UNIT 2 - BASIC PRINCIPLES OF BODY CHEMISTRY

LECTURE NOTES

2.01 BASIC CHEMISTRY TERMS AND CONCEPTS

A. Matter
1. All living things consist of matter.
2. Matter is anything that occupies space and has mass.
3. Matter may be solid, liquid, or gas.
4. Matter is composed of chemical building blocks called elements.
5. Examples include humans, rocks, flowers, and trees.

B. Elements
1. Are the building blocks of matter.
2. Cannot be decomposed into simpler substances by ordinary chemical reactions.
3. An element is a quantity of matter composed of atoms of the same type.
4. There are currently 109 individual elements (92 occurring naturally the rest are man-made).
5. Are designated by letter abbreviations derived from first or two letters of the Latin or English name for the element.
6. There are approximately 26 elements found in the human body.
7. Examples of the most common elements in the body include carbon, hydrogen, oxygen, and nitrogen.

C. Atoms
1. Each element made up of units called atoms.
2. It is the smallest unit of matter that can enter into a chemical reaction.
3. Atoms are made up of two basic components.
   a. Nucleus
      (1). Protons
      Protons are positively charged particles which contribute to the weight of an atom. The overall charge of the atom's nucleus is always positive. The number of protons determines the atom.
      (2). Neutrons
      Neutrons are particles that carry no charge (neutral). Help contribute to the weight of an atom.
   b. Electron Cloud
      (1). Electrons are negatively charged particles orbiting (or moving) around the nucleus.
      (2). The number of electrons always equals the number of protons in a neutral atom.
      (3). Since the protons in the nucleus of an atom are positively charged and the electrons of an atom are negatively charged, and the numbers of protons is equal to the number electrons, an atom has no charge or is electrically neutral.

D. Ions
1. Ions are atoms possessing an electrical charge due to a loss or gain of electrons.
2. Ions in solution are called electrolytes.
3. Common electrolytes in the body include sodium (Na^+), potassium (K^+), chloride (Cl^-), and calcium (Ca^{+2}).

2.02 THE FOUR MAJOR ELEMENTS IN THE BODY

There are approximately 26 elements found in the human body. The most abundant elements are carbon, hydrogen, oxygen, and nitrogen which make up 96% of the body.

2.03 COMPOUNDS AND MOLECULES

A. Molecules

A molecule is the combination of two or more atoms held together by covalent bonds.
1. May be two atoms of the same element such as H_2, and O_2.
2. May be two atoms of different elements such as NaCl (salt) and HCl (hydrochloric acid)

B. Compounds

A compound is any substance composed of atoms of two or more different elements that are chemically combined such as water or H_2O. Most matter is in the form of compounds. All compounds are molecules, but not all molecules are compounds.

2.04 DIFFERENTIATE BETWEEN A CATION AND AN ANION

A. Cation

A cation is formed when an atom loses an electron or electrons to another atom creating an overall positive charge. Example: Na^+

B. Anion

An anion is formed when an atom gains an electron or electrons from another atom creating an overall negative charge. Example: Cl^-

2.05 DESCRIBE THE CHARACTERISTICS OF IONIC, COVALENT, AND HYDROGEN BONDS

When atoms bond with other atoms, they share electrons with other atoms or they gain or lose electrons. The electrons are arranged in shells around the nucleus. The goal for each atom is to complete their outer electron shell in order for them to become stable.

A. Ionic Bonding
1. Ionic bonding is an attraction between atoms when one atom loses an electron(s) and another atom gains an electron(s).

2. The bond is formed by the attraction of two oppositely charged ions. (The bond forms between a cation and an anion).
3. Example: Na^+ + Cl^- = NaCl
4. Ionic bonding is the strongest type of chemical bond.

B. Covalent Bonding
1. Covalent bonding is the sharing of electron pairs by two or more atoms.
2. A single covalent bond is formed by the sharing of one pair of electrons.
3. A double covalent bond is formed by the sharing of two pairs of electrons.
4. A triple covalent bond is formed by the sharing of three pairs electrons.
5. Covalent bonding is responsible for forming long carbon chains which become the backbone of the organic compounds (carbohydrates, lipids, proteins, nucleic acids).

C. Hydrogen Bonds
1. Hydrogen bonds are created by the covalent bonding of two other atoms (usually oxygen or nitrogen) to a hydrogen atom.
2. The bonds are very weak (only 5% as strong as a normal covalent bond).
3. They often serve as bridges between molecules. (Example: The bridges formed between the amino acids in myoglobin).

2.06. DEFINE pH

A. pH is the term used to describe the degree of acidity or alkalinity determined by the relative amounts of H^+ and OH^- found in a solution.

B. Biochemical reactions are extremely sensitive to small changes in the acidity or alkalinity of the environment in which they occur.

2.07. CATEGORIZE THE pH OF A SOLUTION

A. pH Scale
The pH scale has values ranging from 0-14. It is determined primarily upon the number of hydrogen ions (H^+) or hydroxyl ions (OH^-) in a solution.

B. Classifying Solutions Based on pH
1. An acidic solution forms hydrogen ions, H^+, when in solution. On the pH scale, the numbers are below 7.0. Examples include lemons or HCl with a pH of 2.0, tomatoes with a pH of 4.0 or milk with a pH of 5.0.
2. A neutral solution has a pH of 7.0. The best example is distilled water.
3. A basic (or alkaline) solution forms hydroxide ions (OH-) when in solution. The pH scale numbers are above 7.0. Examples include eggs with a pH of 8.0 and drain cleaner with a pH of 13.0.

2.08. pH RANGE OF THE BLOOD

A. The neutral pH is 7.O such as distilled water.

B. The average pH of the blood is slightly basic and ranges from 7.35-7.45.

2.09. PROPERTIES AND CHARACTERISTICS OF WATER

A. Water is the universal solvent which provides an excellent suspension medium for the transport of nutrients and wastes.

1. Solvent
   A solvent describes a liquid or gas in which some other material has been dissolved.
2. Solute
   The solute is the atom, molecule, or compound that has been dissolved in a solvent.
3. Solution
   A solution is the combination of a solvent and solution.

B. Water serves as a transport medium and facilitates the movement of molecules through the body (circulation).

C. Water serves as a lubricant reducing friction and holding substances together in many areas of the body. Water is a major component of blood plasma, mucous, saliva, bile, amniotic fluid, synovial fluid, and serous fluid.

D. Water absorbs and releases heat very slowly which makes it vital in regulating body temperature.

E Water is needed in the process of digestion or the breaking apart of larger molecules into smaller ones.

F. Water is important in removing waste products from the body.

2.10. CHARACTERISTICS OF INORGANIC AND ORGANIC COMPOUNDS

A. Inorganic Compounds
1. Generally lack carbon atoms. If the compound contains carbon, it does not contain both carbon and hydrogen atoms.
2. Vital to normal body physiological functioning.
3. Many inorganic molecules are ionically bonded together.
4. Examples include carbon dioxide, water, and oxygen.

B. Organic Compounds
1. Contain both carbon and hydrogen atoms.
2. Almost exclusively held together by covalent bonds.
3. Carbon atoms can bond together to form long chains and large molecules.
4. Examples include carbohydrates, lipids, proteins and nucleic acids.

2.11 DESCRIPTION OF ORGANIC COMPOUNDS

A. Carbohydrates - also known as Sugars and Starches
   1. Structure of Carbohydrates
      a. Carbohydrate molecules have 2:1 ratio of hydrogen to oxygen.
      b. The general formula for carbohydrates is $(CH_2O)n$.

   2. Functions of Carbohydrates
      a. Provide structural units found in DNA and in the cell membrane
      b. Provide the major energy source for the body.
      c. Each gram of carbohydrate provides 4.5 Kcalories.
      d. Only energy source for brain and nerve cells.
      e. Blood sugar is known as glucose.

B. Lipids (Fats)
   1. Structure of Lipids
      a. Lipids are generally insoluble in water.
      b. Lipids do not have a 2:1 hydrogen to oxygen ratio.
      c. The most common form of lipids is the triglycerides, which are composed of two molecular sub-units: glycerol and fatty acids
   2. Functions of Lipids
      a. Provide the most highly concentrated source of energy by providing the body with 9.2 Kcalories per gram.
      b. Provide the body with its second source of energy.
      c. Protect body organs.
      d. Provide insulation and warmth for the body.
      e. Absorb the fat-soluble vitamins - A, D, E, K.
      f. Form hormones such as the sex hormones and steroids.
      g. Form the phospholipid bilayer of cell membranes.

C. Proteins
   1. Structure of Proteins
      a. All proteins contain the atoms C, H, O, and N.
      b. Many proteins also contain S and P.
      c. Proteins are composed of building blocks known as amino acids.
      d. There are 20 amino acids which make up all known proteins.
      e. Amino acids are bonded to one another by peptide bonds (nitrogen bonds).
   2. Functions of Proteins
      a. Responsible for much of the structure o f body tissues including cell membranes, collagen, keratin, and elastin.
      b. Form enzymes which act as catalysts in chemical reactions to speed up the rate of reactions such as digestion.
      c. Functions as antibodies to help the body fight infection.
      d. Forms hormones which act as chemical regulators for growth and development.

e. Regulate the osmotic pressure of blood and blood clotting.
f. Serve as storage molecules (ferritin).
g. Function as transport molecules (hemoglobin).
h. Form the contractile proteins actin and myosin.
i. Form neurotransmitters to help the nerves communicate with other nerves or muscle fibers.

D. Nucleic Acids

Nucleic Acids are commonly known as DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

1. Structure of Nucleic Acids
    a. All nucleic acids contain the atoms C, H, O, N, and P.
    b. Nucleic acids are composed of nucleotides. A nucleotide is formed by a sugar (deoxyribose or ribose), a phosphate, and a nitrogen base.
2. Function of Nucleic Acids
    a. DNA stores the genetic code within structures called chromosomes. They are found within the nucleus of the cell.
    b. DNA and RNA assist with protein synthesis.
    c. RNA is responsible for transporting the genetic code from the DNA in the nucleus to the ribosomes where the needed proteins are synthesized by bonding the appropriate amino acids together.
3. Structure of DNA
    a. DNA is formed by a double helix of nucleotides.
    b. Nitrogen bases are paired together (A-T) and (C-G). The sequence of the nitrogen bases determine the amino acids to be used in the forming of a new protein. The nitrogen bases form the rungs of the DNA molecule.
    c. The four nitrogen bases found in DNA include:
        (1). adenine (A)
        (2). thymine (T)
        (3). cytosine (C)
        (4). guanine (G)
    d. The sugar is deoxyribose. The nitrogen base is attached to the deoxyribose. The deoxyribose helps to form the sides of the helices.
    e. The sides of the double helix contain a phosphate group which alternates with the deoxyribose forming the sides of the helices.

4. Structure of RNA
   a. RNA is formed by a single helix of nucleotides. A nucleotide is composed of a sugar, a phosphate, and a nitrogen base.
   b. Nitrogen bases are paired together (A-U) and (C-G). The sequence of the nitrogen bases determine the amino acids to be used in the protein. The nitrogen bases form the rungs of the RNA molecule.
   c. The four nitrogen bases of RNA include:
      (1). adenine (A)
      (2). uracil (U)
      (3). cytosine (C)
      (4). guanine (G)
   d. The sugar is ribose. The nitrogen base is attached to the ribose and helps to form the side of the helix.
   e. The side of the helix contains a phosphate group which alternates with the ribose forming the backbone.

2.12 ATP AND ENERGY CONVERSION

A. Adenosine Triphosphate (ATP)
   1. Found in all living organisms.
   2. ATP is a high energy compound that drives most chemical reactions.
   3. ATP is produced by body cells in a process known as cellular respiration. This involves the breaking down of glucose in a series of chemical reactions. The chemical reactions occur within the cytoplasm and the mitochondria of cells.

B. Structure of ATP
   ATP is formed by an adenosine unit (adenine and a five carbon sugar, ribose), and three phosphate groups.

C. Energy is released when the terminal phosphate group is removed by the addition of a water molecule (hydrolysis).

E. The reaction for ATP synthesis and destruction is a reversible reaction.
   ATP ↔ ADP + P + energy