Chemistry/Biochemistry

To truly understand physiology, we must understand the chemistry/biochemistry behind living systems.

Chemistry

Matter - anything that occupies space and has mass (note that mass and weight are not necessarily the same, but for our purposes we will use the terms interchangeably).

Mater exists in three states; solid, liquid, and gas

Energy - the capacity to do work, or to put matter into motion.

There are two types of energy, Kinetic energy and Potential energy

Kinetic energy; energy in action

Potential energy; energy of position (has the capability of doing work but is not presently doing so)

The body uses energy in several forms;

Chemical energy; This is the energy stored in the bonds of chemical substances. This is potential energy that is unleashed and becomes kinetic energy.

Electrical energy; Reflects the movement of charged particles (ions moving across cell membranes)

Mechanical energy; Energy directly involved in moving matter.

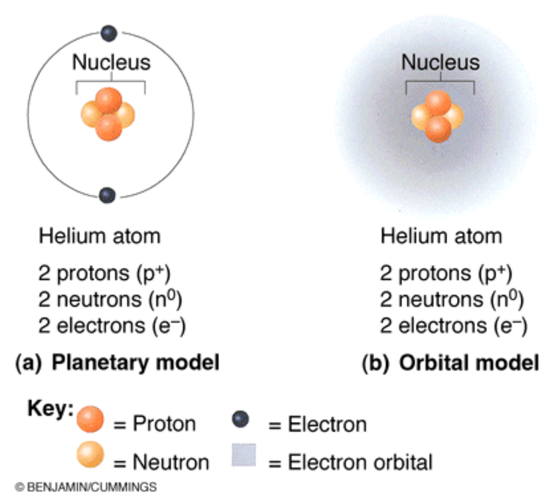
Radiant (electromagnetic) energy; Is energy that travels in waves. These wavelengths may vary and cover a range known as the electromagnetic spectrum. This includes visible light, infrared waves, radio waves, ultraviolet waves, and x-rays.

To understand chemistry, you must start with the atom. Atom comes of the Greek word meaning Indivisible; however, we now know that atoms are made up of smaller particles called protons, neutrons, and electrons. These are called subatomic particles.

Note that an atom's subatomic particles differ in mass, electrical charge, and position in the atom.

The atom has a central nucleus containing the protons and the neutrons. The nucleus is surrounded by orbiting electrons. Protons have a positive electrical charge whereas neutrons have no electrical charge. This gives the nucleus a positive charge. Orbiting electrons have a negative electrical charge. Note that protons and neutrons have approximately the same mass, whereas the mass of an electron is about 1/2000 the mass of a proton

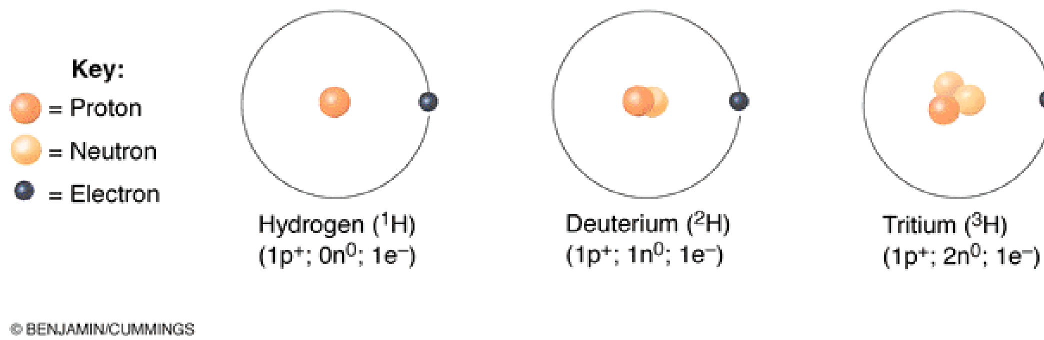
Since all atoms are electrically neutral the number of protons must be precisely balanced by its number of electrons.



Mass Number and Isotopes

The mass number of an atom is the sum of the masses of the protons and neutrons.

Isotopes are essentially an element with more neutrons than the most common form of the element.



Radioisotopes Heavier isotopes of many elements are unstable and their atoms decompose spontaneously into more stable forms. This process of atomic decay is called radioactivity and isotopes that exhibit this behavior are called radioisotopes. The disintegration of a radioactive nucleus may be compared to a tiny explosion. It occurs when alpha (α) particles (packets of 2p = 2n), beta (β) particles (electronlike negative particles), or gamma (γ) rays (electromagnetic energy) are ejected from the nucleus.

Radioisotopes may produce one or more forms of radiation and gradually lose their radioactivity. The time required for a radioisotope to lose 1/2 of its activity is called a half-life. Have lives can vary from milliseconds to thousands of years depending on the radioisotope.

Molecules and mixtures

When two or more atoms are held together by chemical bonds they are referred to as a molecule. Two or more atoms of the same element combine to form a molecule of that particular element.

When two or more different kinds of atoms combine, they form a compound. For example, two atoms of hydrogen combine with one atom of oxygen to form the compound water Note that the properties of compounds are usually very different from those of the atoms they contain.

As an example: Sodium is a silvery white metal, chlorine is a poisonous green gas used to make bleach. Sodium chloride is a white crystalline solid that we sprinkle on our food.

Mixtures: are substances composed of two or more components physically intermixed. There are generally three types of mixtures: solutions, colloids, and suspensions.

Solutions: are homogenous mixtures of two or more components. These may be gases, liquids, or solids. The substance present in the greatest concentration is called the solvent and the substance/s present in lesser quantities are called the solutes.

Solutions are commonly referred to in terms of their concentration.

In chemistry the concentration of a solution is called molarity. The molarity of a solution is the number of moles of substance per 1 liter of solvent. A mole of any element or compound is equal to its atomic or Molecular Weight in grams. This system provides for great precision when preparing solutions. One mole of any substance always contains the same number of particles. 6.02 x 10^{23}. This is termed

Avogadro's number. Remember, whether you weigh out 1 mole of glucose or 1 mole of water, or 1 mole of any compound, you will always have 6.02 X 10^{23} molecules of that substance.

Colloids: are heterogeneous mixtures and usually appear translucent or milky. The particles do not settle out. Colloids usually have unique properties. Many undergo sol-gel transformations, i.e., they can reversibly change from a fluid to a more solid (gel) state and then later return to a fluid state.

S<u>uspensions</u>: are heterogeneous mixtures with large solute particles that often settle out. An example would be sand and water. Blood is a suspension in which the living cells are suspended in the fluid portion of the blood (plasma).

<u>Mixtures vs Compounds</u>

1. no chemical bonding occurs between the components of a mixture. This is not necessarily true of a compound

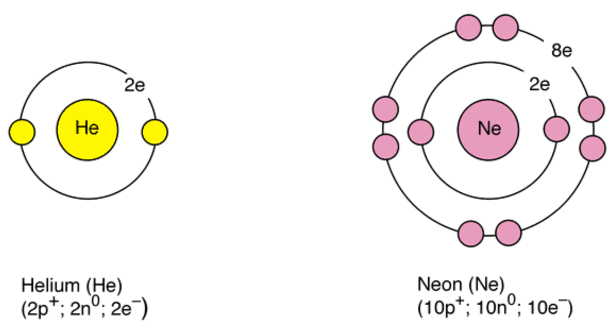
2. A mixture's components can be separated by physical means

3. mixtures can be homogenous or heterogeneous

Electrons and chemical bonding

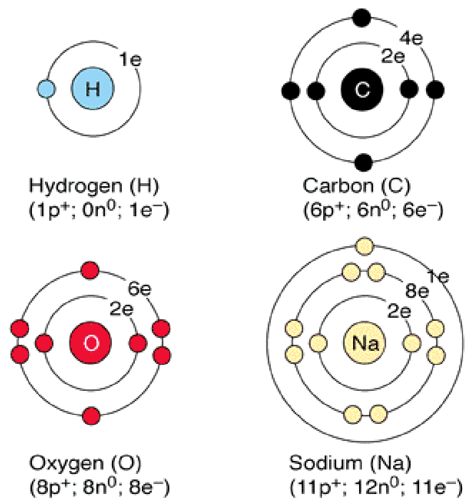
Chemical bonding is depended on interactions between electrons of adjacent atoms.

Atoms are surrounded by electron shells and each electron shell can hold a specific number of electrons. Shell 1 (immediately surrounding the nucleus) can hold only 2 electrons. Shell 2 can hold 8 electrons, and shell 3 has room for 18 electrons. Outer shells hold larger and larger numbers of electrons. Each shell must be completely filled with electron before any electrons appear in the next shell



Note that the outer shell is completely filled with electrons

(a) Chemically inert elements (valence shell complete)



(b) Chemically active elements (valence shell incomplete)

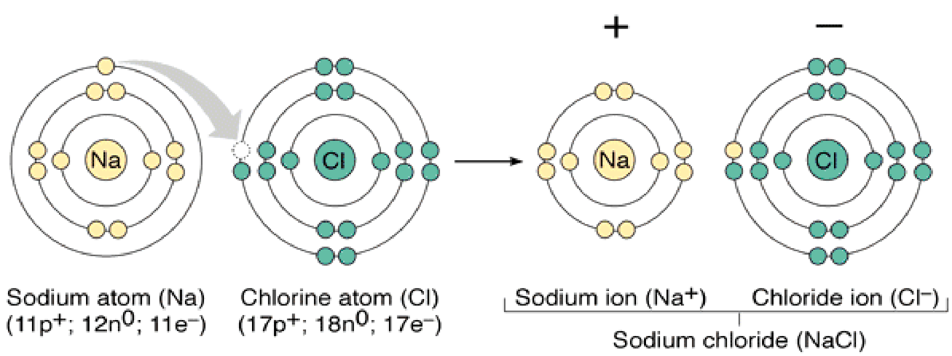
Note that the outer electron shells are not filled. This "valence shell" may contain as little as 1 electron and may contain more than 8 electrons. However, the number of electrons, that can participate in the bonding is still limited to 8. This is called the <u>octet rule</u> of the <u>rule of eights</u>.

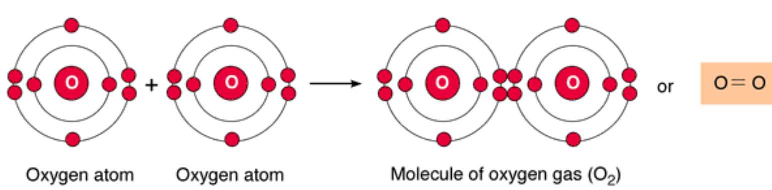
<u>Chemical Bonds</u>

There are three types of chemical bonds:

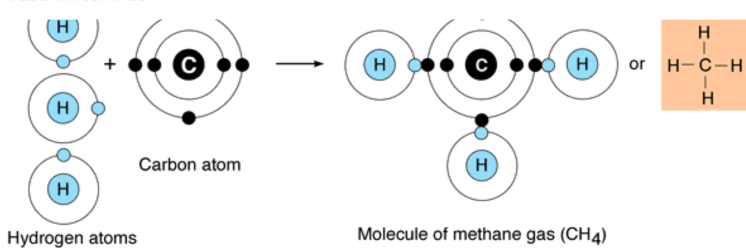
1. Ionic bonds; electrons are passed from one atom to another resulting in the formation of ions (charged particles).

2. Covalent bonds; electrons are shared so that each atom is able to fill its outer electron shell for at least part of the time.



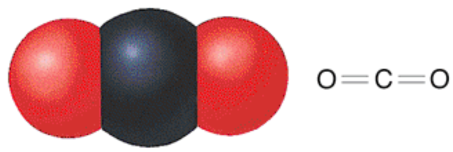


(b) Formation of a double covalent bond



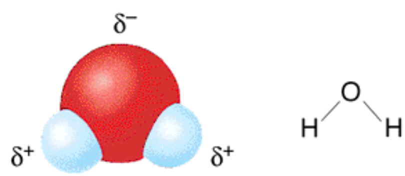
(a) Formation of four single covalent bonds

Covalent bonds are of particular importance in biological systems because they can result in <u>polar</u> and <u>non-polar</u> molecules. In the examples of covalent bonds shown above the electrons are shared equally between the atoms of the molecule. These molecules are electrically balanced and are called non-polar molecules.



(a) Carbon dioxide (CO_2)

When covalent bonds are formed the resulting molecule always has a three-dimensional shape with the bonds formed at definite angles. A molecule's shape helps determine what other atoms or molecules it may bind with.



(b) Water (H_2O)

Covalent bonds can also result in unequal electron sharing and polar molecules.

3. Hydrogen bonds; Hydrogen bonds are to weak to bind atoms together to form molecules. These bonds form when a hydrogen atom, already covalently linked to one electronegative atom, is attracted to another electron-hungry atom, and forms a "bridge" between them.

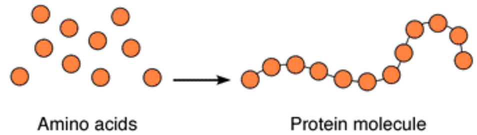
Chemical Reactions

For the most part chemical reactions can be grouped into three major patterns; synthesis, decomposition, or exchange reactions

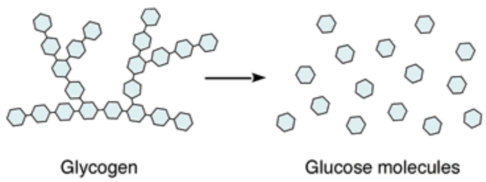
1. synthesis (combination) reaction; when atoms or molecules combine to form a larger more complex molecule. ie., $A + B \rightarrow AB$

2. decomposition reaction; a molecule is broken down into smaller molecules or its constituent atoms. i.e., $AB \rightarrow A + B$

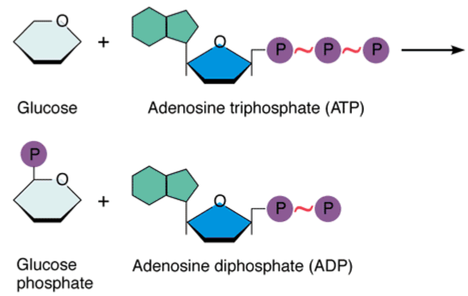
3. exchange (displacement) reactions; involve both synthesis and decomposition reactions,
i.e., $AB + C \rightarrow AC + B$ and $AB + CD \rightarrow AD + CB$



(a) Example of a synthesis reaction: amino acids are joined to form a protein molecule



(b) Example of a decomposition reaction: breakdown of glycogen to release glucose units



(c) Example of an exchange reaction: ATP transfers its terminal phosphate group to glucose to form glucose-phosphate

Factors Influencing the Rate of Chemical Reactions

1. Temperature; increasing the temperature of a substance increases the kinetic energy of its particles and the force of their collisions, therefore an increase in temperature increases the rate of a chemical reaction.

2. Particle size; smaller particles move faster than larger ones (given the same temperature) and therefore tend to collide more frequently and more forcefully. Therefore, the smaller the reacting particles, the faster the chemical reaction.

3. concentration; the higher the concentration of the reacting particles the faster the reaction. This is due to an increased chance of collision between the particles.

4. Catalysts; are substances that increase the rate of chemical reactions without themselves becoming chemically changed or becoming part of the product. Biological catalysts are enzymes.