

Chapter 2 Chemistry

The chemical compositions of the body's structures determine their function.

- I. **Basic Chemistry** – Chemistry is the scientific discipline concerned with the *atomic* composition and structure of substances and the reactions they undergo
 - A. **Matter** – anything that occupies space and has *mass* – composition of all living and nonliving things – *atoms* (individual components) held together by energy
 - B. **Mass** – the amount of *matter* in an object (the international unit for mass is the kilogram (kg) which is a 1000 grams)
 - C. **Weight** – gravitational force acting on an object of a given *mass*

- II. **Elements and Atoms**
 - A. **Elements** – the simplest type of mater with **unique** chemical properties composed of only one *kind* of atom (112 known elements)
 - B. **Atom** – the smallest particle of an element that has the *chemical characteristics* of that element
 - * About 96% of the body's *weight* results from the elements *oxygen, carbon, hydrogen, and nitrogen*

- III. **Atomic Structure** – characteristics of all matter results from the *structure, organization and behavior* of atoms – *atoms* are composed of 3 types of subatomic particles with electric charges
 - A. **Neutrons** – have **no** electrical charge (neutral) – found in the atom's nucleus
 - B. **Protons** – have a positive electrical charge (+) – found in the atom's nucleus
 - C. **Electrons** – have a negative electrical charge (-) – have negligible as weight to the atom – are the building blocks of an atom – rotate/orbit around the nucleus in areas of limited space called orbitals (energy levels – 3 of them)
 1. **first orbital** – can hold 2 *electrons*
 2. **second orbital** - can hold 8 *electrons*
 3. **third orbital** – can hold 8 *electrons*
 - D. **Terms**
 1. **Atomic Mass Unit** (AMU) – the weight of a proton or neutron
 2. **Atomic Mass** – protons + neutrons
 3. **Atomic Number** – the number of protons in an element – used to define an element
 4. **Valence Orbital** – outer most orbital of an atom
 5. **Electron Cloud** – a representation showing the possibility of where electrons are located in an atom
 - * The number of protons and electrons in an atom are equal making the atom neutral in its electrical charge (neither positive nor negative). The protons and neutrons, which make up the nucleus, are responsible for the majority of the atom's mass/weight; however the volume of the atom is occupied by rapidly moving Electrons

- IV. **Electrons & Chemical Bonding** – chemical behavior is largely determined by *outer most electrons* (electrons located in the *valence orbital*)

- A. **Chemical Bonding** – occurs when the outer most electrons are *transferred* or *shared* between atoms – 2 major types of bonding
1. **Ionic Bonding** – is characterized by **transferred electrons** (one atom loses an electron (creating an (-) ion) and one atom gains an electron (creating an (+) ion) – the 2 oppositely charged ions are then attracted to each other and form a bond) – FYI; salt is formed this way
 - a. **Ion** – a charged particle, created by the transference of electrons – 2 kinds
 - **Cation** – carries a positive (+) charge
 - **Anion** – carries a negative (-) charge
 2. **Covalent Bonding** – characterized by the formation of **molecules** (created by the *sharing* of one or more pairs of electrons between atoms) – strongest type of bond – 3 types
 - a. **Single covalent bond** – when 1 electron pair is shared between 2 atoms – symbolized by a single dash mark (C – C)
 - b. **Double covalent bond** – when 2 electron pairs are shared between 2 atoms – symbolized by a double dash mark or equal sign (C = O)
- * High energy bonds are symbolized by a curved dash (O ~ P)
- c. **Polar covalent bond** – unequal sharing of electrons resulting in one end (pole) of the molecule having an electrical charge opposite the other end (pole)
- * Molecules with an *asymmetrical* electrical charge, caused by *polar covalent bonding*, are called **polar molecules**
- V. **Hydrogen Bonds** – weakest bond – involves *polar molecules* (created by *polar covalent bonding*) – created by the slight positive (+) and negative (-) charges at the ends (poles) of the *polar molecules* being attracted to one another (ex: **water** → formed by hydrogen bonds between **water molecules** → formed by polar covalent bonds) – FYI; in **one second** hydrogen bonds between water molecules break and reform 500 billion times
- VI. **Molecules & Compounds** – compounds can be molecules but not all molecules are compounds
- A. **Molecule** – formed by two or more atoms chemically combined to form a structure that behaves as an independent unit (ex: hydrogen molecule (H₂) made of 2 hydrogen atoms)
 - B. **Compound** – formed by two or more **types** of atoms chemically combined (ex: water molecule (H₂O) made of 2 hydrogen atoms and 1 oxygen atom)
- VII. **Dissociation** – when **ionic compounds** (compound made of electrically charged atoms called *ions*) dissolve in water (the ions **dissociate** (or separate) because the positively charged ions are attracted to the negative poles of the water molecules and the negative ions are attracted to the positive poles of the water molecules)
- A. **Solvent** – a liquid that holds other substances in solution (ex: water)
 - B. **Solute** – a substance that can be dissolved (ex: salt)
 - C. **Solution** – a homogeneous mixture
 - * **Solvent + Solute = Solution** (always *all* polar or nonpolar)
 - D. **Electrolyte** – ions that *dissociate* in water – any substance that produces ions when dissolved in water and can conduct electricity

VIII. **Chemical Reactions & Classifications** – an *interaction of* or *between* atoms, ions, molecules, and/or compounds that form or break chemical bonds – 3 classifications

A. **Terms**

1. **Reactants** – are substances entering into the chemical reaction
2. **Products** – are substances that result from the chemical reaction

B. **Synthesis Reaction** – when two or more *reactants* combine to form a larger, more complex *product* – **A + B = AB** (ex: *ATP* (adenosine triphosphate) a high energy molecule consisting of an adenosine molecule and 3 phosphate groups is *synthesized* when *ADP* (adenosine diphosphate), which is adenosine with 2 phosphate groups, is joined with another phosphate group)

C. **Decomposition Reaction** – *reactants* are broken down into smaller, less complex *products* – **AB → A & B** (*ATP → ADP & P*)

D. **Exchange Reactions** – is a combination of *decomposition* and *synthesis* – *products* are broken down (decomposed) and then recombined (synthesized) into other *products* – **AB + CD → AC & BD** (*HCl* (hydrochloric acid) + *NaOH* (sodium hydroxide) → *NaCl* (table salt) and *H₂O* (water))

IX. **Reversible Reaction** – is a chemical reaction in which the reaction proceeds from the *reactants* to *products* and *products* to *reactants* – example

(runs in one place in the body) $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$ (runs in a different place in the body)

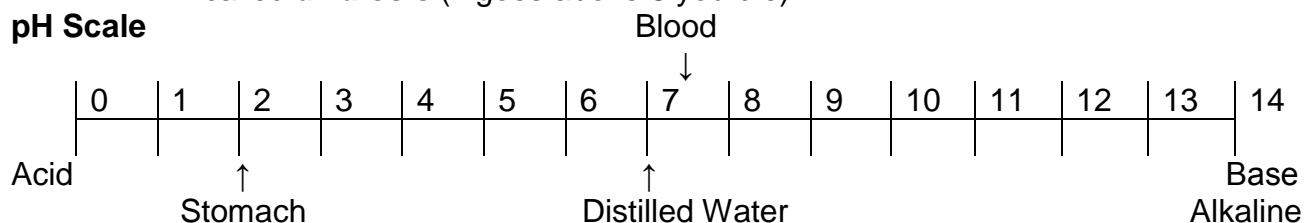
* **Equilibrium** - if *product formation* is equal to *reactant formation* - is unusual or unlikely

X. **Acids & Bases**

- A. **Acid** – is a proton donor – hydrogen without it's electron is a proton (H^+)
- B. **Base** (alkaline) – is a proton acceptor (ex: OH^- hydroxide ions)
- C. **pH** – power of hydrogen – H^+ (hydrogen ions)

XI. **pH Scale** – ranges from 0-14 and indicates the concentration of H^+ (hydrogen ions) in a solution

- A. **Neutral Solution** – has an equal number of H^+ and OH^- and has a pH of 7.0 (distilled water) ($\text{H}^+ = \text{OH}^-$)
- B. **Acid Solution** – has a pH *less than* 7.0 with a greater concentration of H^+ than OH^- (Acid = $\text{H}^+ > \text{OH}^-$)
- C. **Basic/Alkaline Solution** – has a pH *greater than* 7.0 with a lesser concentration of H^+ than OH^- (Base = $\text{H}^+ < \text{OH}^-$)
- D. **Acceptable Ranges**
 1. **Stomach** – pH between 2-4
 2. **Blood** – pH between 7.35-7.45 – blood pH below 7.35 is a condition called **acidosis** (if goes below 6.8 you die) and blood pH above 7.45 is a condition called **alkalosis** (if goes above 8 you die)



- XII. **Salts** – compound consisting of a positive ion (cation) other than H^+ and a negative ion (anion) other than OH^-
- XIII. **Buffers** – a chemical that resists changes in pH (either acid or alkaline) – helps stabilize the pH of solutions when an acid or alkaline (base) is added (ex; blood has many **bicarbonate** (HCO_3^-) as a primary buffer)
- XIV. **Inorganic Chemistry** – deals with those substances that **do not** contain *carbon* (C) – 2 exceptions
- A. **Carbon dioxide** (CO_2)
 - B. **Carbon monoxide** (CO)
- XV. **Organic Chemistry** – characterized by a series of carbon atoms bound together by *covalent* bonds creating the “back-bone” of many large molecules – 4 major groups of organic molecules essential to living organisms
- A. **Carbohydrates** – consists of *carbon* (C), *hydrogen* (H), and *oxygen* (O) in a ratio of CH_2O (ex; monosaccharides and polysaccharides)
 - B. **Lipids** – consists of C, H, O, with Phosphorus (P) and/or Nitrogen (N) in some (ex; glycerol, fatty acids)
 - C. **Proteins** – consists of C, H, O, N, with a Sulfur (S) in most **amino acids** (the building blocks of *proteins* which are the building blocks of most every thing else)
 - D. **Nucleic Acids** – (nucleotides) consists of C, H, O, N, P
- XVI. **Carbohydrates** – composed of CH_2O (in the same one-two-one ratio) – chemical formula for **glucose** (sugar) is $C_6H_{12}O_6$ arrangement of these determine the structure of type
- A. **Monosaccharide** – the smallest *carbohydrate* – simple sugar – building blocks of all *carbohydrates* – 2 kinds
 1. **Glucose** – blood sugar
 2. **Fructose** – fruit sugar > (structural isomers in different arrangements)
 3. **Galactose** – brain sugar
 - B. **Disaccharides** – created by the joining of 2 *monosaccharides* by covalent bonds called **glycoside linkages** (ex: *glucose* + *fructose* = **sucrose** (table sugar))
 - C. **Polysaccharides** – the joining of many (3 or more) monosaccharides in long chains – 3 kinds
 1. **Glycogen** (animal starch) – is broken down into glucose to be used as an energy source
 2. **Plant Starch** – can also be broken down into glucose to be used
 3. **Cellulose** – an important structure of plant cell walls – **humans can not digest**, due to *glycoside linkages*, it is eliminated in feces and provides bulk – is broken down by **cellulose** (an enzyme made by bacteria in cow’s digestive tract)
- XVII. **Lipids** – nonpolar, only broken down in nonpolar solvents (alcohol or acetone) – contain a lower portion of *oxygen* to *carbon* in the C_1H_1O bonds
- A. **Fats** – important energy storage molecules – pad and insulate the body – 2 building blocks
 1. **Glycerol** – a three carbon molecule with a **hydroxyl group** ($-OH$) attached to each carbon atom
 2. **Fatty Acid** – is a carbon chain with a **carboxyl group** ($-COOH$) attached at one end – 2 classes (one with 2 subclasses)

triglycerides <

- a. **Saturated** – contains only *single covalent bonds* between the carbon atoms
 - b. **Unsaturated** – contains one or more *double covalent bonds* between the carbon atoms
 - **Monounsaturated** – contains 1 *double covalent bond* between carbon atoms
 - **Polyunsaturated** – contains 2 or more *double covalent bonds* between carbon atoms
- B. **Triglycerides (tricylglycerols)** – most common type of fat molecule – have three *fatty acids* bound to a *glycerol* chain – formed by *dehydration synthesis* (loses a water molecule each time) – source of energy storage and protection (by insulating and padding) for the body
- C. **Phospholipids** – a diglyceride + phosphocolene molecule – similar to a *triglyceride* except that one of the *fatty acids*, bound to the *glycerol* is replaced by a molecule containing phosphorus (making the end with the phosphorus *polar* and the end with the fatty acid *nonpolar*) – used in cell membrane construction
1. **Hydrophilic** – *water loving* – the *polar* end of a phospholipid
 2. **Hydrophobic** – *water fearing* – the *nonpolar* end of a phospholipid
- D. **Steroids** – composed of carbon atoms bound together into four “ring-like” structures
1. **Cholesterol** – the most important *steroid* because other steroids are synthesized from it - also an important component of cell membranes
 2. **Bile salts** – synthesized from cholesterol – important for fat absorption in the intestines
 3. **Hormones** – chemical messengers in the body – synthesized from *cholesterol*
 - a. **Estrogen** – important to the female reproductive system
 - b. **Progesterone** – important to the female reproductive system
 - c. **Testosterone** – important to the male reproductive system
 - d. **Cortisol** – stress hormone
 - e. **Aldosterone** – produced by the adrenal glands – important in regulating sodium (Na^+) and potassium (K^+) levels in the body
 4. **Prostaglandin** – a modified *fatty acid* with a 5 carbon ring structure and a tail extending off of it (first found in prostate secretion) – made by **all** tissues (in response to damage) – ***inflammatory chemical*** (creates the ***inflammatory response*** (redness, heat, swelling, pain, and loss of function))
- XVIII. **Proteins** – contain *carbon, hydrogen, oxygen, and nitrogen* (most have some *sulfur* as well) – consist of many ***amino acids*** joined together in long chain like structures
- A. **Amino Acids** – building blocks of proteins – contain an *amine group* ($^-\text{NH}_2$) and a *carboxyl group* – 20 basic types (humans synthesize 12 of these from simple organic molecules but the other 8 (essential amino acids) must be obtained through diet)
 - B. **Protein Formation** – formed from the 20 different amino acids, joined in a chain-like structure by ***peptide bonds*** (a type of covalent bond), they differ in sequence and number of ***aa (amino acids)***

1. **Hydrogen bonds** – formed between different **aa** at different levels/areas on the chain cause the **aa** chain to fold and/or coil creating the unique three dimensional shape of the protein
 2. **Function** – protein function is dependent on the **shape** of the protein
 3. **Denature** – denaturation of a protein occurs when *hydrogen bonds* are broke causing the protein to loss it's unique shape and making it *nonfunctional* – caused by high temperatures or changes in pH
- C. **Enzymes** – are protein *catalysts* (anything that increases the rate of a chemical reaction without being changed by the reaction) – different one for each reaction – are always globular in shape – increase the chemical reaction rate by **lowering** the *activation energy* (level of energy necessary to start the chemical reaction)

***Lock and Key** – the three dimensional shape of the *enzyme* is critical for its normal function because it binds (like a fitted key into a lock) to the *reactants* bringing the *reactants* closer together which lowers the *activation energy*

- D. **ATP** (adenosine triphosphate) – is an RNA nucleotide – a high energy molecule – energy currency of the body – relies on *enzymes* (myosin ATPase) to produce/assist the reaction that releases energy through the breaking of bonds changing the *reactant* (ATP) into the *products* (ADP & P)
- E. **Structures of Proteins**
1. **Primary Structure** – created by the sequence of *amino acids* in the protein chain
 2. **Secondary Structure** – created by the *hydrogen bonds* which cause the chain to fold or coil
 3. **Tertiary Structure** – further bending and folding resulting from: ¹hydrophobic R groups associating with each other and avoiding water; ²hydrophilic R groups attraction to surrounding water – 4 kinds of bonds
 - a. **Sulfide Crosslink**
 - b. **Disulfide (salt) Bridges** – hold separate *polypeptide chains* (portion of the protein chain) together
 - c. **Hydrophobic Interactions**
 - d. **Hydrogen Bonds**
 4. **Quaternary Structure** – globular shape resulting from highly folded protein and polypeptide chains bonding together – more than one protein involved

XIX. **Nucleic Acids** – DNA and RNA

- A. **Nucleic acids** – composed of *carbon, hydrogen, oxygen, nitrogen, phosphorus* – large molecules
1. **DNA** – deoxyribonucleic acid, genetic instructions within the cells passed (copied) from one generation to another – composed of two strands of *nucleotides* joined together in a 'twisted ladder' shape called a **double helix** – creates *chromosomes* and *genes* – created in the nucleus of cells (also found in the mitochondria)
 2. **RNA** – ribonucleic acid, structurally related to *DNA* – plays an important role in protein synthesis – single strand molecule dealing with *transcription and translation* – formed by using *DNA* as a template
- B. **Nucleotides** – composed of a *nitrogenous base* (*single* or *double* carbon-nitrogen ring), a *monosaccharide* (sugar; *deoxyribose* in *DNA*, *ribose* in *RNA*), and one or more **phosphate groups**

1. **Nitrogenous bases** – governed by the ***law of complimentary base pairing***
 - 2 groups bound together by hydrogen bonds
 - a. **Pyrimidines** – have a *single* carbon-nitrogen ring
 - **Cytosine** – binds only to ***guanine*** – found in DNA & RNA
 - **Thymine** – binds only to ***adenine*** – found in DNA
 - **Uracil** – binds only to ***adenine*** – found in RNA
 - b. **Purines** – have *double* carbon-nitrogen rings
 - **Adenine** – binds only to ***thymine*** (DNA) or ***uracil*** (RNA) – found in DNA & RNA
 - **Guanine** – binds only to ***cytosine*** – found in DNA & RNA

*Chromosomes – made of chromatin (DNA) and histone (a protein that turns genes on and off). Gene (a segment of a DNA strand) – contains the instructions to create a protein (one gene per one protein).