CHAPTER 2:

CHEMICAL BASIS OF LIFE

**2.1 Introduction**

Learning Outcome 1: Give examples of how the study of living material requires an understanding of chemistry.

1. Lecture Suggestions and Guidelines
   1. Discuss what is meant by the term *chemicals*.
2. Application Question(s)
   1. Provide the students with a description (or photo) of a meal.

Answer: Answers will vary depending upon the meal. An example might be a breakfast of orange juice, coffee, toast with butter, and salted eggs. The chemicals in these foods include water (OJ, coffee), caffeine (coffee), fat (butter, egg yolk), carbohydrate (toast), salt, and proteins (egg white).

1. Critical Thinking Issue(s)
   1. Debate whether or not chemicals are safe to use.

Answer: Answers will vary. Students might consider organic vs inorganic produce, carcinogens in products such as shampoos and lotions, natural grass-fed vs. hormone-induced meats, consumption of too much water in a short amount of time.

**2.2 Fundamentals of Chemistry**

Learning Outcome 1: Describe the relationships among matter, atoms, and molecules.

1. Lecture Suggestions and Guidelines
   1. Discuss the relationship between matter and elements.
   2. Describe which elements are most common in the human body.
2. Application Question(s)
   1. Provide students with a copy of the periodic table of elements. Choose 50 of the most common element symbols and ask students to make a set of flash cards that indicate the element name on one side and the element symbol on the other.

Answer: Repetition is the key word. Students should become very familiar with elements and their symbols. Quiz the students often.

* 1. Have students work in small groups with each group receiving a set of these 50 flashcards, and ask the students to determine which of these elements are most common in the human body.

Answer: Students should determine that the following elements are in their pile of most common in the human body: oxygen, caron, hydrogen, nitrogen, calcium, phosphorus, potassium, sulfur, sodium, and magnesium. They might also include the trace elements: chromium, cobalt, copper, fluorine, iodine, iron, manganese, and zinc.

1. Critical Thinking Issue(s)
   1. Ask students to examine a copy of the periodic table of elements. Choose a particular column or row, and ask students to comment on any relationships among the elements you have chosen.

Answer: For example, all of the elements in column 1 (Group IA) have one electron in their outer orbit. These elements tend to donate this outer electron to form an ionic bond with other elements seeking to receive an electron. Also, since the number of protons increases as we proceed down the column, the atomic mass will also increase.

b) Ask students to give some common uses of the major minerals found in the human body.

Answer: Calcium - bone formation, tooth structure, transmission of nerve impulses, blood clotting mechanisms; Phosphorus - acid/base balance, bone formation, tooth structure; Potassium - muscle and nerve function, water balance; Sulfur - chemical component of many substances, including proteins; Chorine - acid/base balance, water balance; Sodium - muscle and nerve function, water balance; Magnesium - used in the formation of several enzymes.

Learning Outcome 2: Describe the general structure of an atom.

1. Lecture Suggestions and Guidelines
   1. Introduce the concept of electrons, protons, and neutrons and their locations.
2. Application Question(s)
   1. Ask students to indicate the number of protons, electrons, neutrons in each common element, and include their atomic mass.

Answer: oxygen (p-8,n-8,e-8,atomic mass=16.00), sodium (p-11,n-12,e-11,atomic mass=22.99), and so on.

1. Critical Thinking Issue(s)
   1. Radiation is often used as a form of therapy to treat certain cancers, such as breast and protate cancers. Ask students to research then discuss how radiation works to help treat cancer.

Answer: Ultimately, student should discover that radiation therapy uses high doses of radiation to slow down their growth by targeting and breaking down their DNA, which ultimately kills the cells and shrinks the tumors.

**2.3 Bonding of Atoms**

Learning Outcome 1: Describe how atomic structure determines how atoms interact.

1. Lecture Suggestions and Guidelines
2. Briefly introduce the concept of electron shells.
3. Define *ions*.
4. Application Question(s)
   1. Give students flashcards that each contain an ion common in the human body, such as Na+, Cl-, Ca2+, PO43-, H+, HCO3-, K+, and ask them to categorize the ions into one of two categoriesCations or Anions.

Answer: Cations = Na+, Ca2+, H+, K+; Anions = Cl-, PO43-, HCO3-

Learning Outcome 2: Identify the three types of bonding.

1. Lecture Suggestions and Guidelines
2. Describe an ionic bond.
3. Describe a covalent bond.
4. Describe a hydrogen bond.
5. Application Questions(s)
   1. Give students the following descriptionsand have them determine the type of bonding that is taking place: Adding salt crystals to chicken noodle soup; combining olive oil and avocado oil for dipping bread; a water molecule; water.

Answer: Adding salt crystals to chicken noodle soup = ionic bonding; combining olive oil and avocado oil for dipping bread = nonpolar covalent bonding; a water molecule = polar covalent bonding; water = hydrogen bonding.

Learning Outcome 3: Describe the difference between ionic and covalent bonding.

1. Lecture Suggestions and Guidelines
   1. Distinguish between covalent and ionic bonds.
   2. Give examples of single and double covalent bonds.
   3. Distinguish between polar and nonpolar covalent bonds.
2. Application Question(s)
   1. Rest a paperclip on top of a glass full of water and show this to students. Ask students to explain what prevents the paperclip from sinking.

Answer: Students should explain that water molecules are held together by polar covalent bonds. Because of the slight charged ends, these water molecules form hydrogen bonds between them, where the slightly positive charged hydrogen of one wate molecule forms a bond with the slightly negative changed oxygen of another water molecule, and so on. The cohesiveness of the hydrogen bonding of water molecules to form water, produce a force at the surface called surface tension, as the water molecules slowly evaporate at the air-water interface. This surface tension allows the paperclip to stay afloat. This is also how certain insects, such as water striders, are able to walk on water.

1. Critical Thinking Issue(s)
   1. In premature neonates, the air sacs (alveoli) of their lungs may contain too much water because certain cells in the lungs are not yet developed to produce a surfactant that weakens the molecular forces of hydrogen bonding. Ask students to discuss the effect of this condition as it relates to the cohesion property of water.

Answer: With a deficiency of surfactant, the surface tension created by the hydrogen bonding of water molecules would make it difficult if not impossible for the air sacs to expand (open). This would lead to respiratory distress. In these situations, medical personnel would give the neonate surfactant which would enable the air sacs to expand and collapse normally during breathing.

**2.4 Molecules, Compounds, and Chemical Reactions**

Learning Outcome 1: Explain how molecular and structural formulas symbolize the composition of compounds.

1. Lecture Suggestions and Guidelines
   1. Define *molecules* and *compounds*.
   2. Give examples of common compounds.
   3. Discuss molecular and structural formulas.
2. Application Question(s)
   1. Prepare ball-and-stick models of several simple molecules and compounds. Ask students to identify them based on the combination of elements the models contain.

Answer: Some examples include water, carbon dioxide, glucose, and methane.

1. Critical Thinking Issue(s)
   1. Provide students with a number of common compounds. Based on the information learned in this chapter, ask them to identify which elements are present in each.

Answer: Examples may include sucrose, baking soda, ethyl alcohol, natural gas, aspirin, human blood, table salt, etc.

Learning Outcome 2: Describe three types of chemical reactions.

1. Lecture Suggestions and Guidelines
   1. Introduce chemical reactions as reactions that form or break bonds between atoms, ions, or molecules, generating new chemical combinations.
   2. Give examples of synthesis, decomposition, exchange, and reversible reactions.
   3. Describe the role of catalysts.
2. Application Question(s)
   1. Provide students with a number of examples of chemical reactions and ask them to determine whether the reaction would be considered synthesis, decomposition, or exchange.

Answer: An example of a synthesis reaction would include iron + oxygen gas yields iron (III) oxide, or rust. Another example of a synthesis reaction is sodium oxide + water yields sodium hydroxide. An example of a decomposition reaction would be potassium chlorate decomposing to yield potassium chloride and oxygen. Another example is calcium hydroxide decomposing to form calcium oxide and water. An example of a simple exchange reaction would be zinc + copper (II) sulfate reacts to yield copper + zinc sulfate.

1. Critical Thinking Issue(s)
   1. Glucose is converted to carbon dioxide and water within body cells. Ask students to describe which type of chemical reaction this is. Then, briefly describe to students the intermediate steps involved in this reaction.

Answer: Glucose is first converted into glucose-6-phosphate, which is broken down by catalysts into pyruvate. Pyruvate is decomposed to carbon dioxide and water by a sequence of reactions requiring oxygen.

**2.5 Acids and Bases**

Learning Outcome 1: Define *acids*, *bases*, and *buffers*.

1. Lecture Suggestions and Guidelines
   1. Describe acids as electrolytes that release hydrogen ions in water.
   2. Describe bases as electrolytes that release ions that bond with hydrogen ions.
   3. Give examples of acids and bases in the human body.
   4. Discuss how buffers resist chemical change.
2. Application Question(s)
   1. Ask students to complete a chart that illustrates the reaction of table salt dissolved in water.

Answer: The chart should contain information demonstrating the release of sodium ions and chloride ions in water.

1. Critical Thinking Issue(s)
   1. Ask students to discuss the effects of electrolyte imbalance on homeostasis.

Answer: Responses will vary, but should include, at a minimum, a discussion of sodium, chloride, potassium, and bicarbonate.

Learning Outcome 2: Define *pH* and be able to use the pH scale.

1. Lecture Suggestions and Guidelines
   1. Introduce the terms acids, bases, and electrolytes, and give examples of each.
   2. Describe pH as a value that measures hydrogen ion concentration.
   3. Discuss the pH scale.
   4. Briefly describe the terms acidosis and alkalosis.
2. Application Question(s)
   1. Ask students to draw a pH scale and label it with 10 examples of common substances based on their pH.

Answer: The scale should be labeled from 0 to 14, with 7 being neutral. All substances that fall below 7 are considered to be acidic; all substances with a pH of greater than 7 are considered to be basic, or alkaline. It should be noted that there is a tenfold increase in hydrogen ion concentration when the pH decreases by one whole number, and a tenfold increase in the hydroxyl ion concentration when the pH increases by one whole number.

1. Critical Thinking Issue(s)
   1. Ask students to describe the implications when the pH of human blood falls below or rises above normal ranges. What is the normal range for blood pH? Is this range considered to be acidic or alkaline? Why?

Answer: The normal pH range of human blood is approximately 7.35 to 7.45. When the blood’s pH falls below this level, a patient is in acidosis. When the pH rises above this range, the patient is experiencing alkalosis. Either abnormality may be clinically significant. Human blood is slightly alkaline in nature, since its pH is above 7.0, or neutral.

**2.6 Chemical Constituents of Cells**

Learning Outcome 1: List the major inorganic chemicals in cells and identify the functions of each.

1. Lecture Suggestions and Guidelines
   1. Describe water as the most abundant compound in living matter.
   2. Introduce the roles of oxygen and carbon dioxide in the human body.
   3. Give examples of common inorganic salts found in the body.
   4. Discuss how electrolytes and nonelectrolytes differ.
2. Application Question(s)
   1. Ask students to complete a chart that lists the major inorganic molecules and ions common in cells. The chart should include the molecule or ion name, symbol or formula, and function.

Answer: The chart should contain information regarding water, oxygen, carbon dioxide, bicarbonate ions, calcium ions, carbonate ions, chloride ions, magnesium ions, phosphate ions, potassium ions, sodium ions, and sulfate ions.

1. Critical Thinking Issue(s)
   1. Using the chart developed in the above application question and the information learned in the previous chapter, ask students to comment on the imbalances to homeostasis that would occur should the levels of any of the inorganic molecules or ions become compromised.

Answer: Responses will vary but should emphasize the importance of maintaining a stable internal environment.

Learning Outcome 2: Describe the general functions of the four main classes of organic chemicals

in cells.

1. Lecture Suggestions and Guidelines
   1. Introduce carbohydrates, lipids, proteins, and nucleic acids.
   2. Give examples of carbohydrates, including monosaccharides, disaccharides, and polysaccharides.
   3. Give examples of lipids, including fats and steroids.
   4. Give examples of proteins, including antibodies and enzymes. Describe amino acids as the building blocks of proteins.
   5. Give examples of nucleic acids, including RNA and DNA.
2. Application Question(s)
   1. Ask students to develop a chart describing the major organic compounds in cells. Quiz them on the information that they provide in their charts.

Answer: The chart should include information regarding carbohydrates, lipids, proteins, and nucleic acids. Each of the four organic compounds should be analyzed on the chart in terms of elements present, building blocks, and functions. Students should then provide specific examples of each type of compound.

1. Critical Thinking Issue(s)
   1. Using ball-and-stick models and illustrations, ask students to identify and compare the chemical composition of carbohydrates, lipids, proteins, and nucleic acids.

Answer: Some comparisons may include the typical ring structure of a glucose molecule, a triglyceride molecule consisting of a glycerol portion and three fatty acid portions, an amino acid chain of protein twisted to form a coil, and a nucleic acid molecule consisting of nucleotides joined in a chain.