proprep

Workbook

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Water

Basics of Water

Questions

1) Part I: Which of the following is true?

a. A loss of just 4% of total body water is fatal in humans.
b. Water is a major component in the cell; a cell is composed of 50-70% water.
c. Water is the most abundant substance in living systems.
d. As a nonpolar molecule, water acts as a major solvent, and thus is crucial to cell function.
e. All of the above.

Part II: Adjust the sentences that are incorrect, so that they are true as well.

2) Name properties of water that contribute to its major role for cell function and life?

3) What can be said about water with regard to human's total body weight and its importance?

4) Describe the structure of the water molecule.

5) Which of the following statement is false?

a. Water is the universal solvent.
b. Water destabilizes temperature.
c. Water is essential for life.
d. Water cohesive and adhesive properties are responsible for surface tension.

6) Match between each item of A-C to its corresponding description in I-III:

A. Hydrogen bonds	I. These tend to cluster together and are poorly soluble in water because they interfere with water-water interactions while unable to form water-solute interactions.
B. Polar biomolecules	II. These provide the cohesive forces that make water a liquid at room temperature and a crystalline solid – ice at cold temperatures.
C. Nonpolar biomolecules	III. These readily dissolve in water because they can replace the water-water interactions with more energetically favorable water-solute interactions.

7) Part I: Define the term solution, solvent and solute.
Part II: When water is the solvent, what is the liquid it results in?

8) Part I: Please explain how water dissolves other substances.
Part II: Give an example of this.

Answer Key

1) Part I: C.
Part II:
a. A loss of just 4% of total body water results in dehydration.
b. Water is a major component in the cell; a cell is composed of 70-95% water.
d. As a polar molecule, water acts as a major solvent, and thus is crucial to cell function.

2) The forces of attraction between water molecules, and the slight tendency of water to ionize are of crucial importance to the structure and function of biomolecules.

3) Water makes up 60-75% of human body weight.

4) Two small, positively charged hydrogen atoms and one large negatively charged oxygen atom.

5) b.

6) A – II, B – III, C – I

7) Part I:
A **solution** is a liquid consisting of two or more substances evenly mixed.
The dissolving agent is called the **solvent**.
The dissolved substance is called the **solute**.
Part II:
The result is called an **aqueous solution** (aq)

8) Part I: water molecules can form bonds with and surround the polar molecules of another substance, effectively breaking the substance apart and dissolving it.
Part II: When putting Sugar crystals in water.

Weak Noncovalent Interactions

Questions

1) Which bond represents a weak chemical bond?
a. Hydrogen bond.
b. Nonpolar covalent bond.
c. Covalent bond.
d. Polar covalent bond.

2) What is a characteristic of water that results in the cohesive forces that make water a liquid at room temperature and a crystalline solid – ice at cold temperatures?

3) Complete the sentence and explain why:
Water in comparison to other common solvents has a _____:
- Melting point.
- Boiling point.
- Heat vaporization.

4) Define and explain the term cohesion.

5) Which of the following statement is true?
a. Hydrogen bonds are shorter than covalent bonds
b. Hydrogen bonds are responsible for cohesive properties of water.
c. Ice is more dense than liquid water since it has more hydrogen bonds per molecule
d. Covalent bonds are the weakest bond.
e. None of the above is true.

6) Name a few attributes of liquid water with regard to hydrogen bonds.

7) Which of the following is true?
a. Water is a polar solvent.
b. Water readily dissolves charged or polar compounds.
c. Most biomolecules fall into this category.
d. All of the above.

8) Define the terms hydrophilic and hydrophobic.

9) Explain the interaction that enables water to dissolve polar substances such as salts.

10) What are the 3 factors that contribute to the strength of ionic interactions?

11) Which is false about nonpolar gases?

a. These are poorly soluble in water.
b. The molecules of the biologically important gases: CO_2, O_2, and N_2 are nonpolar.
c. The change of such molecules from the disordered gas phase into aqueous solution constrains their motion and the motion of water molecules, thus resulting in a decrease in entropy.
d. All organisms have water-soluble "carrier proteins" (such as hemoglobin and myoglobin) that facilitate the transport of nonpolar molecules and this allows the transport and utilization of such molecules for biological functions.
e. 2 phases form when they are mixed with water - neither liquid is soluble in the other.
f. Nonpolar compounds are hydrophobic.

12) What are micelles?

13) Explain the phenomenon called: The hydrophobic effect.

14) Define and amphipathic compound and give an example of one.

15) Many biomolecules are amphipathic, give an example of how this dual characteristic plays an important role in a cell/organism.

16) Define van der Waals Interactions and what is another term for these?

17) Which of the following is true about van der Waals interactions?

a. When 2 uncharged atoms are very close to each other - their electron clouds influence each other.
b. Random variations in the positions of the electrons around one nucleus can create a transient electric dipole in one atom, which induces a transient, opposite electric dipole in the nearby atom.
c. The 2 dipoles weakly attract each other, bringing the nuclei closer, and these weak attractions are - van der Waals interactions.
d. Each atom has a characteristic van der Waals radius, which is a measure of how close that atom will allow another to approach.
e. All of the above.

18) Explain the term van der Waals contact.

19) Explain how though noncovalent bonds are weaker than covalent bonds, these aren't easily disrupted between biomolecules, and give an example.

20) Fill in the blanks:
For macromolecules the most _____ (meaning the native) structure is that in which _____ interactions are maximized.

21) Which of the following statement is true?

a. Ionic bond is the strongest bond.
b. Hydrogen bonds are responsible for cohesive and adhesive properties of the water.
c. Van der Waals interactions are the strongest bond.
d. Covalent bonds are the weakest bond.
e. None of the above is true.

Answer Key

1) a.

2) Hydrogen bonds between water molecules provide the cohesive forces that make water a liquid at room temperature and a crystalline solid.

3) Higher.

4) cohesion is the sticking together of particles of the same substance. In regard to water, hydrogen bonds cause water molecules to "stick" together giving water a high surface tension.

5) b.

6) At any given time, most of the molecules in liquid water are hydrogen-bonded. The lifetime of each hydrogen bond is a mere 1 to 20 picoseconds (1ps = 10^{-12}s). When 1 hydrogen bond breaks, another hydrogen bond forms with the same partner or a new one within 0.1ps.

7) d.

8) **Hydrophilic** - describes ions or polar molecules that interact well with other polar molecules such as water.
Hydrophobic - describes uncharged non-polar molecules that do not interact well with polar molecules such as water.

9) It replaces the solute-solute hydrogen bonds with solute-water hydrogen bonds. When salts dissolve and break away from the crystal lattice and form into ions (like Na^+ and Cl^-) they acquire greater freedom of motion.

10) 1. The magnitude of the charges (Q), 2. The distance between the charged groups (r), 3. The dielectric constant (ε) of the solvent in which the interactions occur.

11) d.

12) Micelles are stable structures, which can contain hundreds or thousands of molecules, that are held together by the nonpolar regions of the amphipathic molecules composing them.

13) When considering an amphipathic compound in aqueous solution:

- The polar (hydrophilic) region interacts with water and tends to dissolve.
- The nonpolar (hydrophobic) region tends to avoid contact with water.

14) Amphipathic molecules are chemical compounds that contain both polar (or charged) and nonpolar (apolar) regions [or portions] in their structure.
Examples - phospholipids [of membranes], proteins, some vitamins.

15) Structures composed of these molecules are stabilized by the hydrophobic effect which favors aggregation of the nonpolar – hydrophobic/water repelling regions – and these play important roles (micelles are an example of such a structure).

16) van der Waals Interactions are weak intermolecular forces between molecules, which is a result of each molecule inducing polarization in the other.

17) e.

18) When the 2 nuclei of the two molecules draw closer together, their electron clouds begin to repel each other, and at the point where the net attraction is maximal between the (2 nuclei), the nuclei are said to be in van der Waals contact.

19) While these are all individually weaker than covalent bonds, the cumulative effect of any such interactions can be very significant.

20) Stable, weak.

21) b.

Colligative Properties

Questions

1) List the 4 colligative properties and define colligate.

2) Which of the options is correct for each statement:

a. The concentration of water is *higher/lower* in solutions than in pure water.
b. The effect of solute concentration on the colligative properties of water is *dependent/independent* of the chemical properties of the solute.
c. The concentration depends on the *number/mass* of solute particles in a given amount of water.
d. Water molecules tend to move from *higher/lower* water concentration to *higher/lower* concentration.

3) Part I: Define Osmotic pressure (Π) - the measure of force necessary to resist water movement.
Paer II: What are factors that affect osmotic pressure?

4) Define Osmosis and Osmotic pressure.

5) What are the 3 terms that illustrate the concentration of a solution relative to the concentration of a cell.

6) What causes osmotic lysis of cells and how to organisms/cells prevent this from occurring?

Answer Key

1) Vapor pressure, Boiling point, Melting point (freezing point), Osmotic Pressure.
2) Lower, independent, number, higher, lower.
3) Part I: Osmotic pressure (Π) - can be defined as the measure of force necessary to resist water movement.
   Part II: Osmotic pressure can be approximated by the van't Hoff equation: Π = icRT.
4) Osmosis is the term that describes water movement across a semipermeable membrane driven by differences in osmotic pressure.
   Osmotic pressure (Π) can be defined as the measure of force necessary to resist water movement.
5) Isotonic solutions, Hypertonic solutions, Hypotonic solutions.
6) To view the answer to this exercise' please refer to the appropriate video on site.

Ionization of Water

Questions

1) Define Ionization and the two types of ions that form.

2) Part I: Which statement is true?

a. The ionized form of water is solely responsible for its solvent properties.
b. Weak bases become protonated when dissolved in water, which means they lose a proton.
c. Ionization of water is irreversible and can be described by an equilibrium constant.
d. The total H^+ concentration can be measured experimentally, and is expressed as the pH of the solution.

Part II: For the statements that aren't true, please adjust them so that they are true.

3) Explain and describe ionization of water.

4) Can and if so, how is ionization of water measured?

5) What is the formula used to calculate the equilibrium constant for ionization of water?

6) What is K_W and how is it calculated?

7) What would the formula look like at neutral pH?

8) What is the pH value and what is the basis for the pH Scale?

9) Define the solution based on this information and give an example of each:

a. Solutions with a pH>7 are _____
b. Solutions with a pH<7 are _____
c. Solutions with a pH=7 are _____

10) Explain how pH is measured?

11) Give an example of when and why measuring pH is important.

12) When a base is added to a solution, the pH should _____.

a. Decrease
b. Increase
c. Stay the same
d. Cannot tell without testing

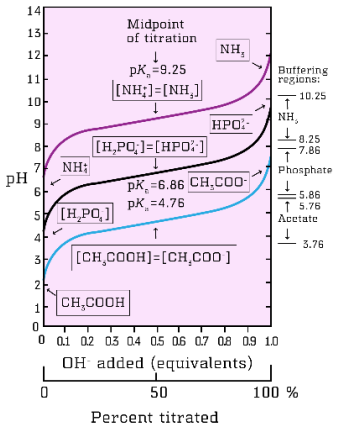
13) Define acids and bases by completing the following statements:

a. Acids may be defined as _____ donors.
b. Bases can be defined as _____ _____.
c. A proton donor and its corresponding proton acceptor make up a conjugate _____ pair.

14) Strong acids and bases have a similarity as do weak acids and bases with regard to aqueous solutions. Expand on this.

15) a. Explain a titration curve and its function.
b. How does the titration curve relate to pKa and explain with an example?

16) What does the midpoint of the titration curve signify?



17) Explain what can be observed in the figure, depicting the titration curves of 3 acids.

18) Which statement is false?

a. Acids donate hydrogen ions; (H^+) bases donate hydroxide ions (OH^-).
b. Both addition of bases and acids, can change the pH of a solution.
c. Acids and bases will not neutralize each other.
d. Acids and bases can mix together.

19) An acidic solution has a high concentration of _____.

a. Hydroxide ions (OH^-).
b. Hydrogen ions (H^+).
c. Carboxylic aids.
d. Sodium.

20) Define buffers and their significance.

21) What is the buffering region?

22) What can be said about the concentrations of the buffer components?

23) What is the Henderson-Hasselbalch equation?

24) a. Calculate the pKa of lactic acid, given that when the concentration of lactic acid is 0.010 M and the concentration of lactate is 0.087 M, the pH is 4.80.
b. Calculate the pH of a mixture of 0.10 M acetic acid and 0.20 M sodium acetate. The pKa of acetic acid is 4.76.
c. Calculate the ratio of the concentrations of acetate and acetic acid required in a buffer system of pH 5.30.

25) A basic solution has a _____ pH and can be neutralized by _____.

a. Low; adding more hydrogen ions.
b. High; adding more hydroxide ions.
c. Low; removing hydrogen ions.
d. High; removing hydroxide ions.
e. None of the above.

26) How do proteins in the cytoplasm contribute to cellular pH?

27) Two important biological buffers were mentioned in the lesson, name and explain one of these.

28) Biological control of the pH of cells and body fluids is of central importance for proper functioning. What are biological implications of a change in pH of human blood plasma?

29) What is especially sensitive to pH with regard to proper cell functions, and what is the pH optimum?

30) How do buffers prevent pH changes?

31) a. What are the 2 main types of reactions mentioned in which a water molecule is involved as a reactant?
b. Define these 2 types of reactions, and give an example of each.

32) Hydrolysis and condensation reactions are the reverse one of the other. With regard to energy investment, do they require investment of energy or result in the release of energy, and what are the terms relating to energy.

33) Cells are faced with a thermodynamic obstacle in which crucial polymerization reactions are endergonic. How do cells overcome this obstacle in order to form the much needed polymers?

34) Water and carbon dioxide are the end products of the oxidation of fuels, while green plants and algae use solar energy along with water molecules in the process of photosynthesis. Show these 2 reactions.

Answer Key

1) Ionization - Ionization is a process of forming or splitting of molecules to their respective cations and anions.
Cation - An atom that has a slight positive charge.
Anion - An atom that has a slight negative charge.

2) Part I: d.
Part II:

a. Both the uncharged form of water and the ionized form of water are responsible for its solvent properties, the small degree of ionization of water contributes to these properties.

b. Weak bases become protonated when dissolved in water, which means they gain a proton - consume H^+.

c. Ionization of water is reversible and can be described by an equilibrium constant.

3) Ionization of water is when a water molecule (H_2O) deprotonates (loses a proton H^+) and forms a negatively charged ion (an anion) OH^-, a hydroxide ion. Proton formed from the water molecule instantly protonates another water molecule and forms Hydronium ion (H_3O^+), and this shows the amphoteric nature of water.

4) Yes, ionization of water can be measured in 2 ways.

5) $K_{eq} = \frac{[H^+]_{eq}[OH^-]_{eq}}{[H_2O]_{eq}}$

6) K_W - the ion product of water at 25°C. (55.5 M)(K_{eq}) = $[H^+][OH^-] = K_W$.

7) $\left[H^+\right] = \sqrt{K_W} = \sqrt{1\times10^{-14}}M^2$

8) pH tells us whether a solution is acidic or basic.

9) a. basic b. acidic c. neutral

10) pH can be approximately measured with various indicator dyes that undergo color changes as a proton (H^+) dissociates from the dye molecules. Accurate determination of pH is made with a glass electrode that is selectively sensitive to H^+ concentrations, but insensitive to other cations (positive ions).

11) The pH affects the structure and activity of biomolecules. Measurement of pH of blood and urine are commonly used in medical diagnoses; these can be indicative of disease.

12) b.

13) a. proton b. proton acceptors c.acid-base

14) Hydrochloric, sulfuric, and nitric acids are examples of strong acids, which completely ionize in dilute aqueous solutions.

15) a. Titration Curves are used to determine the amount of an acid in a given solution.

b. pKa is analogous to pH, and is defined by the equation: $K_a = \log\frac{1}{K_a} = -\log K_a$

16) The midpoint of the titration curve is where is where exactly 0.5 equivalent of NaOH has been titrated to the acid.

17) This figure compares the titration curves of three weak acids with very different dissociation constants: Acetic acid (pKa 4.76), Dihydrogen phosphate $H2PO4^-$ (pKa 6.86), Ammonium ion $NH4^+$ (pKa 9.25).

18) c.

19) b.

20) Buffers are aqueous systems that resist changes in pH when small amounts of acid (H^+) or base (OH^-) are added. Almost every biological process is pH dependent; a small change in pH produces a large change in the rate of the process.

21) At the midpoint of the titration curve flat zone extending about 1 pH unit on either side of its midpoint pH is the buffering region. In this zone, an amount of H^+ or OH^- added to the system has less effect on pH than the same amount added outside the buffer range.

22) When H^+ or OH^- is added to a buffer, the result is a small change in the ratio of the relative concentrations of the weak acid and its anion and thus a small change in pH.

23) The shape of the titration curve of any weak acid is described by the Henderson-Hasselbalch equation: $pH = pK_a + \log\frac{[A^-]}{[HA]}$, $pH = pK_a + \log\frac{proton\_acceptor}{proton\_donor}$.

24) a. $pK_a = 3.9$ b. $pH = 5.1$ c. 3.5

25) d.

26) The intracellular and extracellular fluids of multicellular organisms have a characteristic and nearly constant pH, which is crucial for proper functioning.

27) The two important biological buffers are the phosphate and bicarbonate systems.

28) Human blood plasma normally has a pH close to 7.4.

29) the catalytic activity of enzymes is especially sensitive.The pH optimum differs between enzymes.

30) Buffers absorb the free hydrogen ions and hydroxide ions that result from chemical reactions.

31) a+b. Hydrolysis reaction - is any chemical reaction in which a molecule of water breaks one or more chemical bonds.
Condensation reaction - is one in which the elements of water are eliminated – removed from the participating molecules and resulting in water molecules.

32) Enzymatic Depolymerization – catalyzed by the enzyme hydrolases – exergonic.
Polymerization – endergonic.

33) Cells circumvent this thermodynamic obstacle by coupling endergonic condensation reactions to exergonic processes, such as breakage of the anhydride bond in ATP, which results in the release of energy, which can then be used to form a polymer.

34) Water and carbon dioxide are the end products of the oxidation of fuels:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Green plants and algae use solar energy to split water in the process of photosynthesis:

$$2H_2O + 2A \xrightarrow{light} O_2 + 2AH_2$$

Biological Aspects of Water

Questions

1) It can be said that water acts as a “heat buffer”, what does this mean and how does this contribute to viability of organisms?

2) Explain how water in solid form is inducive of aquatic life.

3) Describe a way that hydrogen bonding of water molecules contributes to plants’ viability?

Answer Key

1) Water essentially acts as a "heat buffer," keeping the temperature of an organism relatively constant, even if the temperature of the surroundings fluctuates, and though heat is generated as a byproduct of organisms' metabolism.

2) Water in solid form is ice. The density of ice, which is lower than that of liquid water, results in the liquid environment to freeze from the top down. This results in a layer of ice at the top, which insulates the water below from frigid air, preventing the body of water, and thus the organisms in it from freezing solid.

3) Hydrogen bonding between water molecules results in cohesion, this high degree of internal cohesion of liquid water is utilized by plants for transporting dissolved nutrients from the roots to the leaves, which enables its function and growth.