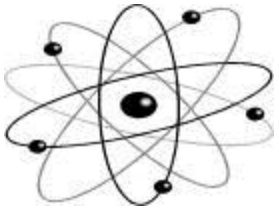
The Chemistry of Life

Chapter 2

Sec. 2-1 The Nature of Matter

Atoms

- An atom is the basic unit of matter.
- Three subatomic particles make up atoms:
  - protons (positive charge +)
  - neutrons (no charge)
  - electrons (negative charge -)



- The nucleus, which is at the center , contains both protons and neutrons.
- Electrons are in constant motion in the space surrounding the nucleus.
- Atoms are neutral because the subatomic particles have equal but opposite charges.

Elements and Isotopes

- An element is a pure substance that consists entirely of one type of atom.
- More than 100 elements are known.
- Only 2 dozen are commonly found in living organisms.
- Elements are represented by a one- or two-letter symbol.
  - H for hydrogen, C for carbon, Na for sodium

H C Na

An Element in the Periodic Table

Atomic Number → 6

Element Symbol → C

Element → Carbon

Atomic Mass → 12.011

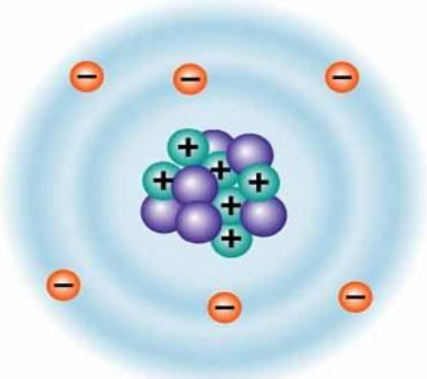
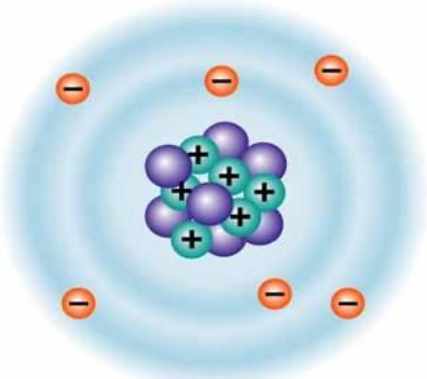
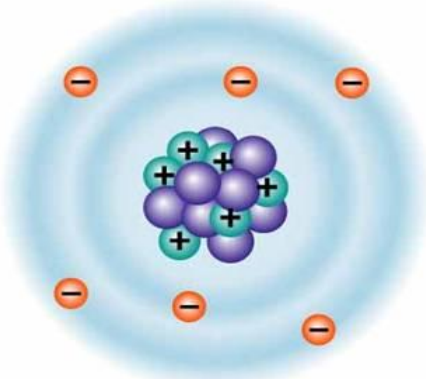
- The number of protons in an atom of an element is the element's atomic number.

Isotopes

- An isotope is an atom of the same element that differs in the number of neutrons they contain.
- The sum of the protons and neutrons in the nucleus of an atom is called its mass number.
- The weighted average of the masses of an element's isotopes is called its atomic mass.
- The number of electrons does not change in an isotope so, all the chemical properties are the same.

Isotopes of Carbon

- Isotopes are identified by their mass numbers.

Nonradioactive carbon-12	Nonradioactive carbon-13	Radioactive carbon-14
		
6 electrons 6 protons 6 neutrons	6 electrons 6 protons 7 neutrons	6 electrons 6 protons 8 neutrons

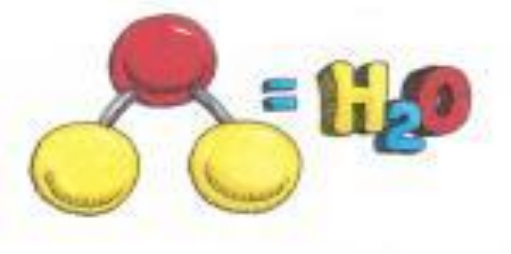
Radioactive Isotopes

- Have an unstable nuclei that break down at a constant rate over time.
- Radiation given off can be both dangerous and have practical uses.
  - determine the ages of rocks and fossils
  - treatment for cancer
  - kill bacteria that spoils food
  - "tracers" that follow the movements of substances within organisms

Chemical Compounds

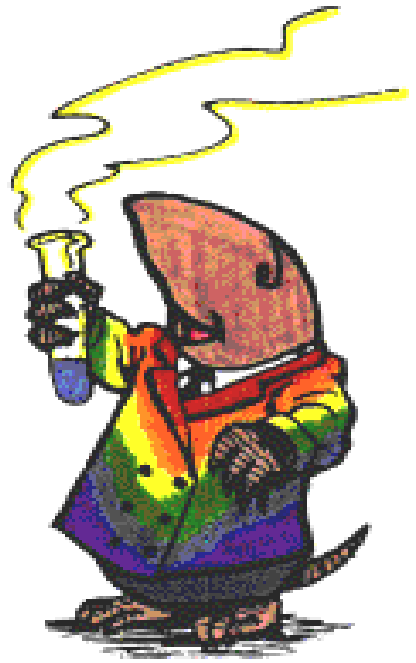
- A chemical compound is a substance formed by the chemical combination of two or more elements in definite proportions.
- A chemical formula is used to illustrate the composition of compounds.

  Ex) Water - two atoms of hydrogen for each atom of oxygen has a chemical formula of



- The physical and chemical properties of a compound are usually very different from those of the elements from which it is formed.

  Ex) hydrogen and oxygen are gases at room temperature, which combine explosively to form liquid water.



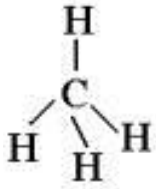
Chemical Bonds

- The atoms in compounds are held together by chemical bonds.
- The main type of chemical bonds are ionic bonds and covalent bonds.
- Two Types:

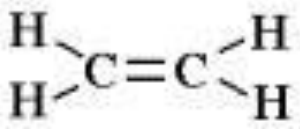
    1. Ionic Bond - formed when one or more electrons are transferred from one atom to another.
    2. Covalent Bond - formed when electrons are shared between atoms.

- An ion is a positively or negatively charged atom.
- Oppositely charged ions have a strong attraction.
- When atoms share:

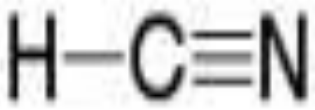
  - two electrons - single covalent bond



  - four electrons - double bond

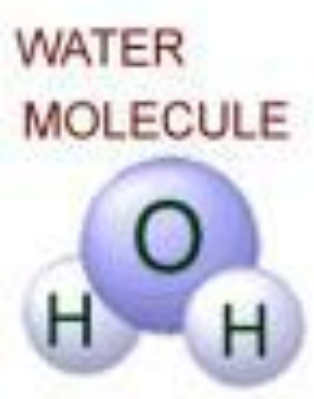


  - six electrons - triple bond



- The structure that results when atoms are joined together by covalent bonds is called a molecule.
- A molecule is the smallest unit of most compounds.

  Ex) water is a molecule with each hydrogen atom forming a single covalent bond with the oxygen atom.



Sec. 2-2 Properties of Water

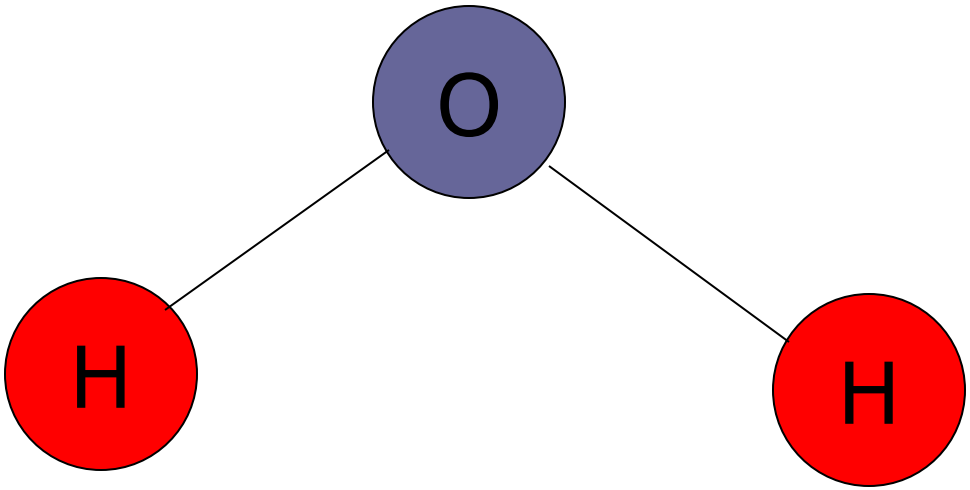
- Three fourths of the Earth's surface is covered by water.
- Water is the single most abundant compound in most living things.

The Water Molecule

- The water molecule (H_2O) is neutral.

Polarity

Negative Charge (-)

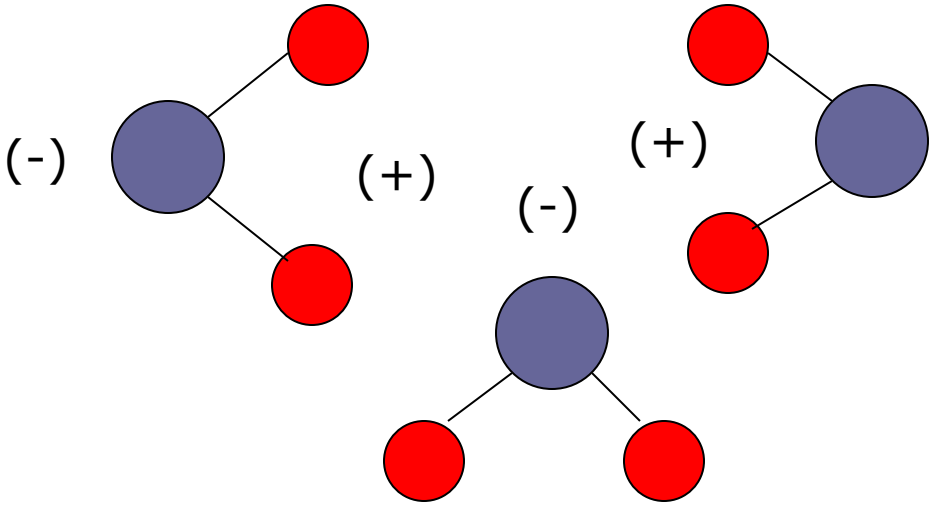


Positive Charge (+)

- A molecule in which the charges are unevenly distributed is called a polar molecule.
- The molecule is like a magnet with poles.

Hydrogen Bonds

- Polar molecules such as water can attract each other.
- The charges on a polar molecule are written with parentheses, (-) or (+), to show they are weaker than the charges on ions such as Na^+ and Cl^-.

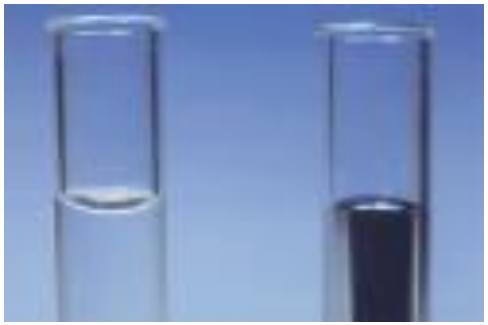


The attraction between the H atom on one water molecule and the O atom on another molecule is an example of a hydrogen bond.

Cohesion and Adhesion

- Cohesion is an attraction between molecules of the same substance.
- Water is extremely cohesive because of its ability to form multiple hydrogen bonds.
  - causes molecules on the surface of water to be drawn inward, which is why drops of water form beads on a smooth surface.

- Adhesion is an attraction between molecules of different substances.
  - the surface of the water in a graduated cylinder dips slightly in the center because of adhesion between water molecules and glass molecules is stronger then the cohesion between water molecules.



Solutions and Suspensions

- A mixture is a material composed of two or more elements or compounds that are physically mixed together but not chemically combined.
  - salt and pepper stirred together
  - sugar and sand
  - Earth's atmosphere is a mixture of gases

Solutions

- When NaCl (table salt) is placed in water, water molecules surround and separate the positive and negative ions.
- The ions gradually become dispersed in the water, forming a solution.
- All the components of a solution are evenly distributed throughout the solution.
- In a salt-water solutions:
  - table salt is the solute - substance that is dissolved
  - water is the solvent - the substance in which the solute is dissolved.
- Water is the greatest solvent on Earth.

Suspensions

- Some materials do not dissolve when placed in water but separate into pieces so small that they do not settle out.
- A suspension is a mixture of water and nondissolved material.
  - blood
  - cornstarch and water

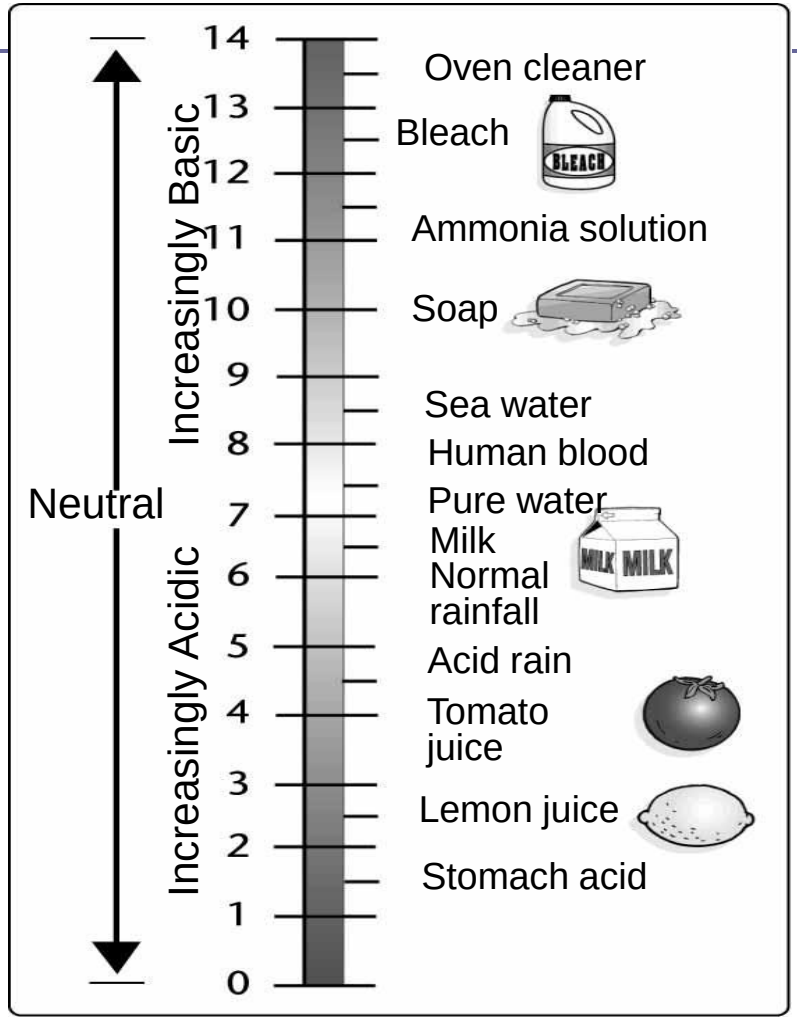
- A colloid is between a solution and a suspension.
  - milk, fog and jello

Acids, Bases, and pH

The pH scale

- The pH scale is a measurement device used to indicate the concentration of H^+ ions in solution.
- The pH scale ranges from 0 to 14.
- A pH of 7, the concentration of H^+ ions and OH^- ions is equal.
- Solutions with a pH below 7 are acidic.
- Solutions with a pH above 7 are basic.

pH Scale


14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Increasingly Basic
Neutral
Increasingly Acidic
Oven cleaner
Bleach
BLEACH
Ammonia solution
Soap
Sea water
Human blood
Pure water
Milk
MILK
Normal rainfall
Acid rain
Tomato juice
Lemon juice
Stomach acid

Acids and Bases

- An acid is any compound that forms H^+ ions in solution.
- They have more H^+ ions than OH^- ions.
- Strong acids tend to have pH values that range from 1 to 3.
  - Hydrochloric acid produced by the stomach to help digest food is a strong acid.
- A base is a compound that produces hydroxide ions (OH^-) in solution.
- Strong bases, such as lye, tend to have pH values ranging from 11 to 14.

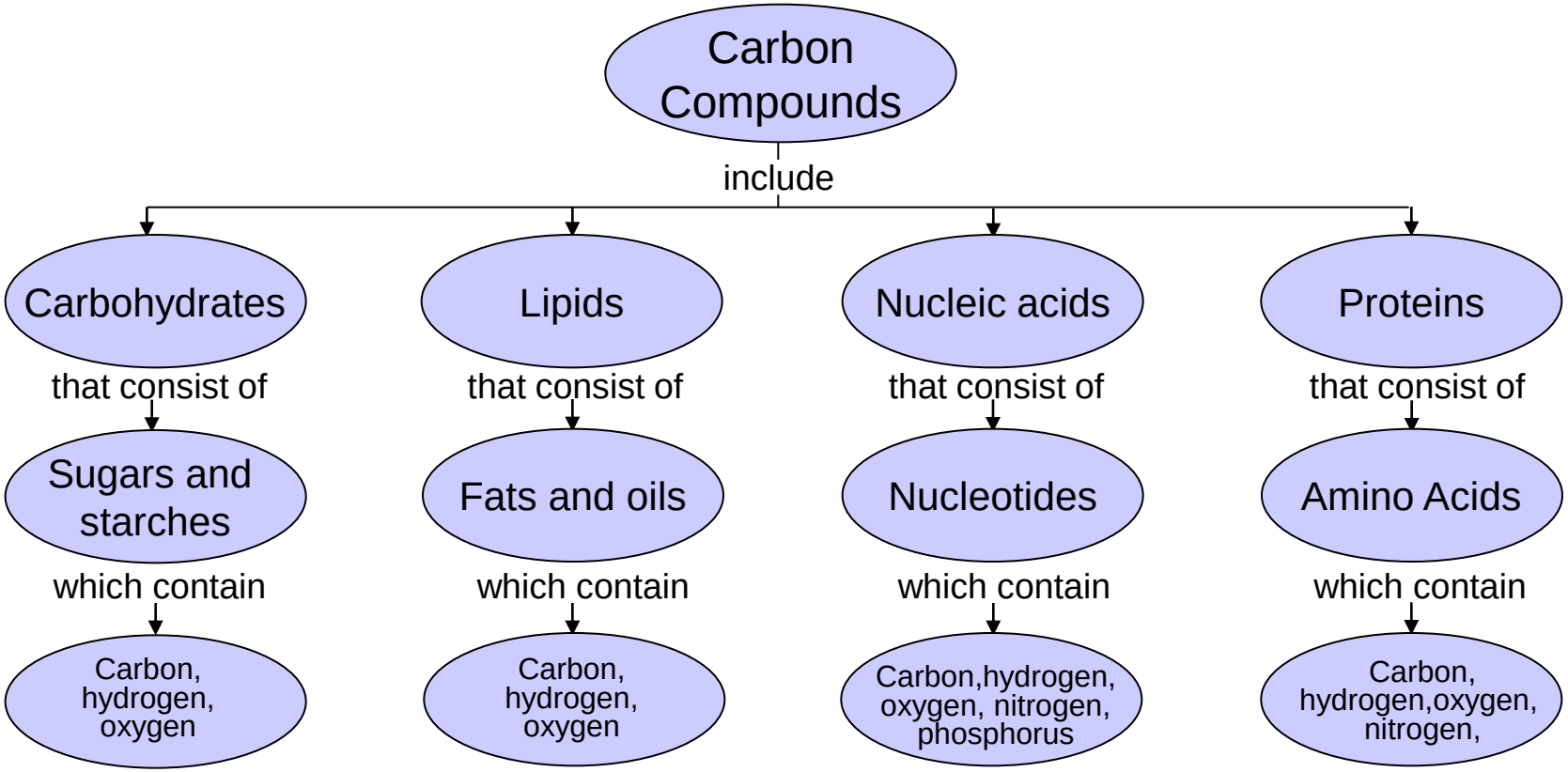
Buffers

- The pH of the fluids within most cells in the human body must generally be kept between 6.5 and 7.5.
- pH is important for maintaining homeostasis.
- Buffers are weak acids or bases that can react with strong acids or bases to prevent sharp, sudden changes in pH.

Carbon Compounds
Section 2-3

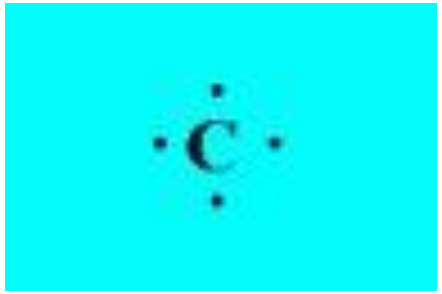
- **Organic chemistry is the study of all compounds that contain bonds between carbon atoms.**

Carbon Compounds Overview



The Chemistry of Carbon

- Carbon atoms have 4 valence electrons which form covalent bonds.
- Carbon can bond with itself or with H, O, P, S, N.
- Carbon-carbon bonds can be single, double, or triple covalent bonds.



Macromolecules

- A macromolecule is a "giant molecule" made from thousands or hundreds of thousands of smaller molecules.
- Polymerization is the process in which smaller units are joined together to make larger ones.
- A monomer is the "smaller unit".
- A polymer is many units linked together.

Identical Units like links in a watch band

Different Units like beads in a necklace

Carbohydrates

- A carbohydrate is a compound made up of C, H, and O atoms is a 1:2:1 ratio.
- Main source of energy for living things.
- A monosaccharide is a simple sugar molecule.
  - glucose come from photosynthesis in plants and cellular respiration in animals.

  - galactose comes from milk

  - fructose comes from fruit and is the sweetest

- A disaccharide is a molecule formed from two monosaccharides.
  - sucrose is found in sugar cane and sugar beets

  - lactose is milk sugar (glucose + galactose)

- A polysaccharide is a large molecule formed from three or more monosaccharides.
- Three types:
  - Glycogen is stored glucose or animal starch
  - Starch is stored glucose or plant starch
  - Cellulose gives plants strength and rigidity

Lipids

- A lipid is a fatty acid compound made up of C, H, and O.
- Lipids come in three types:

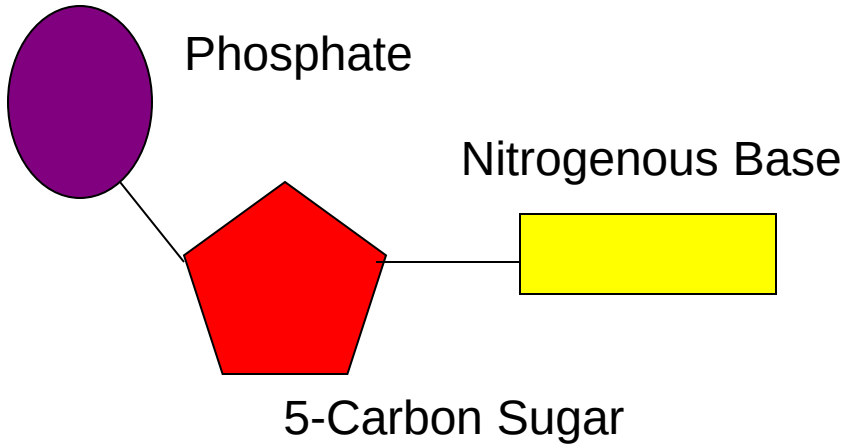
  - Triglycerides
    - oils - liquid at room temperature, found in plants
    - fats - solid at room temperature, found in animals
  - Waxes are long chain fatty acids joined to a long alcohol chain
  - Steroids don't dissolve in water and are found in hormones, nerve tissue, toad venom and plant poison

- Important parts of biological membranes (cell membrane) and waterproof coverings
- Saturated is used when fatty acids are joined by a single bond
- Unsaturated is used when there is at least one carbon to carbon double bond
  - olive oil

- Polyunsaturated is used when there is more than one double bond
  - corn oil, sesame oil and peanut oil

Nucleic Acids

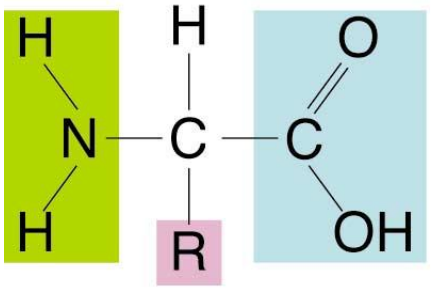
- A nucleic acid is a macromolecule containing H, O, N, C, and P.
- The monomers are nucleotides joined by covalent bonds.
- A nucleotide consists of three parts:
  - a 5-carbon sugar (deoxyribose or ribose)
  - a phosphate group
  - a nitrogenous base



- Stores and transmits hereditary, or genetic information.
- There are two kinds:
  - DNA (deoxyribonucleic acid)
  - RNA (ribonucleic acid)

Protein

- A protein is a macromolecule that contains C, H, O and N.
- The monomers are amino acids which have an amino group at one end and a carboxyl group at the other end.



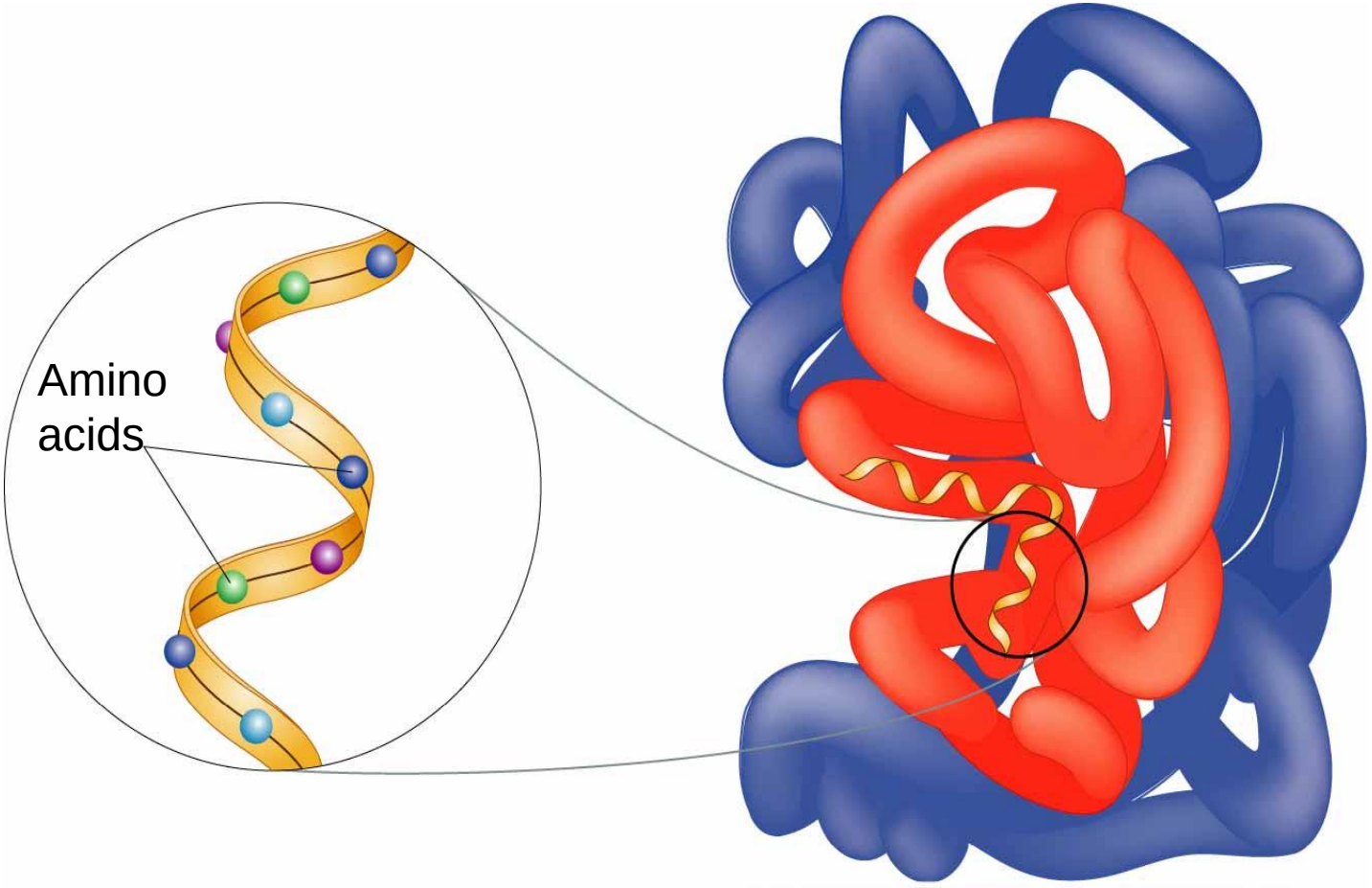
Amino group Carboxyl group

General structure

- 20 amino acids share the same basic structure except where the R-group is bonded

- DNA codes the arrangement of amino acids for the formation of proteins
- Roles of proteins might be:
  - control the rate of reactions
  - regulate cell processes
  - form muscle and bones
  - transport substances into and out of the cells
  - help fight diseases

- Proteins are made up of chains of amino acids folded into complex structures.



Chemical Reactions and Enzymes

Section 2-4

- Everything that happens in an organism is based on chemical reactions!

Chemical Reactions

- A chemical reaction is a process that changes one set of chemicals into another set of chemicals.
- Reactants are elements or compounds that enter into a chemical reaction.
- Products are elements or compounds produced by a chemical reaction.
- Chemical reactions always involve breaking bonds in reactants and forming bonds in products.

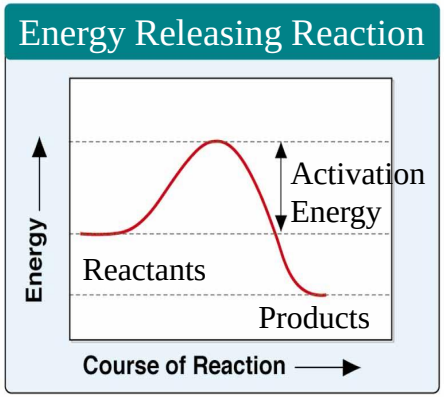
$$CO_2 + H_2O \text{-----} > H_2CO_3$$

Energy in Reactions

- Energy is released or absorbed whenever chemical bonds form or are broken.
- Chemical reactions involve changes in energy.

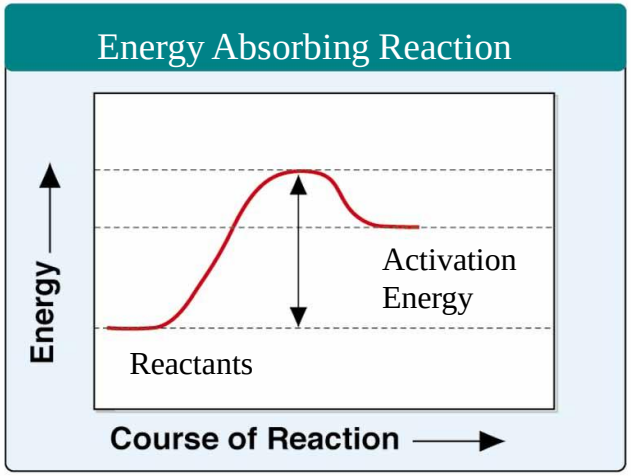
Energy Changes

- Chemical reactions that release energy often occur spontaneously.
  - Ex) hydrogen gas burning, or reacting with oxygen to produce water
    - energy is released in the form of heat
    - hydrogen gas explodes - light and sound

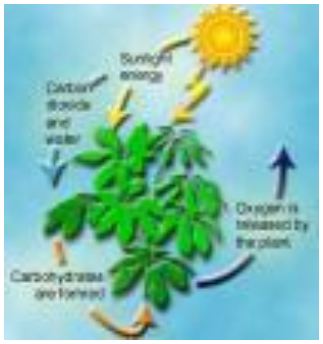


Energy Changes

- Chemical reactions that absorb energy will not occur without a source of energy.
  - Ex) water changes into hydrogen and oxygen gas
    - Must pass an electrical current through water to decompose water into hydrogen and oxygen gas



- Plants get their energy from trapping and storing sunlight and animals when they consume plants or other animals.



- Humans release energy when they metabolize, or break down, digested food.

Activation Energy

- Chemical reactions that release energy do not always occur spontaneously.
  - Ex) The cellulose in paper burns in the presence of oxygen releasing heat and light but will burn only if you light it with a match
- Activation energy is energy needed to get a reaction started.
- Activation energy is a factor in whether the overall chemical reaction releases energy or absorbs energy.

Enzymes

- Some chemical reactions are too slow or have activation energies that are too high to make them practical for living tissues.
- A catalyst is a substance that speeds up the rate of a chemical reaction.
- Catalysts work by lowering a reaction's activation energy.
- Enzymes are proteins that act as biological catalysts.

Enzymes and Substrates

- Enzymes speed up chemical reactions that take place in cells
- Enzymes are very specific, generally catalyzing only one chemical reaction.
- Enzymes provide a site where reactants can be brought together.
- This site reduces the energy needed for a reaction.

- The reactants of enzyme-catalyzed reactions are known as substrates.
- The substrates bind to a site on the enzyme called the active site
- The substrate and active site have complementary shapes and are often compared to a "lock and key".
- When the reaction is over, the enzyme is free to start the process all over again.