Chapter 02 - Water: The Medium of Life

1. Properties of water that render it so suited to its role as a medium of life include all EXCEPT:
   a. Unrivaled ability to form hydrogen bonds.
   b. Unusually high dielectric constant of water explains water's ability to surround ions and increase the ions' attraction for one another.
   c. Unparalleled ability to orient around nonpolar solutes to promote hydrophobic interactions.
   d. The small, but significant, tendency to form H^+ and OH– ions.
   e. None, all are true.

ANSWER: b

2. All are true for water for a substance of its molecular weight that is neither metallic nor ionic EXCEPT:
   a. a high surface tension.
   b. a chemically inert solvent, which has a great capacity to dissolve a diverse spectrum of molecules and ions.
   c. a positive volume of melting.
   d. a high dielectric constant.
   e. a high capacity to form hydrogen bonds

ANSWER: c

3. The unrivaled ability to form ____ hydrogen bonds per liquid water molecule is the source of the strong intermolecular attractions unique to water.
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

ANSWER: d

4. Because of its highly polar nature, water is an excellent solvent for polar substances, but NOT for:
   a. salts.
   b. sugars.
   c. aldehydes and ketones.
   d. hydrocarbons.
   e. alcohols and amines.

ANSWER: d

5. The solvent with the highest dielectric constant in this group is:
   a. water.
   b. acetic acid.
   c. ethanol.
   d. hexane.
   e. benzene.

ANSWER: a

6. Hydrogen bonds in ice are all EXCEPT:
   a. directional.
   b. straight.

c. weak.
d. responsible for the lower density of ice over liquid water.
e. holding water molecules in ice apart.

ANSWER: c

7. Pure liquid water consists of H_2O molecules:
a. held in a rigid three-dimentional network.
b. with local preference for linear geometry.
c. with large numbers of strained or broken hydrogen bonds.
d. which do not switch H-bonds readily.
e. all are true.

ANSWER: c

8. The average lifetime of a hydrogen bond connection in water is on the order of 10:
a. picoseconds.
b. microseconds.
c. milliseconds.
d. seconds.
e. nanoseconds.

ANSWER: a

9. The ____ bonding of water with the polar functional groups on nonionic polar solutes such as sugars are ____ than the intermolecular attractions between solute molecules allowing solute molecules to readily dissolve in water.
a. ionic, stronger
b. hydrogen, weaker
c. hydrophobic, stronger
d. hydrogen, stronger
e. ionic, weaker

ANSWER: d

10. The H-bonded water around an ionic substance tends to ____; and the H-bonded water around nonpolar solutes tends to ____.
a. inhibit ionization, promote hydrophobic interactions
b. inhibit ionization, inhibit hydrophobic interactions
c. not impact ionization, inhibit hydrophobic interactions
d. promote ionization, not impact hydrophobic interactions
e. promote ionization, promote hydrophobic interactions

ANSWER: e

11. Amphiphilic (amphipathic) molecules include:
a. sugars.
b. acidic amino acids.
c. inorganic salts.
d. water.
e. salts of fatty acids.

ANSWER: e

12. In micelles:
    a. polar ends form hydrophobic interactions with water.
    b. nonpolar ends form hydrophilic interactions with water.
    c. hydrocarbon tails form hydrophobic interactions with water.
    d. polar ends are hydrophobic and nonpolar ends are hydrophilic.
    e. hydrocarbon tails are excluded from the water into hydrophobic domains.

ANSWER: e

13. By limiting the orientation that neighboring water molecules can assume, solutes give ____ to the solvent and ____ the dynamic interplay among H_2O molecules that occurs in pure water.
    a. pressure, disrupt
    b. disorder, increase
    c. disorder, decrease
    d. order, diminish
    e. order, increase

ANSWER: d

14. To ____ the osmotic pressure created by the contents of their cytosol, cells tend to store substances such as amino acids and sugars in ____ form.
    a. increase, monomeric
    b. minimize, polymeric
    c. minimize, monomeric
    d. maximize, polymeric
    e. increase, polymeric

ANSWER: b

15. Water ionizes because:
    a. the smaller electronegative oxygen atom strips the electron from one of its hydrogen atoms, leaving the proton to dissociate.
    b. the larger electronegative oxygen atom strips the electron from one of its hydrogen atoms, leaving the proton to dissociate.
    c. the smaller electropositive oxygen atom strips the electron from one of its hydrogen atoms, leaving the proton to dissociate.
    d. the larger electropositive oxygen atom strips the electron from one of its hydrogen atoms, leaving the proton to dissociate.
    e. None of the above

ANSWER: b

16. Grapefruit juice at pH 3.2 contains about ____ times as much H^+ as orange juice at pH 4.3.
    a. 0.9
    b. $10^{-7.5}$
    c. 10^{-2}
    d. 12

e. 101

ANSWER: d

17. All are examples of weak electrolytes EXCEPT:
    a. hydrochloric acid.
    b. acetic acid.
    c. lactic acid.
    d. phosphoric acid.
    e. carbonic acid.

ANSWER: a

18. If 0.1 moles of Na_2HPO_4 and 0.1 moles of NaH_2PO_4 are mixed in water, what is the resulting pH? The pK_a values for phosphoric acid are 2.1, 7.2, 12.4.
    a. 2.1
    b. 4.65
    c. 7.2
    d. 9.8
    e. 12.4

ANSWER: c

19. Estimate the pH of the resulting solution prepared by mixing 1.0 mole of solid disodium phosphate (Na_2HPO_4) and 1.25 mole of hydrochloric acid. The pK_a values for phosphoric acid are 2.1, 7.2, 12.4.
    a. pH < 2.1
    b. pH = 2.1
    c. 2.1 < pH < 7.2
    d. pH = 7.2
    e. 7.2 < pH < 12.4

ANSWER: c

20. Which of the following pairs would be the best buffer at pH 10.0?
    a. Acetic acid and sodium acetate (pK_a = 4.76)
    b. H_2CO_3 and $NaHCO_3$ (pK_a values are 3.77 and 10.4)
    c. Lactic acid and sodium lactate (pK_a = 3.86)
    d. NaH_2PO_4 and Na_2HPO_4 (pK_a values are 2.1, 7.2, 12.4)
    e. Sodium succinate and succinic acid (pK_a = 4.21)

ANSWER: b

21. What ionic form(s) is/are most prevalent at pH 7.0? The pK_a values of phosphoric acid are 2.1, 7.2, and 12.4.
    a. HPO_4^{-2}
    b. $H_2PO_4^-$
    c. HPO_4^{-2} and PO_4^{-3}
    d. $H_2PO_4^-$ and HPO_4^{-2}

e. All are correct

ANSWER: b

22. A plasma pH of 6.8 doesn't seem too far away from a normal pH of 7.4, but at pH 6.8 the H^+ concentration is ____ times greater than at pH 7.4 and results in severe acidosis.

a. 0.1
b. 0.6
c. 4
d. 10
e. 20

ANSWER: c

23. pH = pK_a when:

a. [A–]/[HA] = 0
b. log ([A–]/[HA]) = 1
c. [A–] >> [HA]
d. [A–] = [HA]
e. log ([HA]/[A–]) = 1

ANSWER: d

24. Buffers have all of the following characteristics EXCEPT:

a. they have relatively flat titration curves at the pH(s) where they buffer.
b. they resist changes in their pH as acid or base is added.
c. they are typically composed of a weak acid and its conjugate base.
d. they buffer best for polyprotic acids half-way between the two pK_a values.
e. buffer where the amounts of conjugate base are nearly equivalent to the amounts of weak acid.

ANSWER: d

25. Buffer systems are effective when the pH values are within ____ pH unit(s) of the pK_a value.

a. 1
b. 2
c. 3
d. 4
e. 5

ANSWER: a

26. Intracellular pH is maintained primarily by the ____ and ____ buffer systems, and the extracellular pH by the ____ buffer system.

a. $HPO_4^{2-}/H_2PO_4^-$; HCO_3^-/H_2CO_3; histidine
b. $H_3PO_4/H_2PO_4^-$; histidine; HCO_3^-/H_2CO_3
c. HCO_3^-/H_2CO_3; $H_3PO_4/H_2PO_4^-$; histidine
d. $HPO_4^{2-}/H_2PO_4^-$; histidine; HCO_3^-/H_2CO_3
e. HCO_3^-/H_2CO_3; histidine; $H_3PO_4/H_2PO_4^-$

ANSWER: d

27. Hyperventilation is a physiological mechanism to:
    a. lower [CO_2 (g)] in the blood and increase blood pH.
    b. raise [CO_2 (g)] in the blood and increase blood pH.
    c. lower [CO_2 (g)] in the blood and decrease blood pH.
    d. raise [CO_2 (g)] in the blood and decrease blood pH.
    e. lower [CO_2 (g)] in the blood and increase [HCO_3^-].

ANSWER: a

28. Water is particularly suited as a solvent for biosystems because it has all of the following characteristics EXCEPT:
    a. Water is a medium for ionization enhancing the variety of chemical species.
    b. Water is innocuous, yet a powerful solvent.
    c. Water is an excellent solvent for nonpolar substances.
    d. Water is relatively chemically inert, yet dissolves a variety of solutes.
    e. Through hydrophobic interactions, lipids coalesce into membranes in water.

ANSWER: c

29. Which of the following weak acids would make the best buffer at pH = 5.0?
    a. acetic acid ($K_a = 1.74 \times 10^{-5}$, $pK_a = 4.76$)
    b. $H_2PO_4^-$ ($K_a = 1.38 \times 10^{-7}$, $pK_a = 7.20$)
    c. bicarbonate ($K_a = 6.3 \times 10^{-11}$, $pK_a = 10.24$)
    d. *tris*-hydroxymethyl aminomethane ($K_a = 8.32 \times 10^{-9}$, $pK_a = 8.07$)
    e. lactic acid ($K_a = 1.38 \times 10^{-4}$, $pK_a = 3.86$)

ANSWER: a

30. The enzyme fumarase has a pH optimum of about 7.6. What would be the buffer of choice to study this enzyme?
    a. lactic acid ($K_a = 1.38 \times 10^{-4}$, $pK_a = 3.86$)
    b. bicarbonate ($K_a = 6.3 \times 10^{-11}$, $pK_a = 10.24$)
    c. acetic acid ($K_a = 1.74 \times 10^{-5}$, $pK_a = 4.76$)
    d. succinate ($K_a = 2.34 \times 10^{-6}$, $pK_a = 5.63$)
    e. tris-hydroxymethyl aminomethane ($K_a = 8.32 \times 10^{-9}$, $pK_a = 8.07$)

ANSWER: e

31. When preparing an acetate buffer at pH 4.5 with 0.01 M solutions of acetic acid ($pK_a = 4.8$) and sodium acetate, the volume of acetic acid needed would be ____ the volume of sodium acetate solution.
    a. equal to
    b. less than half of
    c. more than half of
    d. about six times
    e. about twice

ANSWER: e

32. Hypoventilation is characterized by inability to excrete CO_2 rapidly enough and can be caused by all EXCEPT:
    a. anesthetics.
    b. depressant drugs.
    c. narcotics.
    d. lung diseases.
    e. encephalitis.

ANSWER: e

33. Aspirin contains a carboxylic acid with a pK_a of 3.5. Which of the following is true?
    a. Aspirin will be mostly protonated in the stomach
    b. Aspirin will be mostly protonated in the bloodstream
    c. Aspirin will be easily absorbed in the stomach due to its negative charge
    d. Aspirin will be easily transported in the bloodstream due to its negative charge
    e. both a and d are correct

ANSWER: e

34. If a weak acid is 25% deprotonated at pH 4, what would the pK_a be?
    a. 3.40
    b. 3.52
    c. 4.48
    d. 4.60
    e. cannot determine from given information

ANSWER: c

35. Which of the following would be the conjugate acid of hydrogen phosphate, HPO_4^{-2}?
    a. $H_2PO_4^-$
    b. H_3PO_4
    c. $H_2PO_4^{-2}$
    d. $H_2PO_4^-$
    e. none of the above

ANSWER: a

36. Formic acid is the active agent in an ant bite. What is the ratio of base/acid for formic acid (pKa = 3.9) in the blood stream at pH 7.4?
    a. 3.16×10^{-4}
    b. 3.16×10^{3}
    c. 0.54
    d. 1.90
    e. cannot be determined based upon the provided information

ANSWER: b

37. Which of the following statements is INCORRECT about the nature of the hydrogen bond
   a. The donor is a hydrogen atom bonded to an atom that is less electronegative than hydrogen.
   b. The more linear the bond, the stronger the interaction.
   c. The acceptor is a fairly electronegative atom containing a nonbonding pair of electrons.
   d. It is a type of noncovalent bond.
   e. All of the above statements are true about the nature of the hydrogen bond.

ANSWER: a

38. A weak acid is 33% dissociated at pH 5.0. What is the pK_a for this acid?
   a. 4.5
   b. 4.7
   c. 5.3
   d. 5.5
   e. cannot be determined from the information provided

ANSWER: c

39. Discuss the dielectric constant of water. Write the equation used to calculate the dielectric constant.

ANSWER: The attractions between the water molecules interacting with, or hydrating, ions in solution are much stronger than the attractions between oppositely charged ions. Water's ability to surround ions in dipole interactions and diminish their attraction for each other is a measure of its dielectric constant, *D*. Indeed, ionization in solution depends on the dielectric constant of the solvent; otherwise, the strongly attracted positive and negative ions would unite to form neutral molecules. The strength of the dielectric constant is related to the force, *F*, experienced between two ions of opposite charge separated by a distance, *r*, as given in the relationship

$$F = e_1 e_2 / D r^2$$

where $e1$ and $e2$ are the charges on the two ions.

TOPICS: 2.1 What Are the Properties of Water?

40. Calculate the equilibrium constant, K_{eq}, for 1 L of pure water.

ANSWER: The dissociation of water into hydrogen ions and hydroxyl ions occurs to the extent that 10^{-7} mol of H^+ and 10^{-7} mol of OH^- are present at equilibrium in 1 L of water at 25°C.

$$H_2O \rightarrow H^+ + OH^-$$

The equilibrium constant for this process is

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

where brackets denote concentrations in moles per liter. Because the concentration of H_2O in 1 L of pure water is equal to the number of grams in a liter divided by the gram molecular weight of H_2O, or 1000/18, the molar concentration of H_2O in pure water is 55.5 *M* (molar). The decrease in H_2O concentration as a result of ion formation ($[H^+]$, $[OH^-] = 10^{-7}M$) is negligible in comparison; thus, its influence on the overall concentration of H_2O can be ignored. Therefore,

$$K_{eq} = \frac{(10^{-7})(10^{-7})}{55.5} = 1.8 \times 10^{-16} M$$

TOPICS: 2.1 What Are the Properties of Water?

41. Explain weak electrolytes with an example.

ANSWER: Substances with only a slight tendency to dissociate to form ions in solution are called weak electrolytes. Acetic acid, CH_3COOH, is a good example:

$$CH_3COOH + H_2O \leftrightarrow CH_3COO^- + H_3O^+$$

The acid dissociation constant is represented as K_a. K_a is also termed an ionization constant because it states the extent to which a substance forms ions in water. The relatively low value of K_a for acetic acid reveals that the un-ionized form, CH_3COOH, predominates over H^+ and CH_3COO^- in aqueous solutions of acetic acid. Viewed another way, CH_3COO^-, the acetate ion, has a high affinity for H^+.

TOPICS: 2.2 What Is pH?

42. Discuss the Phosphate Buffer System in living systems.

ANSWER: The intracellular pH of most cells is maintained in the range between 6.9 and 7.4. Phosphate is an abundant anion in cells, both in inorganic form and as an important functional group on organic molecules that serve as metabolites or macromolecular precursors. Phosphate has a characteristic pK_2 of 7.2. At physiological pH, phosphate can donate or accept hydrogen ions to buffer any changes in pH. For example, if the total cellular concentration of phosphate is 15 m*M* (millimolar) and the pH is 7.3, the distribution of the major phosphate species is given by

$$pH = pK_2 + \log_{10}\frac{[HPO_4^{2-}]}{[H_2PO_4^-]}$$

$$7.3 = 7.20 + \log_{10}\frac{[HPO_4^{2-}]}{[H_2PO_4^-]}$$

$$\frac{[HPO_4^{2-}]}{[H_2PO_4^-]} = 1.25$$

Thus, if $[HPO_4^{2-}] + [H_2PO_4^-] = 15 mM$, then
$[HPO_4^{2-}] = 8.33$ m*M* and $[H_2PO_4^-] = 6.67$ m*M*

TOPICS: 2.3 What Are Buffers, and What Do They Do?

43. Explain the role that water plays in living systems.

ANSWER: Water is a "poor" solvent for nonpolar substances. Thus, through hydrophobic interactions, lipids coalesce, membranes form, boundaries are created delimiting compartments, and the cellular nature of life is established. Because of its very high dielectric constant, water is a medium for ionization. Ions enrich the living environment in that they enhance the variety of chemical species and introduce an important class of

chemical reactions. They provide electrical properties to solutions and therefore to organisms. The thermal properties of water allow effective temperature regulation in living organisms. The heat generated within an organism as a result of metabolism can be efficiently eliminated through evaporation or conduction of water.

TOPICS: 2.4 What Properties of Water Give It a Unique Role in the Environment?