Chapter 2: The Chemical Basis of Life

Guided Reading Activities

Big idea: Elements, atom, and compounds

Answer the following questions as you read modules 2.1–2.4:

1. Match the following terms with their correct definitions: matter, trace element, emergent properties, element, and compound.
   a. A substance required by humans in small quantities: **Trace elements**
   b. A substance that cannot be chemically broken down into a simpler substance: **Element**
   c. Anything that takes up space and has mass: **Matter**
   d. Substances with two or more elements in a fixed ratio: **Compound**
   e. A substance with different properties than the elements that make it up: **Emergent properties**

2. Fill in the following diagram at right, which illustrates the relationship between compounds and elements. Provide an example of each in the space below.
   An example of a compound is NaCl (table salt).
   An example of an element is Na.
3. Neapolitan ice cream is vanilla, chocolate, and strawberry combined in a 1:1:1 ratio. Briefly explain how Neapolitan ice cream is a good analogy that helps students understand the relationship between compounds and elements.
Neapolitan ice cream is an “ice cream compound” in that it is made from a combination of three different “elemental” ice cream flavors: chocolate, vanilla, and strawberry. If you wanted, you could take a knife and separate the three flavors from one another. This analogy allows you to see how elements can be combined to make new substances or broken into their elements.

4. Students tend to think that, because trace elements are required in tiny quantities, they are not important. List two trace elements that humans require and briefly explain why those two trace elements are important.
Iron and iodine are two trace elements required by your body. Iron is needed for the proper transportation of oxygen in your blood; iodine is needed for hormones made in the thyroid.

5. Use the two examples that you provided in question 4 to describe how these trace elements have been introduced into our diets and habits.
Iron has been added to certain cereals as a way to get people to consume enough of it. Iodine has been added to salt for the same reason.

6. Complete the following table that lists key features about subatomic particles.

<table>
<thead>
<tr>
<th></th>
<th>Protons</th>
<th>Neutrons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical charge</strong></td>
<td>+</td>
<td>Neutral</td>
<td>−</td>
</tr>
<tr>
<td><strong>Location in an atom</strong></td>
<td>Nucleus</td>
<td>Nucleus</td>
<td>Around the nucleus in a cloud</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>1 AMU</td>
<td>1 AMU</td>
<td>0 AMU</td>
</tr>
</tbody>
</table>

7. An atom of carbon has six protons. What if you change the number of protons to seven? Is it still carbon? Briefly explain your answer.
It would no longer be carbon because you changed the number of protons. The number of protons determines the element.

8. Which of the following are atoms of an element that vary in the number of neutrons?
   a. Electrons
   b. Isotopes
   c. Atomic number
   d. Protons

9. True or false: A radioactive isotope is unstable, which means it gives off energy and particles. If false, make it a correct statement.
   True
10. Complete the following table by filling each line with the correct value.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic number</th>
<th>Mass number</th>
<th>Number of protons</th>
<th>Number of neutrons</th>
<th>Number of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-12</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Hydrogen-1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Phosphorous-31</td>
<td>15</td>
<td>31</td>
<td>15</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Fluorine-19</td>
<td>9</td>
<td>19</td>
<td>9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Carbon-13</td>
<td>6</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

11. Radioactive isotopes are commonly referred to as “biological spies.” Briefly explain why this is an accurate description. Your explanation should include two specific examples of radioactive isotopes being used as “spies.” They are described as “radioactive spies” because the cells of an organism incorporate them the same as they would the nonradioactive isotope of that element. The use of radioactive carbon to study photosynthesis and the use of radioactive iodine to help kill thyroid cancer cells are two examples.

**Big idea: Chemical bonds**

Answer the following questions as you read modules 2.5–2.9:

1. Electrons are found in _____shells_____ that surround the nucleus at distinct distances.

2. Any orbital can hold only how many electrons?
   a. 1
   b. 0
   c. 2
   d. 8

3. What are the three ways in which atoms can interact with one another with respect to their electrons? Atoms can give electrons away, take them, or share them.
4. Which of the following would be considered a covalent bond?
   a. Double bond
   b. Single bond
   c. Nonpolar covalent bond
   d. All of the above

5. Complete the Venn diagram that compares polar covalent bonds to nonpolar covalent bonds.

   ![Venn diagram](image)

6. You are a research scientist working for an oil exploration company. A molecule is isolated from a sample taken from a new test well the company is drilling. Initial tests indicate that the molecule is nonpolar. What elements are likely to make up the molecule? Briefly explain your answer.
   Carbon and hydrogen are the elements likely to make up the molecule because they always form nonpolar covalent bonds with each other, which make a nonpolar molecule.

7. True or false: An ionic bond is based on the transfer of electrons between two atoms. If false, make it a correct statement.
   True
8. Complete the diagram illustrating ionic bonds. Atom X gives one electron to each atom Y. What are the ions that form as a result? Put the charges under each atom.

![Diagram of ionic bonds](image)

9. Many students have difficulty understanding how giving up an electron to another atom fills the valence of the atom that gave up the electron. It seems counterintuitive to them that losing an electron actually fills their valence. Imagine you are a teacher trying to explain this particular concept to a student. Briefly describe what you would say.

   By losing the electron, the atom no longer has electrons in the valence shell. If there are no longer electrons in that shell, then that shell is no longer the valence shell. The next shell closer to the nucleus becomes the valence shell and the original shell is full.

10. Match the following terms with their definitions: ionic bond, covalent bond, polar covalent bond, nonpolar covalent bond, and hydrogen bond.

   a. A weak attraction between a slightly positive hydrogen and a slightly negative atom: **hydrogen bond**
   
   b. Two atoms sharing electrons: **covalent bond**
   
   c. Atoms sharing electrons equally: **nonpolar covalent bond**
   
   d. A bond that forms between oppositely charged atoms: **ionic bond**
   
   e. A bond based on the unequal sharing of electrons: **polar covalent bond**

11. **Chemical bonds** are changes in matter that result in new substances being made by breaking existing chemical bonds, rearranging the atoms into new substances, and forming new chemical bonds.

12. In the following chemical equation, identify the products and reactants and indicate whether or not the equation is balanced. If not, balance the chemical equation.

   \[ 6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

   This chemical equation is balanced. The CO\(_2\) and H\(_2\)O are the reactants and the C\(_6\)H\(_{12}\)O\(_6\) and the O\(_2\) are the products.
Big idea: Water’s life-supporting properties

Answer the following questions as you read modules 2.10–2.16:

1. Which of the following is a unique property of water?
   a. Cohesion
   b. Ice floats
   c. Temperature regulation
   d. Acts as a crucial solvent
   e. All of the above are properties of water

2. Match the following terms with their correct definitions: adhesion, temperature, surface tension, evaporative cooling, and thermal energy.
   
   Cooling of a surface due to a substance changing from a liquid to a gas: evaporative cooling
   Measure of how difficult it is to break the surface of a liquid: surface tension
   The random motion of molecules: thermal energy
   The ability of two substances to stick together: adhesion
   Average speed of molecules moving within matter: temperature

3. Because water is polar, it is able to dissolve many of life’s important substances.

4. Oils are nonpolar substances (molecules formed by nonpolar covalent bonds) that do not interact with water. Propose an explanation for why oils are not attracted to water, whereas a substance like NaCl (table salt) is attracted to H₂O.
   Oils are not attracted to water because they have no slightly charged regions for the water to be attracted to. NaCl is attracted to water because it is polar, so the oppositely charged regions of the water and NaCl are attracted to each other.

5. You observe a substance dissolving in water. What is likely to be true about that substance?
   That substance is likely to be polar.
6. As the pH increases the \([H^+]\) ____________, and as the pH decreases the \([H^+]\) ____________.
   a. decreases; increases
   b. increases; decreases
   c. increases; stays the same
   d. decreases; stays the same

7. Complete the following table regarding acids and bases.

<table>
<thead>
<tr>
<th></th>
<th>Acids</th>
<th>Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect on (H^+) when dissolved in a solution</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>pH range</td>
<td>0 up to 7</td>
<td>From after 7 to 14</td>
</tr>
<tr>
<td>Example</td>
<td>HCl</td>
<td>NaOH</td>
</tr>
</tbody>
</table>

8. How much more \([H^+]\) does lemon juice have compared to pure water? Use Figure 2.14 on page 28 of your textbook.
   Lemon juice has a pH of 2 and pure water has a pH of 7. The difference in \(H^+\) is \(10^5 = 100,000 \times H^+\).

9. True or false: Ocean acidification is when \(CO_2\) dissolves in ocean water and lowers the pH. If false, make it a correct statement.
   True

10. The authors describe an experiment where scientists examined the effects of carbonate ion concentration on coral reef calcification. In that study, what variable did they manipulate or test? What variable did they measure to see if the manipulated variable had an effect?
    They manipulated the carbonate ion concentration. They measured the rate of calcification by the reef-building organisms.

11. The search for life on other planets hinges on finding ____water____.

**CONNECTING THE BIG IDEAS**

Use your knowledge of the information contained within this chapter’s “Big Ideas” to answer this question.

As a molecule, \(H_2O\) is essential for life. Answer the following questions regarding water: What elements are found in water? How many of each atom are there in one molecule of water? Identify the types of chemical bonds found in water. Be specific. Which type of water’s chemical bonds contributes to water’s life-supporting properties?