

WEEK 2

The Chemistry of life

Introduction

Last week you learned eight criteria used by scientists to establish whether an object lives. A living creature can grow, develop and utilize either in-organic or organic compounds for its energy needs. This week we will examine the atom, which makes up the compounds of life. Of the 92 different naturally occurring elements, only a relative few form the highly organized material of living cells. The major elements that contributor to living cells are Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorous, and Sulfur (referred to as CHNOPS).

In summary:

Matter is composed of atoms, the smallest units of chemical elements. Atoms are made up of smaller particles. The nucleus of an atom contains positively charged protons and (except for hydrogen, H^1) neutrons. The atomic number of an atom is equal to the number of protons in its nucleus. The atomic weight of atom is the sum of the number of protons and neutron in its nucleus. Its electrons - small, determine the chemical properties of an atom negatively charged particles found outside the nucleus. The number of electrons in an atom equals the number of protons and the atomic number.

The nuclei of different isotopes of the same element contain the same number of protons but different numbers of neutrons. Thus the isotopes of an element have the same atomic number but different atomic weights.

The electron of an atom has differing amounts of energy. Electrons closer to the nucleus have less energy than those farther from the nucleus and thus are at a lower energy level. An electron tends to move to the lowest unoccupied energy level, but with an input of energy, it can be boosted to a higher energy level. When the electron returns to a lower energy level, energy is released.

The number and arrangement of electrons determine the chemical behavior of an atom. An atom is most stable when all of their electrons are at their lowest possible energy levels and those energy levels are completely filled with electrons. The first energy level can hold two electrons, and the second and third energy levels can each hold eight electrons. Chemical reactions between atoms result from the tendency of atoms to reach the most stable electron arrangement possible.

Particles consisting of two or more atoms are known as molecules, which are held together by chemical bonds. Two common types of bonds are ionic and covalent.

Chemical reactions - exchanges electrons among atoms - can be represented by chemical equations. Three general types of chemical reactions are (1) the combination of two or more substances to form a different substance, (2) the dissociation of a substance into two or more substances, and (3) the mutual exchange of atoms among two or more substance.

Six elements (CHNOPS) make up 99 percent of all living matter. The atoms of all of these elements are small and form tight, stable covalent bonds. With the exception of hydrogen, they can all form covalent bonds with two or more atoms, giving rise to the complex molecules that characterize living systems.

Course outcome:

Describe structure and function of the ATOM

Learning goals:

After studying this week's material you should:

1. Know the structure of atom
2. You should know differences between ionic, covalent, and polar covalent bonds.

3. You will be able to describe the properties of water and water biological significance.
4. You should develop a basic idea of substance solubility.
5. Describe the difference between an acid and basic.

Assignments:

1. Read Chapter 2, Chemical Foundations for Cells.
2. Visit the following URL:

<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookCHEM1.html>

Visit the following URL:

<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookCHEM2.html>

Read and study the material here, note the section on the structure of water and its properties. This material is important. This page will provide additional diagrams of biological molecules and information about them. The page takes a long time to load since there are many diagrams and graphics here. Be patient. There is good information to augment material in your text and the diagrams and models of molecules can be very helpful.

<http://www.chem.tamu.edu/class/fyp/mathrev/mr-sigfg.html>

This site corresponds to the measurement's lab. This site discusses aspects of significant figures – what is meant by exact and inexact numbers. Review this site and place away for future chemistry use.

CHAPTER 2 - - - CHEMISTRY Notes

The universe is organized into basis materials we call ELEMENTS.

For example: Carbon -----> as abbreviated as 'C'
or Nitrogen -----> as 'N'

What are the most abundant elements that compose within the human system??

Carbon
Hydrogen
Nitrogen
Oxygen
Phosphorous
Sulfur

Or **CHNOPS**

Do not confuse the concept of most abundant elements as the most important. Rather, Mg, Zn, Ca and a host of other elements are extremely important for regulated life.

Is water an element???? -----> No we would call water (H_2O) a compound.

Give me another compound !!!!!!!!!!!

How about table salt NaCl or glucose $C_6H_{12}O_6$

* Atoms and Elements

Atoms are composed of subatomic particles known as protons (P^+) and neutrons, located in the atoms nucleus and electrons (e^{-1})

If we refer to the periodic chart of chemicals we can see the various symbols for the differing elements. You can see oxygen is abbreviated as 'O.' However the box (ref the Periodic Table of element found in the appendix of the text book) in which oxygen is placed has a number in the upper right hand corner as well as below the abbreviation. These figures represent the atom number, upper corner, (number of protons) and the atomic mass, below the element abbreviation (or weight) of the element.

<http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/pertab.html#c1>

What do I mean by the atomic mass??

The atomic number, 8 in the case of oxygen, denotes that oxygen has 8 protons. However, the atomic mass is much greater than 8! This number denotes additional weight, so to speak. This additional mass represents the weight of additional neutron within an atoms nucleus.

Do these sub-atomic particle have a charge??

Particle	Relative weight	Charge
Proton	1	+
Neutron	1	0
electron	0	-

◇ ISOTOPES

Isotopes are atoms of an element of differing atomic mass

In this case we notice that each carbon atom has a differing atomic mass or weight.

<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookCHEM1.html>

<http://ie.lbl.gov/education/isotopes.htm>

<http://www.colorado.edu/physics/2000/isotopes/>

The most common and stable form of carbon found in nature is Carbon 12. Carbon 14 comes about from radio active decay. Carbon 14 is an unstable radio isotope with 8 neutrons in its nucleus compared to C/12 with 6 neutrons.

http://web.uvic.ca/~qxm/c_14_notes.htm

=Other uses of radioisotopes include

medical use
tracer studies to study metabolism
Bio technology use

◇ Basic Atom

- The basis atom is composed of protons, neutrons and electrons

- Electrons orbit the atom in specific valence shells.

**

: Cl . Electrons repel each other however, there are 2 electrons
** per orbit.

The second valence shell maybe composed of up to 4 e⁻
pairs or 8 electrons

total. These orbital cycle at right angles to each other resulting in a
cloud of e⁻ at anyone time.

<http://www.shef.ac.uk/chemistry/orbitron/AOs/4f/>

- In the third valence shell more e⁻ are possible.

- Atoms with unfilled e⁻ in their outer most orbitals tend be reactive with other atoms

<http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/perlewis.html#c2>

◇ IONS

1. Atoms with a charge - either positive or negative
2. An ion has either lost or gained an electron
 - a. An atom that has gained an electron becomes negative in charge
 - b. An atom that lost an electron becomes positive in charge

- Let us exam chlorine (Cl)

This atom is considered neutral. Rather the Chlorine atom has one unpair e^- within an orbital making it unstable. Chlorine will accept an e^- imparting stability to its makeup. However, in accepting the e^- the chlorine atom has

become IONIZED.

Sodium (Na), on the other hand, becomes stable upon giving up an e^- .

<http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/lewis.html#c1>

* Important Chemical Bonds

- Now we can talk about chemical bonds
= What is a chemical bond??

- 1) A chemical bond is a union between atoms formed when they give up, gain or share electrons
- 2) Whether one atom will bond with another atom depends on the number and arrangement of its electrons

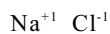
◇ Ionic Bonds

- Ionic Bond

1. Forms between ions
2. Bond between opposite charges
3. Transfer of an electron from one atom to another
4. Relatively weak bonds

- What occurs is a mutual attraction for opposite charges

Like charges repel - - opposite charge attach....



How about Mg^{+2} & Cl^{-1} ??

to balance the equation of charges Mg & Cl is written -----> MgCl_2

- - - - - Know this concept - - - - -

<http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/lewis.html#c2>

◇ **Covalent Bonds**

http://www.accessexcellence.org/AB/GG/cov_IonicBs.html

http://en.wikipedia.org/wiki/Covalent_bond

- A covalent bond is defined as a bond that holds together two atoms that share one or more pairs of e⁻'s and can not completely pull the e⁻ away from the other atom

- Covalent bond

1. Sharing of electrons between atoms
2. Does not involve losing or gaining electrons - SHARING
3. Considered a strong bond
4. Takes energy to make - gives up energy when bonds break
5. Example: CH₄
6. Sometimes the electrons not shared equally: H₂O
 - a. This situation leads to a polar covalent bond

- **NONPOLAR COVALENT** bond result when atoms equally share e⁻'s



- **POLAR COVALENT BOND** occur when e⁻'s are shared unequally. As a result there is a slight difference in the charge between the two poles of the bond. Water is a good example.

◇ **HYDROGEN BONDING**

<http://www.accessexcellence.org/AB/GG/waterProps1.html>

- In a hydrogen bond, an atom or a molecule interacts weakly with a hydrogen atom already taking part in a polar covalent bond

- These bonds impart structure to liquid water and stabilize nucleic acids and other large molecules

Hydrogen bond

Electrostatic bonds formed between 2 molecules between electrostatic positive hydrogen & electrostatic negative species such as oxygen or nitrogen

Properties of Water

<http://ga.water.usgs.gov/edu/waterproperties.html>

<http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookCHEM2.html>

<http://daphne.palomar.edu/jthorngen/latent.htm>

◇ The Polarity of Water

- The polarity of the water molecule influences the behaviour of other substances
 - = Hydrogen bonds form with itself and other polar substances
 - = Polar substances are hydrophilic (water-loving)
 - = Nonpolar substances are hydrophobic (water-hating) and repel water
- ◇ Water has temperature stabilizing effects
 - = Water tends to *stabilize* temperature because it can absorb considerable heat before its temperature changes
 - = This is an important property in evaporative and freezing process

◇ Water has **COHESIVE PROPERTIES**

- = Hydrogen bonding of water molecules provides *cohesivon* (capacity to resist rupturing)
- = Cohesion imparts surface tension

Water is pulled up through plants by this property

◇ Water has **ADHESIVE PROPETIES**

Attraction of unlike molecules for each other

1. Water to surface of a table or inside of a capillary tube
2. Water to the internal surface of a vascular bundle of a plant

◇ Water has capillary activity

1. The combination both of adhesive and cohesive forces allow movement up a capillary tube such as the vascular bundle of a plant

◇ **SOLVENT PROPERTIES**

- = Water is a solvent for ions and polar molecules (solutes)

Table salt (ions >>>> Na⁺ Cl⁻)

Sugar -----> into water

= Solvent properties greatest with polar molecules because of “spheres of hydration” formed around the solute molecules

Water, Dissolved Ions and pH

<http://ga.water.usgs.gov/edu/phdiagram.html>

<http://old.jccc.net/~pdeccl/chemistry/phscale.html>

<http://ga.water.usgs.gov/edu/characteristics.html>

◇ THE DISASSOCIATION OF WATER

Water can disassociate into H^+ and OH^- ions

This disassociation occurs at the rate of $1 \cdot 10^{-7}$ water molecules and the pH Scale measure the H^+ activity in solution

◇ The pH Scale

- pH is a logarithmic measurement of the H^+ concentration in a solution
- The scale extends from 0 (very acidic) to 7 (neutral) to 14 (very basic)
- The interior of living cells is near pH = 7.

= The greater the H^+ the lower the pH scale

- | | |
|--------------------|--------------|
| 1. pH 7 is neutral | $H^+ = OH^-$ |
| 2. pH > 7 is basic | $H^+ < OH^-$ |
| 3. pH < 7 is acid | $H^+ > OH^-$ |

Stomach acid	pH approx	1.5
Cocca cola	pH approx	3.0
Orange juice	pH approx	5.2
Baking soda	pH approx	8.7

◇ **Acids, Bases, and Salts**

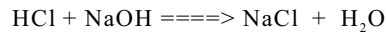
- A substance that releases hydrogen ions (H^+) in solution is an *acid*



- Bases ---> are those substance that release OH^- ions into a solution



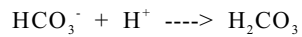
- A salt results when an ionic compound forms when an acid reacts with a base



◇ **Buffers and the pH of body fluids**

<http://www.chemistry.wustl.edu/EduDev/LabTutorials/Buffer/Buffer.html>

- A buffer molecule combines with and release, H^+ to prevent drastic changes in pH
- Carbonic acid is one of the body's major buffers



Consider the blood for a moment.... Carbonate (HCO_3^-) helps restore the blood's pH when it becomes too acidic.. HCO_3^- combines with H^+ to form carbonic acid.

2

CHEMICAL FOUNDATIONS FOR CELLS

Matching

Choose the most appropriate answer for each term.

- | | |
|--------------------------|---|
| 1. ___radiometric dating | A. Unions between the electron structures of atoms |
| 2. ___atoms | B. Radioisotopes used with scintillation counters to reveal the pathway or destination of a substance |
| 3. ___protons | C. Subatomic particles with a negative charge |
| 4. ___trace element | D. Positively charged subatomic particles within the nucleus |
| 5. ___neutrons | E. The time it takes for half of the nuclei in a given amount of a radioactive element to decay into a different element |
| 6. ___electrons | F. Method used to measure proportions of isotopes in a rock-trapped mineral and the daughter isotopes formed in the same rock |
| 7. ___radioactive decay | G. Atoms of a given element that differ in the number of neutrons |
| 8. ___atomic number | H. Spontaneous process that transforms an unstable atom into a different isotope |
| 9. ___mass number | I. Refers to the number of protons in an atom |
| 10. ___elements | J. Radioactive isotopes |
| 11. ___isotope | K. Chemical elements representing less than 0.01 percent of body weight |
| 12. ___radioisotopes | L. Destroys or impairs living cancer cells |
| 13. ___tracer | M. The number of protons and neutrons in the nucleus of one atom nucleus |
| 14. ___half-life | N. Fundamental forms of matter that occupy space, have mass, and cannot be broken down into something else |
| 15. ___chemical bonds | O. Smallest units that retain the properties of a given element |
| 16. ___radiation therapy | P. Subatomic particles within the nucleus carrying no charge |

Matching

Choose the one best answer for each.

- | | |
|-----------------------------|---|
| 1. ___mixture | A. Regions of space around an atom's nucleus where electrons are likely to be at anyone instant |
| 2. ___shells | B. Results when two or more atoms bond together |
| 3. ___lowest energy level | C. Two or more elements are simply intermingling in proportions that usually vary |
| 4. ___inert | D. A series of orbitals arranged around the nucleus |
| 5. ___ orbitals | E. Types of molecules composed of two or more different elements in proportions that never vary |
| 6. ___compounds | F. Energy of electrons farther from the nucleus than the first or~ital . |
| 7. ___ molecule | G. Refers to atoms with no vacancies in their shells, hence showing little tendency to enter chemical reactions |
| 8. ___ higher energy levels | H. Energy of electrons in the orbital closest to the nucleus |

3. Diagram a NEUTRAL atom of Fluorine (Atomic Number: 9; Atomic Mass: 19) showing protons, neutrons, and electrons.
4. Diagram the atom of fluorine again and this time make it STABLE. What is its valence?
5. Distinguish between the following AND give an example of each:
- A ionic bond
 - B. nonpolar covalent bond
 - C. polar covalent bond
 - D. hydrogen bond
6. The hydrogen bond formed between water molecules gives specific characteristics to water. List these properties that are unique to water.

Matching

Choose the most appropriate answer for each.

- | | |
|---------------------------------|--|
| 1. _acid stomach | A. A sometimes irreversible state of unconsciousness |
| 2. _acids | B. CO ₂ builds up in the blood, too much H ₂ CO ₃ forms and blood pH severely decreases |
| 3. _pH scale | C. Hydroxide ion |
| 4. _chemical burns | D. Substances that accept H ⁺ when dissolved in water |
| 5. _H ⁺ | E. An uncorrected increase in blood pH |
| 6. _bases | F. Used to measure H ⁺ concentration in various fluids |
| 7. _examples of basic solutions | G. A partnership between a weak acid and the base that forms when it dissolves in water; counters slight pH shifts |
| 8. _coma | H. Hydrogen ion or proton |
| 9. _acidosis | T. Baking soda, seawater, egg white |
| 10. _OH ⁻ | J. Can be caused by ammonia, drain cleaner, and sulfuric acid in car batteries |
| 11. _tetany | K. Substances that donate H ⁺ when dissolved in water |
| 12. _examples of acid solutions | L. Lemon juice, gastric fluid, coffee |
| 13. _alkalosis | M. Can be caused by eating too much fried chicken or certain other foods |
| 14. _buffer system | N. A potentially lethal pH stage in which the body's skeletal muscles enter a state of uncontrollable contraction |

Self-Quiz

- _ 1. Each element has a unique _____ – which refers to the number of protons present in its atoms.
- isotope
 - mass number
 - atomic number
 - radioisotope
- _ 2. A molecule is
- a combination of two or more atoms
 - less stable than its constituent atoms separated
 - electrically charged
 - a carrier of one or more extra neutrons
- _ 3. If lithium has an atomic number of 3 and an atomic mass of 7, it has _____ neutron(s) in its nucleus.
- one
 - two
 - three
 - four
 - seven
- _ 4. Substances that are nonpolar and repelled by water are _____ –
- hydrolyzed
 - nonpolar
 - hydrophilic
 - hydrophobic
- _ 5. A hydrogen bond is _____ –
- a sharing of a pair of electrons between a hydrogen nucleus and an oxygen nucleus
 - a sharing of a pair of electrons between a hydrogen nucleus and either an oxygen or a nitrogen nucleus
 - formed when a small electronegative atom of a molecule weakly interacts with a hydrogen atom that is already participating in a polar covalent bond
 - none of the above
- _ 6. An ionic bond is one in which _____ –
- electrons are shared equally
 - electrically neutral atoms have a mutual attraction
 - two charged atoms have a mutual attraction due to electron transfer
 - electrons are shared unequally
- _ 7. A covalent bond is one in which _____ –
- electrons are shared
 - electrically neutral atoms have a mutual attraction
 - two charged atoms have a mutual attraction due to electron transfer
 - electrons are lost