PowerLecture:
Chapter 2
Life's Chemical Basis
Section 2.0: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.0 : Elements in the Human Body

- Section 2.0 : Name That Element! *Science World*—A Series of Short Articles

How Would You Vote?

The following is the question for this chapter. See national results below.

- Would you support adding fluoride to your community's water supply?

Impacts, Issues: What Are You Worth?

- Each of us is a collection of elements
- Elements are fundamental substances that consist of only one kind of atom
- An atom is the smallest unit of an element that still retains the element's properties

Impacts, Issues: What Are You Worth?

- Proportions of the most common elements in a human body, Earth's crust, and seawater

Section 2.1: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.1: A Look Inside the Atom

- Section 2.1: Dmitri Mendeleev Online

- Section 2.1: Periodic Table of the Elements

- Section 2.1: The Periodic Table and the Electron. Eric Scerri. *American Scientist,* Nov.–Dec. 1997.

- Section 2.1: A Clash of Symbols. Frederic Jueneman. *R & D,* Jan. 1990.

Elements

- Fundamental forms of matter
- Can't be broken apart by normal means
- 92 occur naturally on Earth

Most Common Elements in Living Organisms

Oxygen
Hydrogen
Carbon
Nitrogen

What Are Atoms?

- Smallest particles that retain properties of an element
- Made up of subatomic particles:
  - Protons (+)
  - Electrons (-)
  - Neutrons (no charge)

Atomic Number

- Number of protons
- All atoms of an element have the same atomic number
- Atomic number of hydrogen = 1
- Atomic number of carbon = 6

Mass Number

Number of protons
+
Number of neutrons

Isotopes vary in mass number

Section 2.2: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.2 : Nobel Foundation—The Curies

- Section 2.2 : Society of Nuclear Medicine

- Section 2.2 : Let's Play PET (Positron Emission Tomography)

- Section 2.2 : Waikato Radiocarbon Dating Lab

- Section 2.2 : The Discovery of Radium. Richard Cavendish. *History Today,* Dec. 1998.

- Section 2.2 : Radionuclide Therapy. Jean-Francois Chatal et al. *The Lancet,* Sept. 11, 1999.

- Section 2.2 : A Clock More Perfect Than Time. Gary Taubes. *Discover,* Dec. 1996.

Isotopes

- Atoms of an element with different numbers of neutrons (different mass numbers)
- Carbon 12 has 6 protons, 6 neutrons
- Carbon 14 has 6 protons, 8 neutrons

Radioisotopes

- Have an unstable nucleus that emits energy and particles
- Radioactive decay transforms radioisotope into a different element
- Decay occurs at a fixed rate

Radioisotopes as Tracers

- Tracer is substance with a radioisotope attached to it
- Emissions from the tracer can be detected with special devices
- Following movement of tracers is useful in many areas of biology

Radioisotopes in Medicine

- Positron-Emission Tomography (PET) uses radioisotopes to form images of body tissues
  - Patient is injected with tracer and put through a PET scanner
  - Body cells absorb tracer at different rates
  - Scanner detects radiation caused by energy from decay of the radioisotope, and radiation then forms an image
  - Image can reveal variations and abnormalities in metabolic activity

Radioisotopes in Medicine

Other Uses of Radioisotopes

- Drive artificial pacemakers

- Radiation therapy

  Emissions from some radioisotopes can destroy cells. Some radioisotopes are used to kill small cancers.

Section 2.3: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.3: Atom in a Box

- Section 2.3: The Recently Claimed Observation of Atomic Orbitals and Some Related Philosophical Issues. Eric Scerri. *Philosophy of Science*, Sept. 2001.

- Section 2.3: Quantum Mechanics: What It Is and How We Might Use It. *Futuretech*, June 11, 2001.

What Determines Whether Atoms Will Interact?

The number and arrangement of their electrons

Electrons

- Carry a negative charge
- Repel one another
- Are attracted to protons in the nucleus
- Move in orbitals - volumes of space that surround the nucleus

Electron Orbitals

- Orbitals can hold up to two electrons
- Atoms differ in the number of occupied orbitals
- Orbitals closest to nucleus are lower energy and are filled first

Shell Model

- First shell
  - Lowest energy
  - Holds 1 orbital with up to 2 electrons
- Second shell
  - 4 orbitals hold up to 8 electrons

Probability Model

- Each model is a 3-dimensional approximation of an electron orbital (pg 22)

Electron Vacancies

- Unfilled shells make atoms likely to react
- Hydrogen, carbon, oxygen, and nitrogen all have vacancies in their outer shells

Chemical Bonds, Molecules & Compounds

- Bond is union between electron structures of atoms
- Atoms bond to form molecules
- Molecules may contain atoms of only one element - O_2

- Molecules of compounds contain more than one element - H_2O

Chemical Bookkeeping

- Use symbols for elements when writing formulas
- Formula for glucose is $C_6H_{12}O_6$
  - 6 carbons
  - 12 hydrogens
  - 6 oxygens

Chemical Bookkeeping

- Chemical equation shows reaction

Reactants ---> Products

- Equation for photosynthesis:

Section 2.4: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.4: Chemical Bonds

Important Bonds in
Biological Molecules

- Ionic Bonds
- Covalent Bonds
- Hydrogen Bonds

Ion Formation

- Atom has equal number of electrons and protons - no net charge
- Atom loses electron(s), becomes positively charged ion
- Atom gains electron(s), becomes negatively charged ion

Ionic Bonding

- One atom loses electrons, becomes positively charged ion
- Another atom gains these electrons, becomes negatively charged ion
- Charge difference attracts the two ions to each other

Formation of NaCl

- Sodium atom (Na)
  - Outer shell has one electron
- Chlorine atom (Cl)
  - Outer shell has seven electrons
- Na transfers electron to Cl forming Na^+ and Cl^-
- Ions remain together as NaCl

Covalent Bonding

Atoms share a pair or pairs of electrons to fill outermost shell

Nonpolar Covalent Bonds

- Atoms share electrons equally
- Nuclei of atoms have same number of protons
- Example: Hydrogen gas (H-H)

Polar Covalent Bonds

- Number of protons in nuclei of participating atoms is *not* equal
- Electrons spend more time near nucleus with most protons
- Water - Electrons more attracted to O nucleus than to H nuclei

Hydrogen Bonding

- Molecule held together by polar covalent bonds has no *net* charge
- However, atoms of the molecule carry different charges
- Atom in one polar covalent molecule can be attracted to oppositely charged atom in another such molecule

Section 2.5: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.5: Properties of Water
- Section 2.5: Biology of Water
- Section 2.5: Water Science for Schools
- Section 2.5: Shockwave Water Biology
- Section 2.5: Ode to H2O. Graeme Buchan. *Journal of Soil and Water Conservation,* Nov.–Dec. 1996.

- Section 2.5: The Rarest Element. Sidney Perkowitz. *The Sciences,* Jan. 1999.

- Section 2.5: Goldilocks and the Three Planets. Neil de Grasse Tyson. *Natural History,* May 1999.

Properties of Water

- Polarity
- Temperature-Stabilizing
- Solvent
- Cohesive

Water Is a Polar Covalent Molecule

- Molecule has no net charge

- Oxygen end has a slight negative charge

- Hydrogen end has a slight positive charge

Hydrophilic & Hydrophobic Substances

- Hydrophilic substances
  - Polar
  - Hydrogen bond with water
  - Example: sugar

- Hydrophobic substances
  - Nonpolar
  - Repelled by water
  - Example: oil

Temperature-Stabilizing Effects

- Liquid water can absorb much heat before its temperature rises

- Why?

- Much of the added energy disrupts hydrogen bonding rather than increasing the movement of molecules

Evaporation of Water

- Large energy input can cause individual molecules of water to break free into air

- As molecules break free, they carry away some energy (lower temperature)

- Evaporative water loss is used by mammals to lower body temperature

Why Ice Floats

- In ice, hydrogen bonds lock molecules in a lattice
- Water molecules in lattice are spaced farther apart then those in liquid water
- Ice is less dense than water

Water Is a Good Solvent

- Ions and polar molecules dissolve easily in water
- When solute dissolves, water molecules cluster around its ions or molecules and keep them separated

Water Cohesion

- Hydrogen bonding holds molecules in liquid water together
- Creates surface tension
- Allows water to move as continuous column upward through stems of plants

Example of Water's Cohesion

Example of Water's Cohesion

Section 2.6: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 2.6: EPA—Acid Rain
- Section 2.6: Acids and Bases—pH Chemistry
- Section 2.6: Acid-Base Buffer Problems
- Section 2.6: Skin Surface pH: A Protective Acid Mantle. Gil Yosipovitch et al. *Cosmetics and Toiletries,* Dec. 1996.
- Section 2.6: pH Values below Zero. William Pryor. *Science,* Mar. 31, 2000.

The pH Scale

- Measures H^+ concentration of fluid
- Change of 1 on scale means 10X change in H^+ concentration

Highest H^+ Lowest H^+
0--------------------7-------------------14
Acidic Neutral Basic

Examples of pH

- Pure water is neutral with pH of 7.0
- Acidic
  - Stomach acid: pH 1.0 - 3.0
  - Lemon juice: pH 2.3
- Basic
  - Seawater: pH 7.8 - 8.3
  - Baking soda: pH 9.0

Acids & Bases

- Acids
  - Donate H^+ when dissolved in water
  - Acidic solutions have pH < 7
- Bases
  - Accept H^+ when dissolved in water
  - Acidic solutions have pH > 7

Weak and Strong Acids

- Weak acids
  - Reluctant H^+ donors
  - Can also accept H after giving it up
  - Carbonic acid (H_2CO_3) is example
- Strong acids
  - Completely give up H^+ when dissolved
  - Hydrochloric acid (HCl) is example

Acid Rain

- A coal-burning power plant emits sulfur dioxide, which dissolves in water vapor to form acid rain (pg. 29)

Salts

- Compounds that release ions other than H^+ and OH^- when dissolved in water
- Example: NaCl releases Na^+ and Cl^-
- Many salts dissolve into ions that play important biological roles

Buffer Systems

- Minimize shifts in pH

- Partnership between weak acid and base it forms when dissolved
- Two work as pair to counter shifts in pH

Carbonic Acid-Bicarbonate Buffer System

- When blood pH rises, carbonic acid dissociates to form bicarbonate and H^+

$$H_2C0_3 \text{ -----> } HC0_3^- + H^+$$

- When blood pH drops, bicarbonate binds H^+ to form carbonic acid

$$HC0_3^- + H^+ \text{ -----> } H_2C0_3$$