


Chapter 2.

The Chemical Context of Life



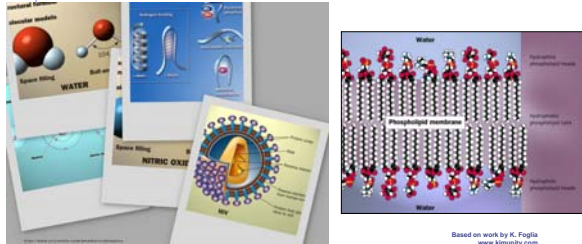
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Based on work by K. Foglia
www.kimolby.com

Molecular formula H_2O
Structural formula $H-O-H$
Molecular models
Space-filling Ball-and-stick
WATER

Why are we studying chemistry?

- **Biology has chemistry at its foundation**




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The Basics

- **Everything is made of matter**
- **Matter is made of atoms**
- **Atoms are made of:**
 - ♦ protons + mass of 1 nucleus
 - ♦ neutrons 0 mass of 1 nucleus
 - ♦ electrons - mass <<1 orbits
- **Different kinds of atoms = elements**



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The World of Elements

Periodic Table of the Elements

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Models of atoms

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Atomic structure determines behavior

- The number of protons in an atom determines the element
 - ◆ # of protons = atomic number
 - ◆ this also tells you # of electrons
- All atoms of an element have same chemical properties
 - ◆ all behave the same
 - ◆ properties don't change

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Life requires ~25 chemical elements

- About 25 elements are essential for life
 - ◆ Four elements make up 96% of living matter:
 - carbon (C)
 - oxygen (O)
 - hydrogen (H)
 - nitrogen (N)
 - ◆ Four elements make up most of remaining 4%:
 - phosphorus (P)
 - sulfur (S)
 - calcium (Ca)
 - potassium (K)

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Table 2.1 Naturally Occurring Elements in the Human Body


Symbol	Element	Atomic Number (See p. 29)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
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

Trace elements (less than 0.01%): 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), and zinc (Zn).

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Isotopes

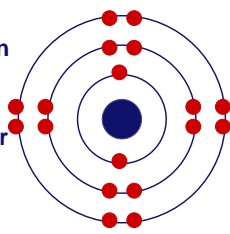
- Different number of neutrons (heavier)
- Some are unstable
 - ◆ nuclear reactions / decay
- Split off neutrons &/or protons
 - ◆ radioactivity
- Biological tool
- Biological hazard



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Bonding properties

- Effect of electrons
 - chemical behavior of an atom depends on its electron arrangement
 - depends on the number of electrons in its outermost shell, the valence shell

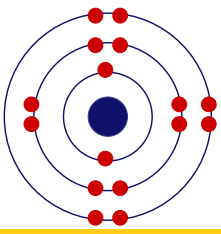
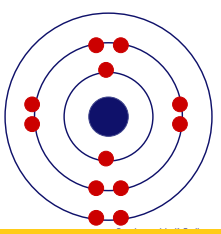


How does this atom behave?

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Bonding properties

- Effect of electrons
 - chemical behavior of an atom depends on number of electrons in its outermost shell

How does this atom behave? How does this atom behave?

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Elements & their valence shells

Elements in the same row have the same number of shells

First shell	Hydrogen ${}^1_1\text{H}$							Helium ${}^2_2\text{He}$
Second shell	Lithium ${}^3_3\text{Li}$	Beryllium ${}^4_4\text{Be}$	Boron ${}^5_5\text{B}$	Carbon ${}^6_6\text{C}$	Nitrogen ${}^7_7\text{N}$	Oxygen ${}^8_8\text{O}$	Fluorine ${}^9_9\text{F}$	Neon ${}^{10}_{10}\text{Ne}$
Third shell	Sodium ${}^{11}_{11}\text{Na}$	Magnesium ${}^{12}_{12}\text{Mg}$	Aluminum ${}^{13}_{13}\text{Al}$	Silicon ${}^{14}_{14}\text{Si}$	Phosphorus ${}^{15}_{15}\text{P}$	Sulfur ${}^{16}_{16}\text{S}$	Chlorine ${}^{17}_{17}\text{Cl}$	Argon ${}^{18}_{18}\text{Ar}$

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Elements & their valence shells

■ Elements in the same column have the same valence & similar chemical properties

First shell	Hydrogen ${}_1\text{H}$							Helium ${}_2\text{He}$
Second shell	Lithium ${}_3\text{Li}$	Beryllium ${}_4\text{Be}$	Boron ${}_5\text{B}$	Carbon ${}_6\text{C}$	Nitrogen ${}_7\text{N}$	Oxygen ${}_8\text{O}$	Fluorine ${}_9\text{F}$	Neon ${}_{10}\text{Ne}$
Third shell	Sodium ${}_{11}\text{Na}$	Magnesium ${}_{12}\text{Mg}$	Aluminum ${}_{13}\text{Al}$	Silicon ${}_{14}\text{Si}$	Phosphorus ${}_{15}\text{P}$	Sulfur ${}_{16}\text{S}$	Chlorine ${}_{17}\text{Cl}$	Argon ${}_{18}\text{Ar}$

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Elements & their valence shells

■ Moving from left to right, each element has a sequential addition of electrons (and protons)

First shell	Hydrogen ${}_1\text{H}$							Helium ${}_2\text{He}$
Second shell	Lithium ${}_3\text{Li}$	Beryllium ${}_4\text{Be}$	Boron ${}_5\text{B}$	Carbon ${}_6\text{C}$	Nitrogen ${}_7\text{N}$	Oxygen ${}_8\text{O}$	Fluorine ${}_9\text{F}$	Neon ${}_{10}\text{Ne}$
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Chemical reactivity

- Atoms tend to
 - ◆ Complete a partially filled outer (valence) electron shell
 - or
 - ◆ Empty a partially filled outer (valence) electron shell
- ◆ **This tendency drives chemical reactions**

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Ionic bonds

Na Sodium atom Cl Chlorine atom

Na⁺ Sodium ion (a cation) Cl⁻ Chloride ion (an anion)

Sodium chloride (NaCl)

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Ionic bonds

“Let’s go to the video tape!”
[\[play movie here\]](#)

- Transfer of an electron
- Forms + & - ions
 - ◆ + = cation
 - ◆ - = anion
- Weak bond

example:
◆ salt = dissolves easily in water

Na Sodium atom Cl Chlorine atom

Na⁺ Sodium ion (a cation) Cl⁻ Chloride ion (an anion)

Sodium chloride (NaCl) by K. Foglia
www.kimnabty.com

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Covalent bonds

- Two atoms need an electron
- Share a pair of electrons
- Strong bond
 - ◆ both atoms holding onto the electrons
- Forms molecules

H₂ (H) (H) H—H

(a) Hydrogen

example:
◆ water = takes energy to separate

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Double covalent bonds

- Two atoms can share more than one pair of electrons
 - double bonds (2 pairs of electrons)
 - triple bonds (3 pairs of electrons)
- Very strong bonds**

(b) Oxygen

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Multiple covalent bonds

- 1 atom can form covalent bonds with two or more other atoms
 - forms larger molecules
 - ex. **carbon**

(d) Methane

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Polar covalent bonds

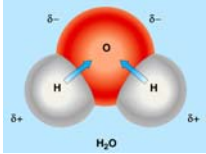
- Pair of electrons not shared equally by 2 atoms
- Water = O + H
 - oxygen has stronger "attraction" for the shared electrons than hydrogen
 - oxygen has higher electronegativity

H₂O

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Polar covalent bonds

- 2 hydrogens in the water molecule form an angle
- Water molecule is **polar**
 - oxygen end is -
 - hydrogen end is +
- Leads to many interesting properties of water....

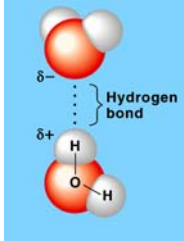


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Hydrogen bonds

- Positive H atom in 1 water molecule is attracted to negative O in another
- Can occur wherever an -OH exists in a larger molecule
- Weak** bonds



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Reductionist view of biology

- Matter is made of atoms
- Life requires ~25 chemical elements
- Atomic structure determines behavior of an element
- Atoms combine by chemical bonding to form molecules
- Weak chemical bonds play important roles in chemistry of life
- A molecule's biological function is related to its shape
- Chemical reactions make & break chemical bonds

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