Chemistry Comes Alive
Outline

Part 1: Basic Chemistry

2.1 Matter is the stuff of the universe and energy moves matter (pp. 23–25)

A. Matter is anything that occupies space and has mass (p. 24).
   1. The mass of an object is equal to the amount of matter in the object.

B. Matter exists in one of three states: solid, liquid, or gas. (p. 24)

C. Energy is the capacity to do work, and exists in two forms: potential (inactive)
energy, and kinetic (active) energy. (p. 24)
   1. Energy exists in several forms:
      a. Chemical energy is stored in chemical bonds, such as the bonds in food molecules.
      b. Electrical energy results from the movement of charged particles, as when ions move across cell membranes.
      c. Mechanical energy is energy directly involved with moving matter: Consider legs pedaling a bicycle.
      d. Radiant energy is energy that travels in waves: light, for example.
   2. Energy is easily converted from one form to another, although some energy is lost to the environment in doing so.

II. Composition of Matter: Atoms and Elements

2.2 The properties of an element depend on the structure of its atoms (pp. 25–28; Figs. 2.1–2.3; Table 2.1)

A. Elements are unique substances that cannot be broken down into simpler substances. (p. 24; Table 2.1)
   1. Four elements—carbon, hydrogen, oxygen, and nitrogen—make up roughly 96% of body weight.
   2. Each element is composed of atoms: mostly identical building blocks.
   3. There are 118 elements recognized; each is designated by a one- or two-letter abbreviation called the atomic symbol.

B. Atomic Structure (pp. 25–26; Figs. 2.1–2.2)
   1. Each atom has a central nucleus made up of protons and neutrons.
      a. Protons have a positive charge, while neutrons have no charge, giving the nucleus a net positive charge.
      b. N Protons and neutrons each weigh 1 atomic mass unit.
   2. Electrons occupy random positions within orbitals surrounding the nucleus, have a negative charge, and weightless 0 atomic mass units.

C. Identifying Elements (pp. 27–28; Fig. 2.3)
   1. Elements are identified based on their number of protons, neutrons, and electrons.
   2. The atomic number of an element is equal to the number of protons of an element; the number of electrons always equals the number of protons.
   3. The mass number of an element is equal to the number of protons plus the number
   of neutrons.
   4. Each element has isotopes, structural variations of an atom that have the same number of protons, but different numbers of neutrons.

5. The atomic weight of an element is a weighted average of the weight's mass numbers of all known isotopes of an element, based on their relative abundance in nature.
6. Radioisotopes are heavier, unstable isotopes of an element that spontaneously
   decompose into more stable forms, producing radioactivity.
   a. The time for a radioisotope to lose one-half of its radioactivity is called the half-life.

2.3 Atoms bound together form molecules; different molecules can make mixtures (pp. 28–30; Fig. 2.4)

A. Molecules and Compounds (pp. 28–29)
   1. A combination of two or more atoms is called a molecule.
   2. A combination of two or more of the same atoms is a molecule of an element: a combination of two or more different atoms is a molecule of a compound.

B. Mixtures (pp. 29–30; Fig. 2.4)
   1. Mixtures consist of two or more substances that are physically mixed.
   2. Solutions are homogeneous mixtures of compounds that may be gases, liquids, or solids.
      a. The substance present in the greatest amount (usually a liquid) is called the solvent, while substances dissolved in the solvent are called solutes.
      b. Solutions may be described by their concentrations, often expressed as a percent, or molarity.
   3. Colloids (emulsions) are heterogeneous mixtures that often appear milky and have larger solute particles that do not settle out of solution.
   4. Suspensions are heterogeneous mixtures with large, often visible solutes that will settle out of solution.

C. Distinguishing Mixtures from Compounds (p. 30)
   1. In mixtures, no chemical bonding occurs between molecules; they can be separated into their chemical components by physical means, and may be heterogeneous.
   2. In compounds, chemical bonding is possible between molecules, chemical processes are required to separate the components, and they are only homogenous.

2.4 The three types of chemical bonds are ionic, covalent, and hydrogen (pp. 30–35; Figs. 2.5–2.10)

A. A chemical bond is an energy relationship between the electrons of the reacting atoms
   (p. 30; Fig. 2.5).
   1. The Role of Electrons in Chemical Bonding (p. 31)
      a. Electrons occupy specific energy levels surrounding the nucleus, and each energy level holds a specific number of electrons.
      b. Electrons fill energy levels beginning closest to the nucleus and progress outward.
      c. The octet rule states that the maximum number of electrons available for bonding in the outer, or valence, shell is eight.
      d. The octet rule, or rule of eights, states that the maximum number of electrons
         available for bonding in the outer, or valence, shell is eight; except for the first

energy shell (stable with two electrons), atoms are stable with eight electrons in their outermost (valence) shell.

B. Ionic bonds are chemical bonds that form between two atoms that transfer one or more electrons from one atom to the other. (p. 32; Figs. 2.6, 2.9)
   1. The atom that receives the electron takes on a negative charge and becomes an anion, while the atom that loses the electron acquires a positive charge, becoming a cation.
      a. Most ionic compounds form salts, and when dry, form crystals that are held together by ionic bonds.
      b. Covalent bonds occur when pairs of atoms share electrons, and atoms may share one, two, or three pairs of electrons, forming single, double, or triple bonds. (pp. 32–33, Figs. 2.7–2.9)
   2. Covalent bonds may be either nonpolar, sharing their electrons equally, or polar,
      sharing their electrons unevenly.
      a. Nonpolar molecules have a balanced distribution of the shared electrons' charge across the bond.
      b. In polar molecules, electrons are more attracted to one atom (an electronegative atom) than the other (an electropositive atom), resulting in the area of the bond closest to the electronegative atom assuming a partial negative charge, while the area close to the electropositive atom takes on a partial positive charge.
      c. A polar molecule is often referred to as a dipole due to the two poles of charges contained in the molecule.

C. Hydrogen bonds are formed when a hydrogen that is covalently bonded to one atom (often oxygen or nitrogen) is attracted to another electronegative atom, forming a sort of "bridge."
   1. Hydrogen bonding is responsible for molecular attractions between water molecules that create surface tension.
   2. Hydrogen bonds are responsible for stabilizing the three dimensional shapes of large molecules.

2.5 Chemical reactions occur when electrons are shared, gained, or lost (pp. 35–38; Fig. 2.11)

A. A chemical equation describes what happens in a reaction by indicating number and type of reactants, chemical composition of the products, and the relative proportion of each reactant and product (if balanced). (p. 35)

B. Types of Chemical Reactions (pp. 36–37; Fig. 2.11)
   1. Synthesis (combination) reactions involve formation of chemical bonds and are the basis of anabolic, or constructive, processes in cells.
   2. In a decomposition reaction, a molecule is broken down into smaller molecules by breaking chemical bonds, and is a degradative, or catabolic, process.
   3. Exchange (displacement) reactions involve both synthesis and decomposition
      reactions, and involve parts of reactants "trading places," forming new products.
   4. Oxidation-reduction reactions are special exchange reactions in which electrons are exchanged between reactants: the molecule losing electrons is oxidized, and the
      molecule receiving the electrons is reduced.

C. Energy Flow in Chemical Reactions (p. 37)

1. In exergonic reactions (often catabolic or oxidative reactions), energy is released, producing products that have lower potential energy than the reactants, while endergonic reactions (often anabolic reactions) result in products that contain more potential energy than the reactants.

D. Reversibility of Chemical Reactions (p. 37)
1. Reversible reactions are indicated by double arrows pointing in opposite directions.
2. A chemical equilibrium occurs when the rate of the forward reaction equals the rate of the reverse reaction, resulting in no net change in the amount of reactants or products, and is shown by the presence of arrows of equal length in the chemical equation.

E. Factors Influencing the Rate of Chemical Reactions (pp. 37–38)
1. Chemicals react when they collide with enough force to overcome the repulsion by their electrons.
2. An increase in temperature increases the rate of a chemical reaction by increasing the kinetic energy of the molecules.
3. Higher concentrations of reactants result in a faster rate of reaction because the likelihood of collisions between molecules increases.
4. Higher concentrations of reactants result in a faster rate of reaction. Smaller molecules move faster, and tend to collide more frequently, increasing the rate of a reaction.
5. Catalysts increase the rate of a chemical reaction without taking part in the reaction.

PART 2: BIOCHEMISTRY

2.6 Inorganic compounds include water, salts, and many acids and bases (pp. 38–41; Figs. 2.12–2.13)

A. Water (p. 38)
1. Water is the most important inorganic molecule, and makes up 60–80% of the volume of most living cells.
2. Water has a high heat capacity, meaning that it absorbs and releases a great deal of heat before it changes temperature.
3. Water has a high heat of vaporization, meaning that it takes a great deal of energy (heat) to break the bonds between water molecules.
4. Water, called the universal solvent, is a polar molecule that plays a role in dissociation of ionic molecules, forms hydration layers that protect charged molecules from other charged particles, and functions as an important transport medium in the body.
5. Water is an important reactant in many chemical reactions.
6. Water forms a protective cushion around organs of the body.

B. Salts (pp. 38–39; Fig. 2.12)
1. Salts are ionic compounds containing cations other than H^+ and anions other than the hydroxyl (OH^-) ion that dissociate in water into their component ions when dissolved.
2. All ions are electrolytes that conduct electrical currents in solution, an important feature to body functions.

C. Acids and Bases (pp. 39–41; Fig. 2.13)
1. Acids, also known as proton donors, have a sour taste and dissociate in water to yield hydrogen ions and anions.
2. Bases, also called proton acceptors, taste bitter, feel slippery, and absorb hydrogen ions.
3. The relative concentration of hydrogen ions is measured in concentration units called pH units.

a. The greater the concentration of hydrogen ions in a solution, the more acidic the solution, and the pH value is lower.
b. The greater the concentration of hydroxyl ions (lower H^+ concentration), the more basic, or alkaline, the solution, resulting in a higher pH value.
c. The pH scale extends from 0–14. A pH of 7 is neutral; a pH below 7 is acidic; a pH above 7 is basic or alkaline.

4. Neutralization occurs when an acid and a base are mixed together, creating displacement reactions that form a salt and water.
5. A buffer is combination of a weak acid and weak base that resists large fluctuations in pH that would be damaging to living tissues by releasing H^+ when pH rises, and binding up H^+ when pH drops.

2.7 Organic compounds are made by dehydration synthesis and broken down by hydrolysis (pp. 41–42; Fig. 2.14)

A. Carbohydrates, lipids, proteins, and nucleic acids are molecules unique to living systems, and all contain carbon, making them organic compounds (pp. 41–42).

2.8 Carbohydrates provide an easily used energy source for the body (pp. 42–44; Fig. 2.15)

A. Carbohydrates are a group of molecules, classified as either monosaccharides, disaccharides, or polysaccharides, that contain carbon hydrogen and oxygen, and include sugars and starches. (pp. 42–43)
B. Monosaccharides are simple sugars, named for the number of carbons they contain, that are single-chain or single-ring structures. (p. 43)
C. Disaccharides are formed when two monosaccharides are joined by dehydration synthesis. (p. 43)
D. Polysaccharides are long chains of monosaccharides linked together by dehydration synthesis: two biologically important polysaccharides are starch and glycogen. (p. 44)
E. In the body, carbohydrates are primarily used as an energy source. (p. 44)

2.9 Lipids insulate body organs, build cell membranes, and provide stored energy (pp. 44–47; Fig. 2.16; Table 2.2)

A. Lipids are insoluble in water, but dissolve readily in nonpolar solvents, and include triglycerides, phospholipids, steroids, and other lipoid molecules. (p. 45)
B. Triglycerides, called neutral fats, consist of glycerol (a sugar alcohol), and fatty acids (linear hydrocarbon chains). (pp. 45–47)
   1. Triglycerides are found mainly beneath the skin, and serve as insulation and mechanical protection.
   2. The fatty acids may be either saturated, having only single bonds between adjacent carbons, or unsaturated, bearing at least one double bond between a pair of carbons in the chain.
C. Phospholipids are diglycerides with a phosphorus-containing group and two fatty acid chains that are primarily used to construct cell membranes. (p. 47) Steroids, including cholesterol, are flat molecules made up of four interlocking hydrocarbon rings and are used in the body in cell membranes and hormones.
D. Eicosanoids are derived from arachidonic acid, and function in blood clotting, and regulation of blood pressure, inflammation, and labor contractions. (p. 47)

2.10 Proteins are the body's basic structural material and have many vital functions (pp. 47–52; Figs. 2.17–2.20; Table 2.3)

A. Proteins are the basic structural material of the body and play vital roles in cell function. (p.47)
B. Proteins are long chains of amino acids connected by peptide bonds, which join the amine of one amino acid to the acid of the next. (p. 48)
C. The structure of proteins has four structural levels: (p. 48)
   1. The linear sequence of amino acids is the primary structure.
   2. Proteins twist and turn on themselves to form a more complex secondary structure; either spiraled α- helices or β- pleated sheets.
   3. A more complex structure is tertiary structure, resulting from protein folding upon itself to form a ball-like structure.
   4. Quaternary structure results from two or more polypeptide chains grouped together to form a complex protein.
D. Fibrous and Globular Proteins (p. 49)
   1. Fibrous proteins are extended, strand-like, insoluble molecules that provide mechanical support and tensile strength to tissues.
   2. Globular proteins are compact, spherical, water-soluble, and chemically active molecules that oversee most cellular functions.
E. Protein denaturation is a loss of the specific three-dimensional structure of a protein, leading to a potential loss of function, that may occur when globular proteins experience changes in environmental factors such as temperature and pH. (pp. 49–50)
F. Enzymes and Enzyme Activity (pp. 51–52)
   1. Enzymes are globular proteins that act as biological catalysts, enabling biological processes to happen quickly enough to support life.
   2. Enzymes may be purely protein or may consist of two parts, the protein apoenzyme and non-protein cofactor, that are collectively called a holoenzyme.
   3. Each enzyme is chemically specific, binding only certain substrates, and possesses an active site, the location on the protein that catalyzes the reaction.
   4. Enzymes work by lowering the energy required by a reaction, the activation energy.

2.11 DNA and RNA store, transmit, and help express genetic information (pp. 52–54; Fig. 2.21; Table 2.4)

A. Nucleic acids have two primary classes: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). (p. 52)
B. Nucleotides are the structural units of nucleic acids, and consist of three components: a pentose sugar, a phosphate group, and a nitrogen-containing base. (p. 52)
C. Five nitrogenous bases are used in nucleic acids: two large, double-ringed purines, adenine (A) and guanine (G), and three smaller, single-ring pyrimidines, cytosine (C), uracil (U), and thymine (T). (p. 53)
D. DNA is the genetic material of the cell and is found within the nucleus. (p. 54)
   1. DNA has two primary roles: it replicates itself before cell division and provides instructions for making all of the proteins found in the body.
   2. The structure of DNA is a double-stranded polymer containing the nitrogenous bases adenine, thymine, guanine, and cytosine, and the sugar deoxyribose.

3. Bonding of the nitrogenous bases in DNA occurs between complementary pairs: A bonds to T, and G bonds to C.

E. RNA is located outside the nucleus and is used to make proteins using the instructions provided by the DNA. (p. 54)

1. The structure of RNA is a single-stranded polymer containing the nitrogenous bases A, G, C, and U, and the sugar ribose.
2. In RNA, complementary base pairing occurs between G and C, and A and U.

2.12 ATP transfers energy to other compounds (pp. 54–55; Figs. 2.22–2.23)

A. ATP is the primary energy transfer molecule used in the cell. (p. 54)

B. ATP is an adenine-containing RNA nucleotide that has two additional phosphate groups attached, connected by high-energy bonds. (p. 54)

C. Energy is transferred from ATP to other systems in cells by removing the terminal phosphate from ATP and binding it to other compounds, a process called phosphorylation.
(p. 55)