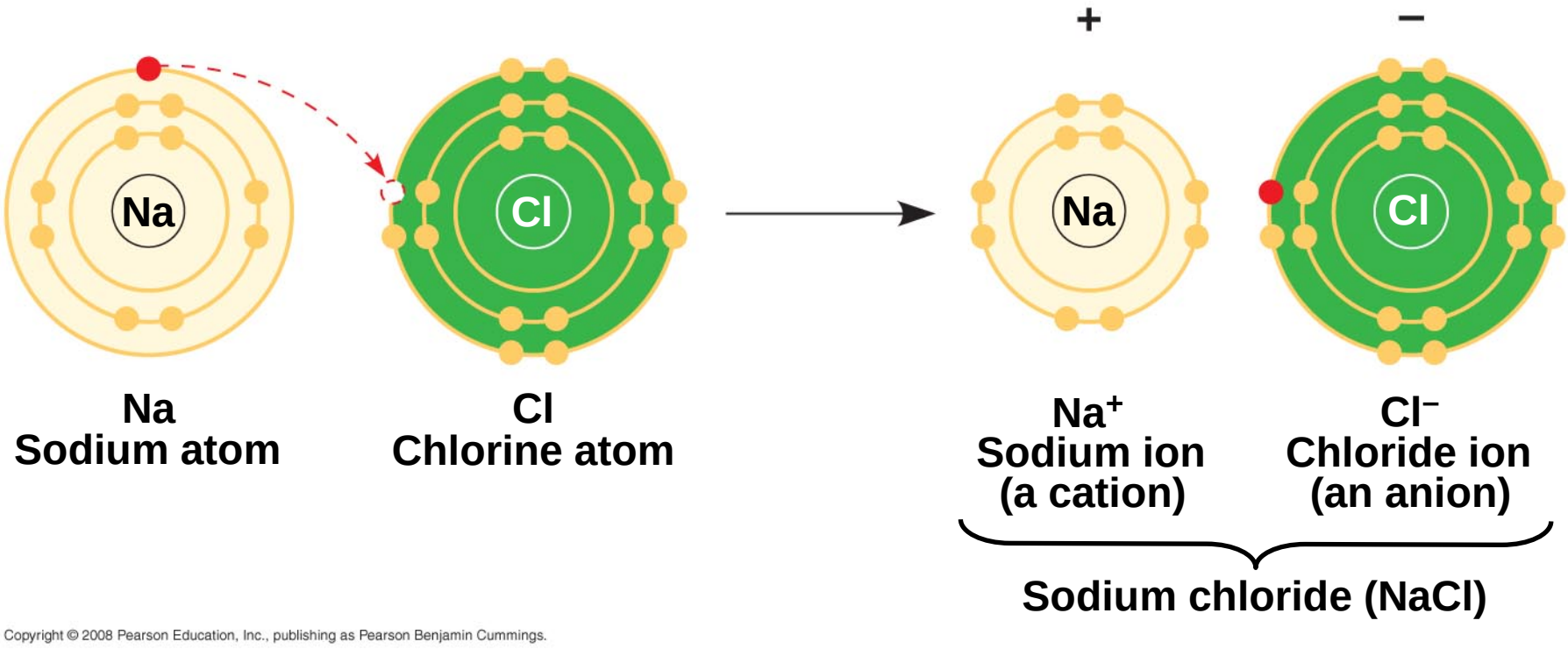


Electronegativity is the tendency of an atom to attract electrons towards itself.

Ionic Bonds

- - ion = an atom that loses or gains an electron develops a net positive or negative charge
- - two ions with opposing charges attract and associate with each other = ionic bond

Ionic Bonds



https://www.dailymotion.com/video/xhqakl

Based on the periodic table shown here, which elements will most likely form an ionic bond, a polar covalent bond, and a covalent bond?

A. Na and Cl

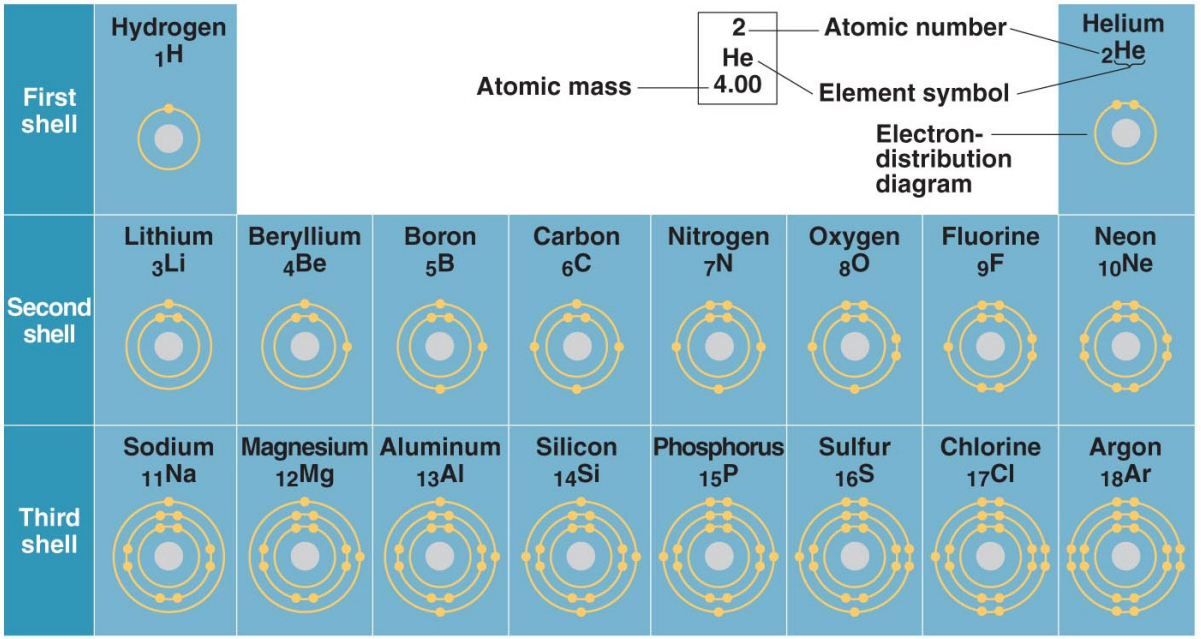
B. Li and F

C. C and O

D. N and O

E. Si and Cl

F. H and H

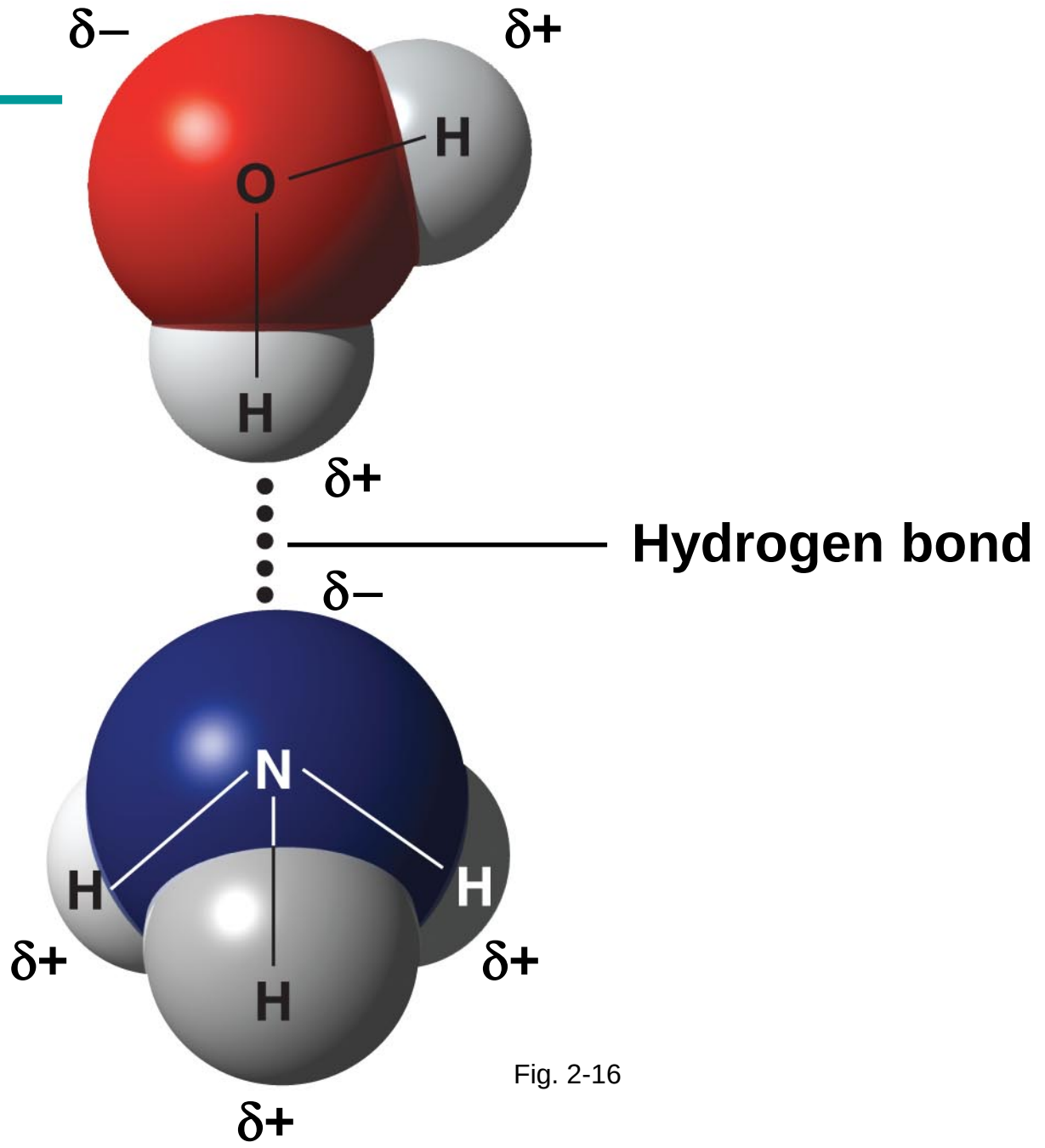


Hydrogen Bonds

- - partially charged atoms with polar covalent bonds attract other oppositely partially charged atoms also with polar covalent bonds
- - usually form between H’s and N’s and H’s and O’s
- - can form within same molecule (e.g., DNA)

Hydrogen Bonds

Water (H_2O)



Ammonia (NH_3)

Fig. 2-16

Weak Chemical Bonds

- Most of the strongest bonds in organisms are covalent bonds that form a cell's molecules
- Weak chemical bonds, such as ionic bonds and hydrogen bonds, are also important
- Weak chemical bonds reinforce shapes of large molecules and help molecules adhere to each other

Van der Waals Interactions

- If electrons are distributed asymmetrically in molecules or atoms, they can result in “hot spots” of positive or negative charge
- **Van der Waals interactions** are attractions between molecules that are close together as a result of these charges

Water is a polar molecule because of the presence of _____ bonds.

A. ionic

B. covalent

C. polar covalent

D. hydrogen

Molecular Shape and Function

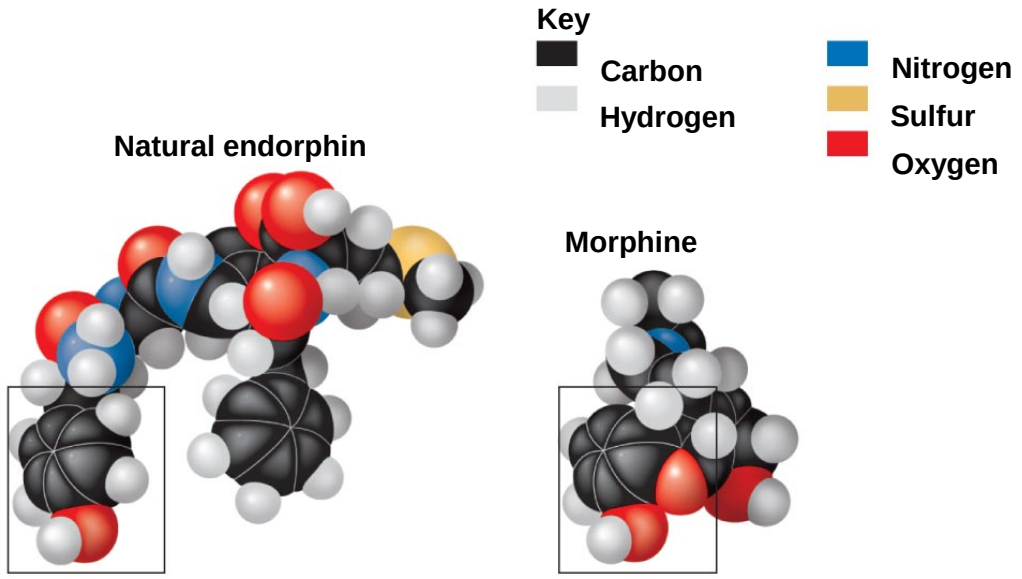
- Each molecule has a characteristic size and shape that determines its function in the living cell.

- The shapes of molecules are determined by the positions of the atoms' orbitals.

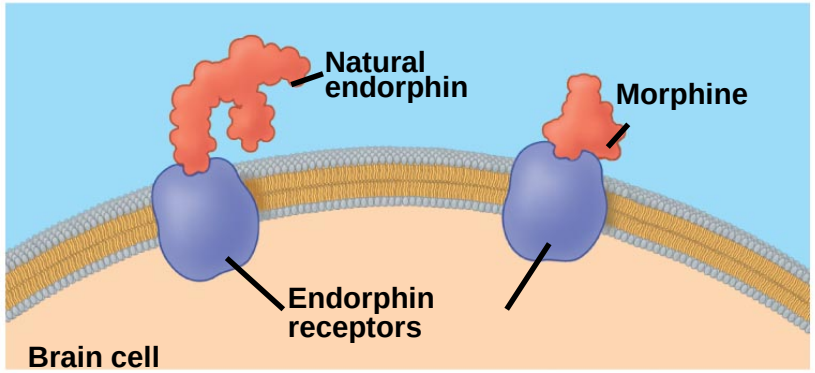
- Molecular shape determines how most molecules recognize and respond to each other.

- Examples: signaling molecules and their receptors, substrates and their enzymes

Molecular Shape and Function



(a) Structures of endorphin and morphine



(b) Binding to endorphin receptors

Fig. 2-18

Concept 2.4: Chemical reactions make and break chemical bonds

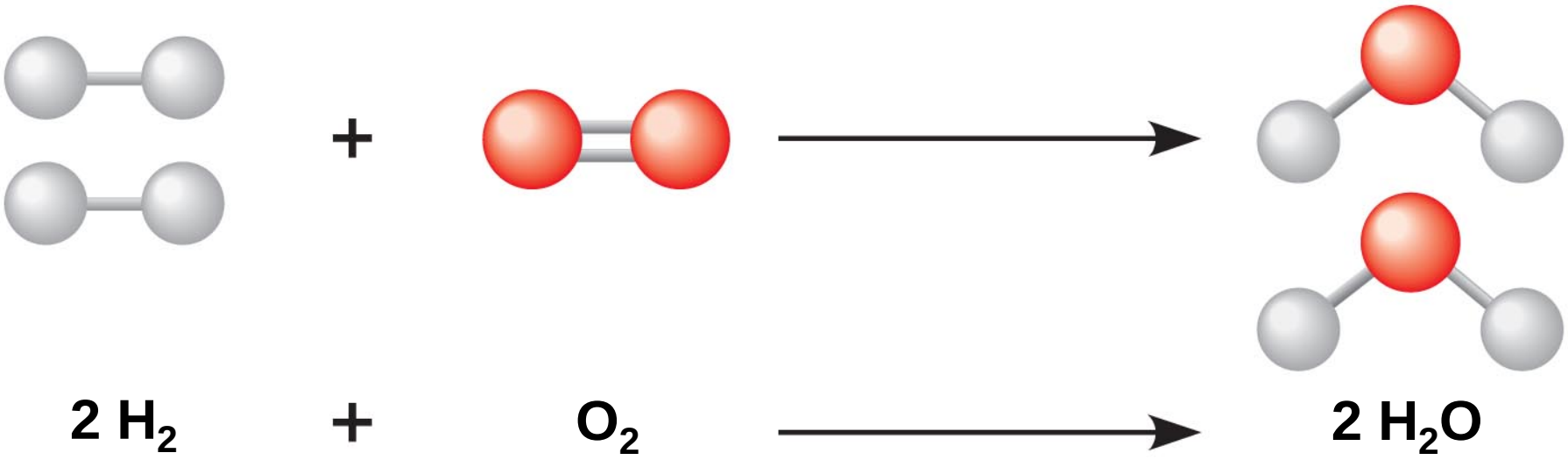
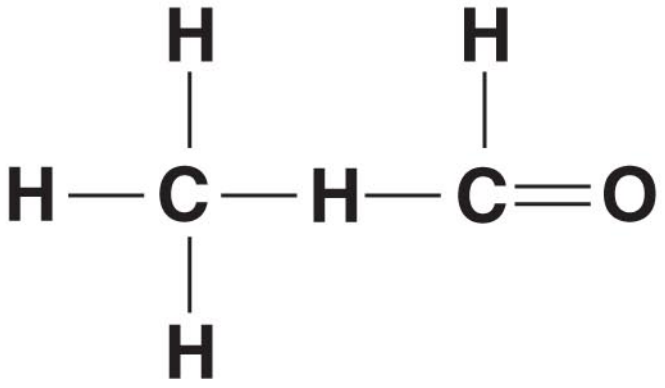
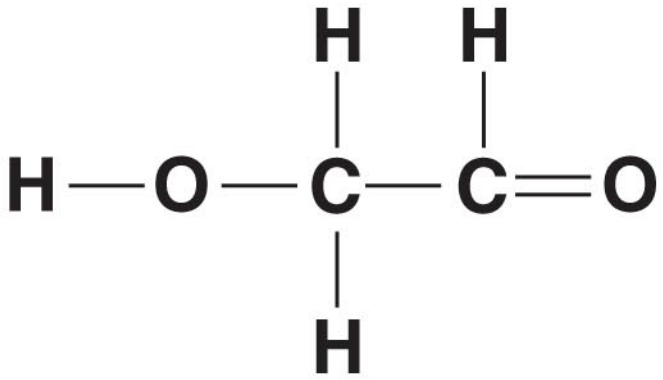


Fig. 2-UN2

Explain why each chemical structure is or is not correct.

a. 

c. 



b.

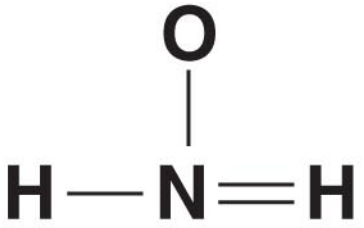
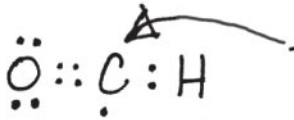
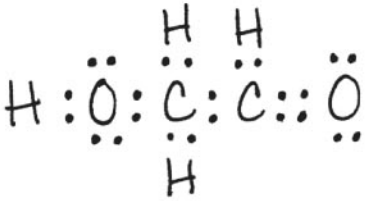
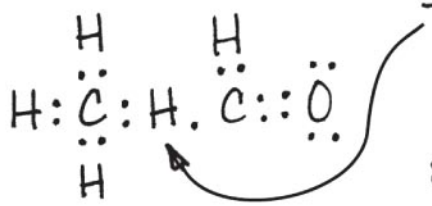
d. 

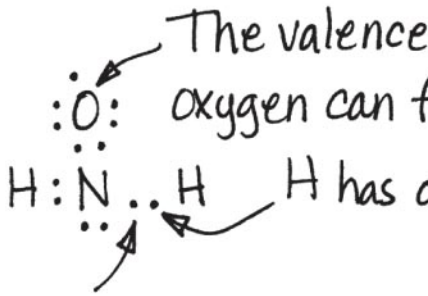
Fig. 2-UN11

a.  This structure doesn't make sense because the valence shell of carbon is incomplete; carbon can form 4 bonds.

b.  This structure makes sense because all valence shells are complete, and all bonds have the correct number of electrons.

c.  This structure doesn't make sense because H has only 1 electron to share, so it cannot form bonds with 2 atoms.

d. This structure doesn't make sense for several reasons:



Nitrogen usually makes only 3 bonds. It does not have enough electrons to make 2 single bonds, make a double bond, and complete its valence shell.