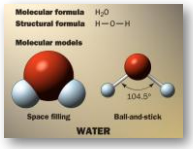
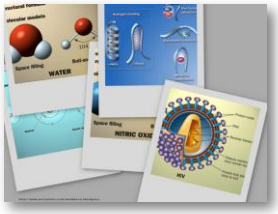
Basics of Chemistry

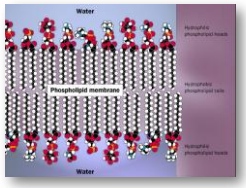


What? You thought you were all done with the Periodic Table?
NEVER!

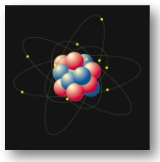
Why are we studying chemistry?

- Biology has chemistry at its foundation



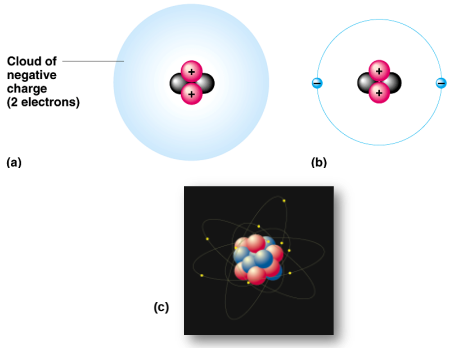


The Basics



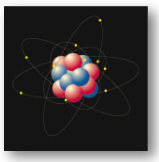
- Everything is made of matter
- Matter is made of atoms
- Atoms are made of:
  - protons + mass of 1 nucleus
  - neutrons 0 mass of 1 nucleus
  - electrons - mass << 1 orbits
- Different kinds of atoms = elements

Models of atoms



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



Life requires ~25 chemical elements

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

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

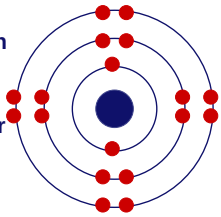
Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

Isotopes

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

Bonding properties

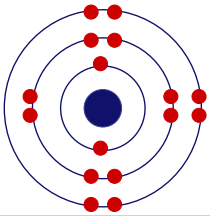
- Effect of electrons
  - chemical behavior of an atom depends on its electron arrangement
  - depends on the number of electrons in its outermost shell, the valence shell



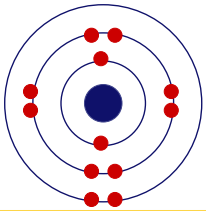
How does this atom behave?

Bonding properties

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

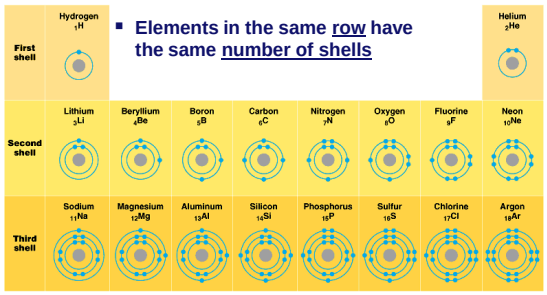


How does this atom behave?



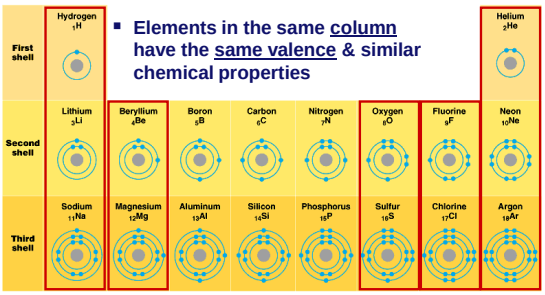
How does this atom behave?

Elements & their valence shells



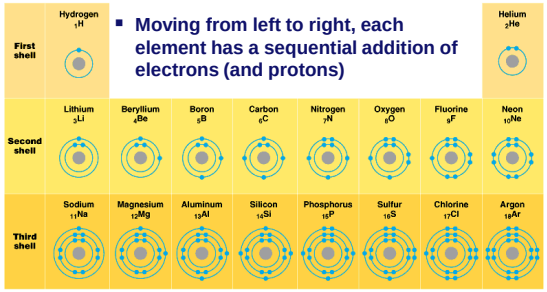
- Elements in the same row have the same number of shells

Elements & their valence shells



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

Elements & their valence shells



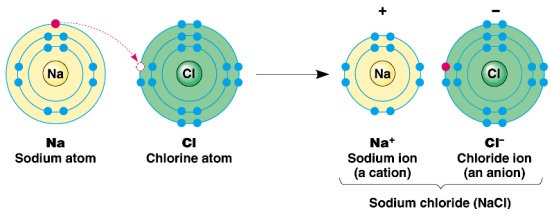
- Moving from left to right, each element has a sequential addition of electrons (and protons)

Chemical reactivity

- Atoms tend to
  - Complete a partially filled outer (valence) electron shell
  - Empty a partially filled outer (valence) electron shell

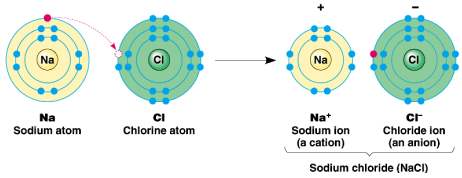
This tendency drives chemical reactions!

Ionic bonds



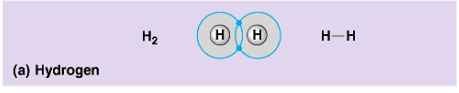
Ionic bonds

- Transfer of an electron
- Forms + & - ions
  - + = cation
  - − = anion
- Weak bond
- example:
  - salt = dissolves easily in water



Covalent bonds

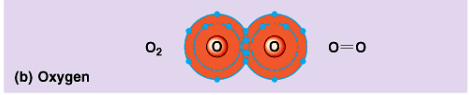
- Two atoms need an electron
- Share a pair of electrons
- Strong bond
  - both atoms holding onto the electrons
- Forms molecules



- example:
  - water = takes energy to separate

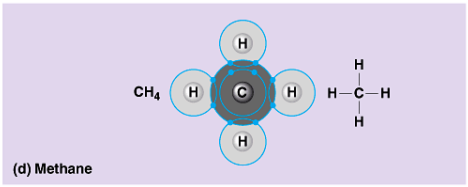
Double covalent bonds

- 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



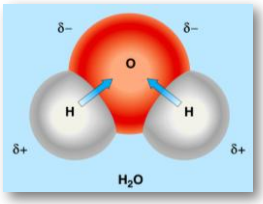
Multiple covalent bonds

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



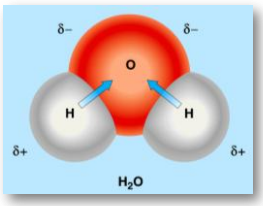
Polar covalent bonds

- 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



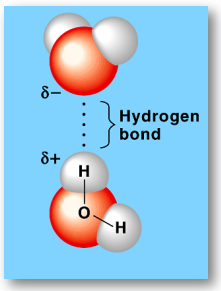
Polar covalent bonds

- 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….



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



Van der Waals forces

- Interactions between nonpolar substances
- Due to random variations in the electron distribution of a molecule
- Very weak forces

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