Name: ______________________ Class: ______________________ Date: ______________

Chapter 02: Water, the Solvent of Life

1. Which statement about hydrogen bonds is NOT true?
   a. Hydrogen bonds account for the high boiling point of water compared to molecules of similar size.
   b. In liquid water, the average water molecule forms hydrogen bonds with three to four other water molecules.
   c. Individual hydrogen bonds are much weaker than covalent bonds.
   d. Individual hydrogen bonds in liquid water exist for many seconds and sometimes for minutes.
   e. The strength of a hydrogen bond depends on the linearity of the three atoms involved in the bond.

ANSWER: d

2. Which statement is true about the hydrophobic effect?
   a. It is the driving force in the formation of micelles of amphipathic compounds in water.
   b. It does not contribute significantly to maintaining the native conformation of water-soluble proteins.
   c. Hydrophobic effect interactions have bonding energies of approximately 20 to 40 kJ/mol.
   d. The hydrophobic effect involves interaction with water to denature proteins.
   e. The hydrophobic effect primarily determines the solubility of polar solutes.

ANSWER: a

3. The hydrophobic effect makes important energetic contributions to:
   a. binding of a hormone to its receptor protein.
   b. enzyme-substrate interactions.
   c. membrane structure.
   d. three-dimensional folding of a polypeptide chain.
   e. All of the answers are correct.

ANSWER: e

4. Adding a solute to water lowers the freezing point of water. The solute changes this colligative property of water by _____ the water.
   a. lowering the concentration of
   b. increasing hydrogen bonding in
   c. altering the ionic bonding within
   d. changing the pH of
   e. changing the temperature of

ANSWER: a

5. An example of osmosis is movement of a _____ molecule across a membrane.
   a. charged solute
   b. gas
   c. nonpolar solute
   d. polar solute
   e. water

ANSWER: e

6. A hydronium ion is:
   a. H_3O^+.
   b. immediately formed when hydrogen ions are released in water.
   c. a hydrated proton.
   d. formed by the dissociation of water.
   e. All of the answers are correct.

ANSWER: e

7. What is the pH of a 1 M HCl solution?
   a. 0
   b. 0.1
   c. 1
   d. 10
   e. –1

ANSWER: a

8. What is the pH of a 0.1 M NaOH solution?
   a. 0.1
   b. 1.0
   c. 12.8
   d. 13
   e. 14

ANSWER: d

9. Which statement is true about the properties of aqueous solutions?
   a. A pH change from 5.0 to 6.0 reflects an increase in the hydroxide ion concentration, $[OH^-]$, of 20%.
   b. A pH change from 8.0 to 6.0 reflects a decrease in the proton concentration, $[H^+]$, by a factor of 100.
   c. Charged molecules are generally insoluble in water.
   d. Hydrogen bonds form readily in aqueous solutions.
   e. The pH can be calculated by adding 7 to the value of the pOH.

ANSWER: d

10. The pH of a sample of blood is 7.4, while gastric juice is pH 1.4. The blood sample has _____ [H+] than the gastric juice.
   a. 0.189 times the
   b. 5.29 times lower
   c. 6 times lower

d. 6,000 times lower
e. one million times lower

ANSWER: e

11. The aqueous solution with the lowest pH is:
a. 0.01 M HCl.
b. 0.1 M acetic acid (pK_a = 4.86).
c. 0.1 M formic acid (pK_a = 3.75).
d. 0.1 M HCl.
e. 10^{-12} M NaOH.

ANSWER: d

12. The aqueous solution with the highest pH is:
a. 1 M HCl.
b. 1 M NH_3 (pK_a = 9.25).
c. 0.5 M $NaHCO_3$ (pK_a = 3.77).
d. 0.1 M NaOH.
e. 0.001 M NaOH.

ANSWER: d

13. Phosphoric acid is tribasic, with three pK_a values: 2.14, 6.86, and 12.4. Which ionic form predominates at pH 4.5?
a. H_3PO_4
b. $H_2PO_4^-$
c. HPO_4^{2-}
d. PO_4^{3-}
e. None of the answers is correct.

ANSWER: b

14. Which statement about buffers is true?
a. A buffer composed of a weak acid of pK_a = 5 has greater buffering capacity at pH 4 than at pH 6.
b. At pH values lower than the pK_a, the conjugate base concentration is higher than that of the conjugate acid.
c. The pH of a buffered solution remains constant no matter how much acid or base is added to the solution.
d. The best buffers are those composed of strong acids and strong bases.
e. When pH = pK_a, the weak acid and conjugate base concentrations in a buffer are equal.

ANSWER: e

15. Substance X has a pK_a of 7.4. What is the pH of the final solution formed by mixing 100 mL of a 1.0 M solution of X that is initially at pH 8.0 and 30 mL of 1.0 M hydrochloric acid?

a. 6.5
b. 6.8
c. 7.2
d. 7.4
e. 7.5

ANSWER: d

16. The Henderson-Hasselbalch equation:

a. allows the graphic determination of the molecular weight of a weak acid from its pH alone.
b. does not explain the behavior of di- or tribasic weak acids.
c. employs the same value for pK_a for all weak acids.
d. is equally useful with solutions of acetic acid and of hydrochloric acid.
e. relates the pH of a solution to the pK_a and the concentrations of acid and conjugate base.

ANSWER: e

17. Consider an acetate buffer, initially at the same pH as its pK_a (4.76). When sodium hydroxide (NaOH) is mixed with this buffer, the:

a. pH remains constant.
b. pH rises more than if the same amount of NaOH is added to an acetate buffer initially at pH 6.76.
c. pH rises more than if the same amount of NaOH is added to unbuffered water at pH 4.76.
d. ratio of acetic acid to acetate ion in the buffer decreases.
e. sodium acetate formed precipitates because it is less soluble than acetic acid.

ANSWER: d

18. A compound is known to have two ionizable groups: a free amino group with a pK_a of 8.8, and another group with a pK_a between 5 and 7. A mixture of 100 mL of a 0.2 M solution of this compound at pH 8.2 and 40 mL of 0.2 M hydrochloric acid has a final pH of 6.2. What is the pK_a of the second ionizable group?

a. The pH cannot be determined from this information.
b. 5.4
c. 5.6
d. 6.0
e. 6.2

ANSWER: c

19. Three buffers are made by combining a 1 M solution of acetic acid with a 1 M solution of sodium acetate in

the ratios shown.

	1 M acetic acid	1 M sodium acetate
Buffer 1:	10 mL	90 mL
Buffer 2:	50 mL	50 mL
Buffer 3:	90 mL	10 mL

Which statement is true of the resulting buffers?

a. pH of buffer 1 < pH of buffer 2 < pH of buffer 3
b. pH of buffer 1 = pH of buffer 2 = pH of buffer 3
c. pH of buffer 1 > pH of buffer 2 > pH of buffer 3
d. The problem cannot be solved without knowing the value of pK_a.
e. None of the statements is true.

ANSWER: c

20. A 1.0 M solution of a compound with two ionizable groups (pK_a values = 6.2 and 9.5; 100 mL total) has an initial pH of 6.8. If a biochemist adds 60 mL of 1.0 M HCl to this solution, what is the final pH?

a. 5.60
b. 8.90
c. 9.13
d. 9.32
e. The pH cannot be determined from this information.

ANSWER: a

21. The objective is to maintain pH = 7.0 for an enzyme-catalyzed reaction that will produce hydrogen ions along with the desired product. At equal concentrations, which weak acid, if any, will serve as the better buffer for the reaction: acid A with pK_a = 6.5, or acid B with pK_a = 7.5?

a. acid A
b. Water is as good as either of the acids available.
c. acid B
d. Both are equally effective.

ANSWER: a

22. Which contributes to water's unusual properties?

a. the geometry of water molecules
b. the polarity of water
c. the ability of water molecules to hydrogen bond
d. the electronegativity of the oxygen in water
e. All of the answers are correct.

ANSWER: e

23. Which factor causes water to have a bent geometry rather than a linear geometry?

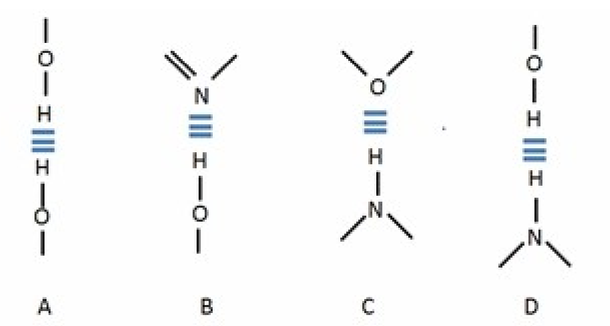
a. the net dipole of a water molecule
b. the unshared electron pairs (nonbonding orbitals) on the oxygen atom
c. the electronegativity difference between hydrogen and oxygen
d. the unequal electron sharing between hydrogen and oxygen
e. All of the answers are correct.

ANSWER: b

24. Ice is _____ dense than water because _____.
a. less; frozen water maintains more hydrogen bonds than liquid water
b. less; liquid water maintains more hydrogen bonds than frozen water
c. more; frozen water maintains more hydrogen bonds than liquid water
d. more; liquid water maintains more hydrogen bonds than frozen water
e. more; frozen water cannot hydrogen bond

ANSWER: a

25. Which correctly represent hydrogen bonding?



a. A and D
b. A and C
c. B and C
d. C and D
e. B and D

ANSWER: c

26. Oxygen and carbon dioxide are both biologically important gases. Which statement about these gases is true?
a. O_2 and CO_2 are both nonpolar and are very soluble in water.
b. O_2 and CO_2 are both polar and are very soluble in water.
c. O_2 and CO_2 are both nonpolar and are poorly soluble in water.
d. CO_2 contains polar bonds and is very soluble in water, but O_2 is nonpolar and is poorly soluble in water.

e. O_2 contains polar bonds and is very soluble in water, but CO_2 is nonpolar and is poorly soluble in water.

ANSWER: c

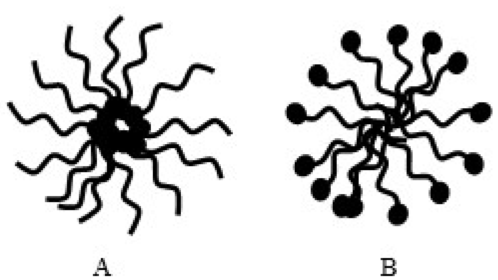
27. Which statement about hydrogen bonds is false?
   a. Hydrogen bonds are highly directional.
   b. Hydrogen bonds are capable of holding molecules in a specific geometric arrangement.
   c. Hydrogen bonds are strongest when the three atoms in the bond are in a straight line.
   d. Hydrogen bonds are strongest when the oxygen atom is perpendicular to the hydrogen donor.
   e. Hydrogen bonds place a hydrogen with a partial positive charge directly between two atoms with partial negative charges.

ANSWER: d

28. In water, which substance would most force surrounding water molecules to become highly ordered?
   a. CH_2O
   b. CH_4
   c. NH_3
   d. CH_3CH_2OH
   e. None of the answers is correct.

ANSWER: b

29. Which diagram correctly illustrates the clustering of lipids in the formation of a micelle?



   a. A
   b. B
   c. both A and B
   d. neither A nor B

ANSWER: b

30. When a nonpolar solute is dispersed in water, which will occur?
   a. the entropy of the water decreases
   b. the entropy of the water increases
   c. the enthalpy of solution is negative

d. the system reaches equilibrium quickly
e. All of the answers are correct.

ANSWER: a

31. Which statement regarding long-chain fatty acids in aqueous solution is NOT true?
   a. Fatty acids in small concentrations are surrounded by highly ordered water molecules in a cagelike structure.
   b. Fatty acids will cluster together to minimize the lipid surface area.
   c. Fatty acids will form micelles to sequester hydrophobic groups from water.
   d. The driving force of solubilizing fatty acids is increasing entropy of the fatty acid.
   e. All of the statements are true.

ANSWER: d

32. Which statement correctly describes the forces that drive the formation of micelles by amphipathic molecules, such as fatty acids, dissolved in water?
   a. Head groups of the molecules are sequestered in the interior of the micelle, maximizing hydrogen bonding of the hydrophobic tail with surrounding solvent molecules.
   b. Head groups of the molecules are exposed on the outer surface of the micelle, maximizing hydrogen bonding between hydrophobic tails.
   c. Head groups of the molecules are exposed on the outer surface of the micelle, minimizing the order of the surrounding water molecules.
   d. Hydrophilic tails are exposed on the outer surface of the micelle, maximizing hydrogen bonding between the tails and surrounding water molecules.
   e. Hydrophobic tails are exposed on the outer surface of the micelle, maximizing hydrogen bonding between head groups.

ANSWER: c

33. Which force plays the greatest role in stabilizing biological membranes?
   a. hydrogen bonding because it a strong noncovalent bond
   b. hydrophobic interactions that increase solvent entropy
   c. covalent interactions because they are very stable interactions
   d. electrostatic interactions between oppositely charged ions
   e. van der Waals interactions because of the attraction between transient dipoles

ANSWER: b

34. Which list correctly shows bond/interaction strength in decreasing order (strongest to weakest)?
   a. covalent bond > hydrogen bond > ionic bond > van der Waals interaction
   b. covalent bond > ionic bond > hydrogen bond > van der Waals interaction
   c. ionic bond > covalent bond > hydrogen bond > van der Waals interaction
   d. covalent bond > van der Waals interaction > ionic bond > hydrogen bond
   e. hydrogen bond > ionic bond > van der Waals interaction > covalent bond

ANSWER: b

35. When two atoms are joined together covalently, the van der Waals radius of the atoms in the covalent bond are _____ than the radius of the atoms alone because the joined atoms are _____.

a. shorter; pulled together by the shared electron pair
b. shorter; pulled together by the attraction of the nucleus to the bonded atom
c. shorter; pulled together by hydrogen bonding
d. longer; repelled due to the shared electron pair
e. longer; repelled due to the nuclear repulsion between bonded atoms

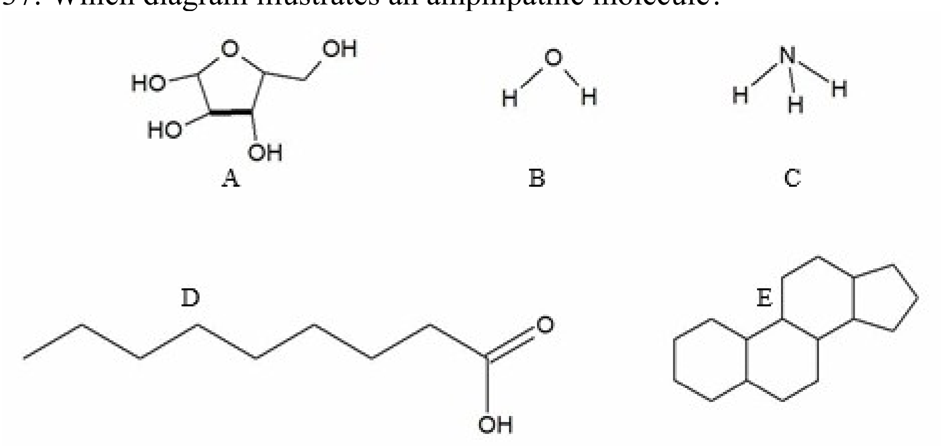
ANSWER: a

36. Which process would NOT disrupt the weak interactions between two biomolecules in solution?

a. heating the solution
b. cooling the solution
c. lowering the pH of the solution
d. increasing the ionic strength of the solution
e. All of the answer choices would disrupt interactions between biomolecules.

ANSWER: b

37. Which diagram illustrates an amphipathic molecule?



a. A
b. B
c. C
d. D

ANSWER: d

38. When water is found bound in the internal structure of a biomolecule, which statement is false?

a. The properties of the bound water molecules are different from those of the "bulk" water of the solvent.
b. The bound water molecules may provide a path for proton hopping.

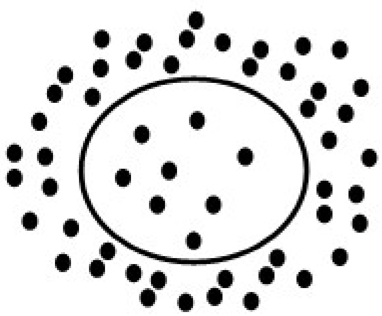
c. The bound water molecules may form an essential part of the protein's ligand-binding site.
d. The orientation of bound water molecules is precise.
e. None of the above; all of the statements are true.

ANSWER: e

39. Which would have the greatest effect on osmotic pressure?
a. 1 M NaCl (molecular weight = 58 g/mol)
b. 1 M $CaCl_2$ (molecular weight = 111 g/mol)
c. 1 M glucose (molecular weight = 180 g/mol)
d. 1 M sucrose (molecular weight = 342 g/mol)
e. All of the answer choices would have the same effect.

ANSWER: b

40. Which statement correctly describes the situation of the cell in the diagram? The black dots represent solute molecules.



a. The cell is in a hypotonic solution; water will move into the cell and cause it to swell.
b. The cell is in a hypotonic solution; solute will move into the cell and cause it to swell.
c. The cell is in a hypotonic solution; water will move out of the cell and cause it to shrink.
d. The cell is in a hypertonic solution; solute will move into the cell and cause it to swell.
e. The cell is in a hypertonic solution; water will move out of the cell and cause it to shrink.

ANSWER: e

41. Which statement does NOT describe a strategy used by multicellular animals to maintain osmotic balance with their surroundings?
a. Cells have a contractile vacuole, an organelle that pumps water out of the cell.
b. Animals have a high concentration of albumin and other proteins in blood plasma.
c. Cells actively pump out Na^+ and other ions.
d. Cells store fuel as a polysaccharide instead of as simple sugars.
e. All of the statements describe a strategy to maintain osmotic balance.

ANSWER: a

42. "Proton hopping" essentially means that:

a. an individual proton jumps from one electronegative group to the next.
b. a free proton moves from one hydroxyl group of ionized water to the next.
c. several protons move between hydrogen-bonded water molecules causing the net movement of a proton over a long distance in a short time.
d. individual protons are freer to move among and between water molecules in solution.
e. hydronium ions are freer to move among and between water molecules in solution.

ANSWER: c

43. Distilled white vinegar has a pH of 2.4. What is the $[H^+]$ of distilled white vinegar?

a. 2.4 M
b. 2.5×10^{-12} M
c. 2.5×10^{-3} M
d. 3.98×10^{-3} M
e. 3.98×10^{-6} M

ANSWER: d

44. If the pH of a solution is 5.5, what is the pOH?

a. 8.5
b. –5.5
c. –8.5
d. 14
e. 6.5

ANSWER: a

45. Milk of magnesia has a pH of 10.2. What is the $[OH^-]$ of milk of magnesia?

a. 6.31×10^{-11} M
b. 1.58×10^{-4} M
c. 1.58×10^{-5} M
d. 1.02×10^{-3} M
e. 6.31×10^{-4} M

ANSWER: b

46. The H^+ concentration of a solution is 5.6×10^{-5} M. What is the pH?

a. –4.25
b. 4.25
c. 5.65
d. –9.75

e. 9.75

ANSWER: b

47. The OH^{-} concentration of a solution is 4.3×10^{-10} M. What is the pH?

a. –9.37
b. 9.37
c. –4.63
d. 4.63
e. 13.4

ANSWER: d

48. If the K_a of an acid is 1.38×10^{-7}, what is the pK_a?

a. 6.86
b. 7.14
c. 4.37
d. 10.7
e. 1.38

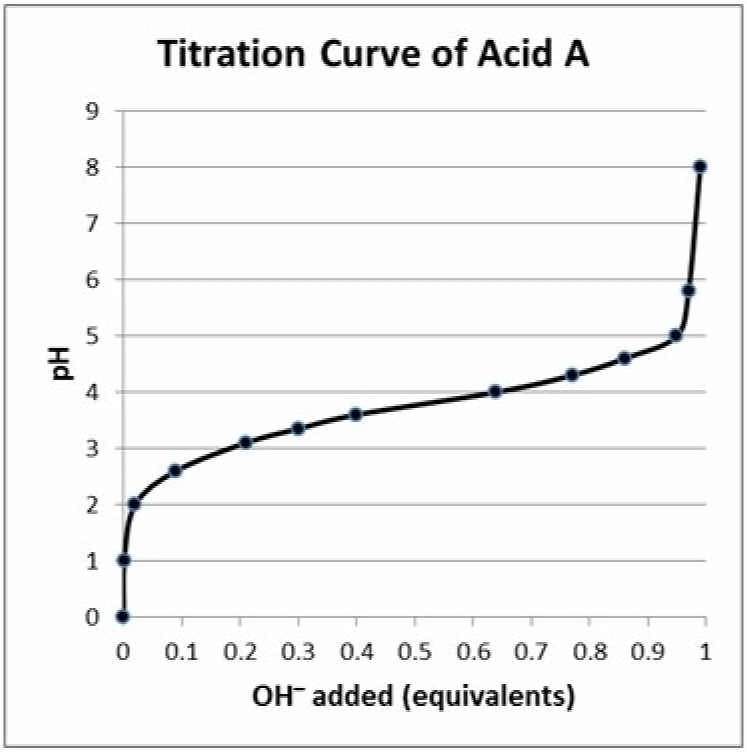
ANSWER: a

49. Which is the conjugate base of $H_2PO_4^{1-}$?

a. H_3PO_4
b. $H_2PO_4^{2-}$
c. HPO_4^{2-}
d. HPO_4^{3-}
e. PO_4^{3-}

ANSWER: c

50. According to the titration curve shown, acid A is _____ because the pH _____.



a. weak; resists change when 50% titrated
b. strong; resists change when 50% titrated
c. weak; changes dramatically when 50% titrated
d. strong; changes dramatically when 50% titrated
e. It cannot be determined from the information given.

ANSWER: a

51. According to the titration curve shown, what is the approximate pK_a of acid A?

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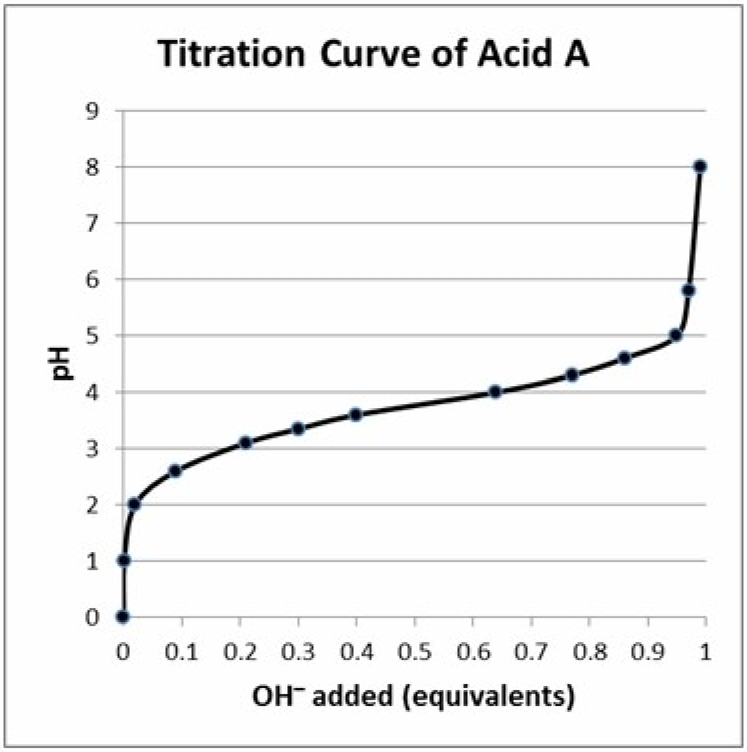
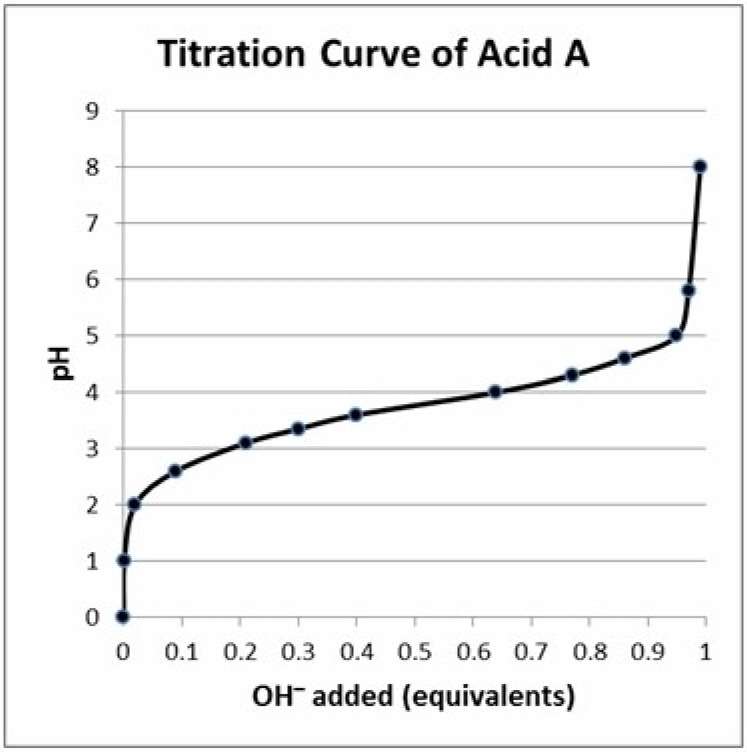


a.	0.2
b.	0.5
c.	3.2
d.	3.8
e.	4.8

ANSWER: d

52. According to the titration curve shown, what is a good buffering range for acid A?



a. 0.3 M to 0.8 M OH^-
b. 0.9 M to 1.0 M OH^-
c. pH 3.5 to pH 4.2
d. pH 2.8 to pH 3.8
e. pH 2.8 to pH 4.8

ANSWER: e

53. Formic acid is in the venom of some ant species. What is the pH of a 0.2 M solution of formic acid (K_a = 1.78×10^{-4} M)?

a. 8.90
b. 4.45
c. 3.75
d. 2.2
e. 1.72

ANSWER: d

54. List the acids in increasing order of strength (weakest to strongest): nitrous acid ($K_a = 4.0 \times 10^{-4}$), carbonic acid ($K_a = 4.4 \times 10^{-7}$), acetic acid ($K_a = 1.7 \times 10^{-5}$), phosphoric acid ($K_a = 7.3 \times 10^{-3}$).

a. acetic acid, carbonic acid, nitrous acid, phosphoric acid
b. carbonic acid, acetic acid, nitrous acid, phosphoric acid
c. acetic acid, nitrous acid, carbonic acid, phosphoric acid

d. phosphoric acid, nitrous acid, acetic acid, carbonic acid
e. carbonic acid, phosphoric acid, nitrous acid, acetic acid

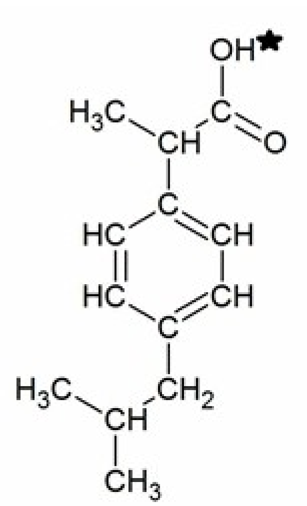
ANSWER: b

55. A 0.6 M solution of a weak acid had a pH of 5.8. What is the pK_a of the weak acid?

a. 11.3
b. 10.5
c. 8.2
d. 5.7
e. 2.9

ANSWER: a

56. Ibuprofen is a weak acid with a pK_a of 4.9 (structure is shown with the ionizable hydrogen marked with a star). Ibuprofen is absorbed through the stomach and the small intestine. In these tissues, absorption is a function of polarity. Charged and very polar molecules are absorbed slowly; neutral hydrophobic molecules absorb quickly. If the stomach pH is about 1.5 and the small intestine pH is about 6, where (and why) will more ibuprofen be absorbed into the bloodstream?



a. More ibuprofen will be absorbed in the small intestine because it will be uncharged due to the pH being greater than the pK_a.
b. More ibuprofen will be absorbed in the stomach because it will be uncharged due to the pH being lower than the pK_a.
c. More ibuprofen will be absorbed in the small intestine because it will be charged due to the pH being greater than the pK_a.
d. More ibuprofen will be absorbed in the stomach because it will be charged due to the pH being lower than the pK_a.
e. Ibuprofen will be absorbed equally well in both the stomach and small intestine.

ANSWER: b

57. Which compound is a diprotic acid?

a. CH_3COOH

b. NH_4^+

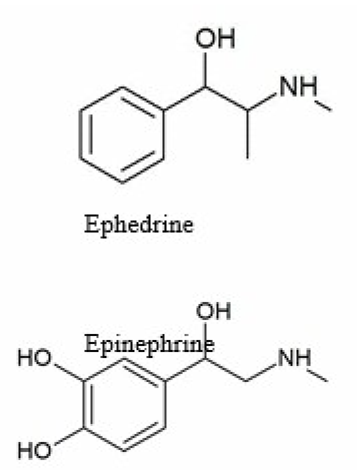
c. H_2CO_3

d. H_3PO_4

e. CH_3CH_2OH

ANSWER: c

58. Polar molecules cannot easily pass through the cell membrane, but hydrophobic molecules can easily pass through the membrane. Both molecules shown can raise blood pressure. Compare the molecules and select the statement that is true.



a. Ephedrine can more easily pass through the cell membrane than epinephrine.
b. Epinephrine can more easily pass through the cell membrane than ephedrine.
c. Both epinephrine and ephedrine can pass through the cell membrane equally well.
d. Neither epinephrine nor ephedrine can pass through the cell membrane.
e. None of the statements is true.

ANSWER: a

59. According to the Henderson-Hasselbalch equation, when is the pH equal to the pK_a?
a. when the concentration of acid is close to zero
b. when the pH approaches 7
c. when the concentration of the conjugate base is equal to the ionization constant for water
d. when the concentration of the conjugate base is equal to the concentration of the acid
e. None of the answers is correct.

ANSWER: d

60. If a person is suffering from mild acidosis, which treatment/action would help counteract the acidosis the

most?

a. intravenous administration glucose
b. deep breathing
c. breathing into a paper bag
d. vigorous exercise
e. All of these treatments/actions could be used to counteract acidosis.

ANSWER: b

61. Which answer choice is involved in important biological buffering systems?

a. histidine
b. bicarbonate
c. phosphate
d. bicarbonate and phosphate
e. histidine, bicarbonate, and phosphate

ANSWER: e

62. Of the seven the steps listed, which four (in the correct order) are needed to prepare 1 L of a 0.02 M Tris buffer solution at pH 7.6? A lab station has a 0.1 M solution of Tris in its protonated form, 0.1 M solution of HCl and NaOH, and plentiful distilled water. The K_a of Tris is 8.32×10^{-9}.

1. Calculate the volume of 0.1 M Tris to use ($C_1V_1 = C_2V_2$).
2. Calculate the volume of 0.1 M HCl to use ($C_1V_1 = C_2V_2$).
3. Calculate the volume of 0.1 M NaOH to use ($C_1V_1 = C_2V_2$).
4. Use the Henderson-Hasselbalch equation to calculate the ratio of Tris base to protonated Tris.
5. Adjust the pH to 7.6 by adding 0.1 M NaOH.
6. Adjust the pH to 7.6 by adding 0.1 M HCl.
7. Fill to 1 L with distilled water.

a. 1, 4, 6, 7
b. 1, 4, 5, 7
c. 1, 2, 4, 7
d. 1, 3, 4, 7
e. 1, 7, 4, 6

ANSWER: b

63. Name and briefly define five types of noncovalent interactions that occur between biological molecules.

ANSWER: (1) Hydrogen bonds: weak electrostatic attractions between one electronegative atom (such as oxygen or nitrogen) and a hydrogen atom covalently linked to a second electronegative atom; (2) electrostatic interactions: relatively weak charge-charge interactions (attractions of opposite charges, repulsions of like charges) between two ionized groups; (3) hydrophobic interactions: the forces that tend to bring two hydrophobic groups together, reducing the total area of the two groups that is exposed to surrounding molecules of the polar solvent (water); (4) van der Waals interactions: weak interactions between the electric dipoles that two close-spaced atoms induce in each other; (5) tightly bound water molecules can form as an essential part of the binding site in a protein for its ligand.

64. Explain the fact that ethanol (CH_3CH_2OH) is more soluble in water than is ethane (CH_3CH_3).

ANSWER: Ethanol can form hydrogen bonds with water molecules, but ethane cannot. When ethanol dissolves, there is some decrease in the system's entropy from formation of clathrate around the alkyl portion, but this is more than compensated for by the favorable interactions (hydrogen bonds) of the hydroxyl group of ethanol with water molecules. Ethane cannot form such hydrogen bonds and is therefore insoluble in water.

65. Explain the fact that triethylammonium chloride ($(CH_3CH_2)_3N$-HCl) is more soluble in water than is triethylamine ($(CH_3CH_2)_3N$).

ANSWER: Triethylammonium chloride is an ionic substance. The positive charge of the triethylammonium ion makes it hydrophilic. This leads to stronger favorable interactions with water, leading to increased solubility. Triethylamine is uncharged.

66. Explain with an appropriate diagram why amphipathic molecules tend to form micelles in water. What force drives micelle formation?

ANSWER: Micelle formation minimizes the surface area of the hydrophobic part of amphipathic molecules that contacts the polar solvent, water. Hydrophobic interactions between hydrophobic moieties are the driving force for micelle formation. When amphipathic molecules form micelles in water, the entropy decrease, due to the formation of ordered arrays of water molecules around the hydrophobic moieties, is minimized (see Fig. 2-7).

67. (a) In terms of osmolarity, briefly define isotonic, hypotonic, and hypertonic solutions. (b) Describe what happens when a cell is placed in each of these types of solutions.

ANSWER: (a) An isotonic solution has the same osmolarity as the solution to which it is being compared. A hypotonic solution has a lower osmolarity than the solution to which it is being compared. A hypertonic solution has a higher osmolarity than the solution to which it is being compared. (b) Higher osmolarity results in osmotic pressure, which generally leads to movement of water across a membrane. In an isotonic solution, in which the osmolarity of the solution is the same as the cell cytoplasm, there will be no net water movement. In a hypotonic solution, water will move into the cell causing the cell to swell and possibly burst. In a hypertonic solution, water will move out of the cell and it will shrink.

68. For each pair, circle the conjugate base.

RCOOH	$RCOO^-$
RNH_2	RNH_3^+
$H_2PO_4^-$	H_3PO_4
H_2CO_3	HCO_3^-

ANSWER: $RCOO^-$, RNH_2, $H_2PO_4^-$, HCO_3^-

69. Phosphoric acid (H_3PO_4) has three dissociable protons with the pK_a values shown. Which form of phosphoric acid predominates in a solution at pH 4? Explain.

Acid	pK_a
H_3PO_4	2.14
$H_2PO_4^-$	6.86
HPO_4^{2-}	12.4

ANSWER: At pH 4, the first dissociable proton (pK_a = 2.14) has been titrated nearly completely, and the second (pK_a = 6.86) has just started to be titrated. The dominant form at pH 4 is therefore $H_2PO_4^-$, the form with one dissociated proton (see Fig. 2-15).

70. Define pK_a for a weak acid in two ways: (1) in relation to its acid dissociation constant, K_a, and (2) by reference to a titration curve for the weak acid.

ANSWER: (1) pK_a = –log K_a. (2) See Fig. 2-17; pK_a is the value of pH at the inflection point in a plot of pH versus extent of titration of the weak acid. At the pK_a, the concentration of ionized acid equals the concentration of nonionized acid.

71. Draw a titration curve for a monoprotic weak acid and indicate the region in which the buffering capacity of the system is greatest.

ANSWER: The inflection point, which occurs when the weak acid has been exactly one-half titrated with NaOH, occurs at a pH equal to the pK_a of the weak acid. The region of greatest buffering capacity (where the titration curve is flattest) occurs at pH values of pK_a ± 1 (see Fig. 2-17).

72. What is the pH of a solution containing 0.2 M acetic acid (pK_a = 4.7) and 0.1 M sodium acetate?

ANSWER:

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\text{conjugate base}]}{[\text{acid}]} = 4.7 + \log(0.1/0/2)$$
$$= 4.7 - 0.3 = 4.4$$

73. A solution is made by combining 50 mL of a 0.1 M sodium acetate solution with 150 mL of 1 M acetic acid (pK_a = 4.7). What is the pH of the resulting solution?

ANSWER:

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\text{conjugate base}]}{[\text{acid}]} = 4.7 + \log(5/150)$$
$$= 4.7 - 1.48 = 3.22$$

74. For a weak acid with a pK_a of 6.0, show how to calculate the ratio of acid to base at pH 5.

ANSWER: $\text{pH} = \text{p}K_a + \log\dfrac{[\text{conjugate base}]}{[\text{acid}]}$, so $\text{p}K_a - \text{pH} = -\log\dfrac{[\text{conjugate base}]}{[\text{acid}]}$

$= \log\dfrac{[\text{acid}]}{[\text{conjugate base}]}$

$6.0 - 5.0 = \log\dfrac{[\text{acid}]}{[\text{conjugate base}]}$. $\dfrac{[\text{acid}]}{[\text{conjugate base}]} = \text{antilog } 1 = 10$

75. After adding 100 mL of a solution containing 0.5 mol of acetic acid per liter to 400 mL of 0.5 M NaOH, what is the final pH? (The pK_a of acetic acid is 4.7.)

ANSWER: Addition of 200 mM of NaOH (400 mL×0.5 M) to 50 mM of acetic acid (100 mL×0.5 mM) completely titrates the acid so that it can no longer act as a buffer and leaves 150 mM of NaOH dissolved in 500 mL, an $[OH^-]$ of 0.3 M. Given $[OH^-]$, $[H^+]$ can be calculated from the equilibrium constant for the dissociation of water (the ion product of water):

$[H^+][OH^-] = 10^{-14}$

$[H^+] = 10^{-14}\ M^2/0.3\ M$

pH is, by definition, log $(1/[H^+])$

pH = log $(0.3\ M/10^{-14}\ M^2) = 12.48$

76. A weak acid HA, has a pK_a of 5.0. If 1.0 mol of this acid and 0.1 mol of NaOH were dissolved in one liter of water, what is the final pH?

ANSWER: Combining 1 mol of weak acid with 0.1 mol of NaOH yields 0.9 mol of weak acid and 0.1 mol of salt.

$\text{pH} = \text{p}K_a + \log\dfrac{[\text{conjugate base}]}{[\text{acid}]} = 5.0 + \log(0.1/0.9) = 4.05$

77. In proteins, the amino acid histidine (His) plays an important role in many biological reactions. The pK_a for the protonation of His to form $HisH^+$ = 6.0. When pH = 7.0, what is the fraction of total histidine that will be in the $HisH^+$ form?

ANSWER: Use the Henderson-Hasselbalch equation to determine the *ratio* of [His] to $[HisH^+]$.

pH = pK_a + log $([His]/[HisH^+])$

7.0 = 6.0 + log $([His]/[HisH^+])$

1.0 = log $([His]/[HisH^+])$

$[His]/[HisH^+]$ = antilog (1) = 10

To determine the *fraction* of the total in the $HisH^+$ form, $[His]_{total} = [His] + [HisH^+]$,

fraction $= [HisH^+]/[His]_{total}$

$= [HisH^+]/([His] + [HisH^+])$ substitute from ratio calculated above

$= [HisH^+]/(10[HisH^+] + [HisH^+])$

= 1/11, or 0.09

78. Recall the equilibria: $H^+ + HCO_3^- \leftrightarrows H_2CO_3 \leftrightarrows CO_2 + H_2O$

Severe diarrhea is accompanied by a loss of HCO_3^-. If untreated, will the condition result in acidosis or alkalosis? Use the bicarbonate buffer system given in the scheme above and Le Chatelier's principle to explain your answer.

ANSWER: Acidosis. The removal of HCO_3^- will pull the equilibria in the direction of HCO_3^-, which will produce H^+, thereby lowering the pH.

79. If ice were denser than water, how would that affect life on Earth?

ANSWER: Ice that formed at the surface of bodies of water would sink; hence, streams, ponds, lakes, and so on would freeze from the bottom up. With a reservoir of ice at the bottom, they would be perpetually cold, and in the limit they would freeze solid, precluding life as we know it.

80. As two atoms get nearer to each other, do van der Waals attractive forces always increase?

ANSWER: No, the attractive forces created by the transient dipole-induced dipole interaction increases until the van der Waals radius is reached, where the net attraction is maximal. At this point, the electron clouds begin to repel each other.

81. Speculate why weak forces, not strong forces, are the basis for molecular recognition among biomolecules.

ANSWER: Weak forces make the biological interactions reversible within physiological constraints. The cumulative effects of many weak interactions can be very significant. Strong forces would require large amounts of energy to reverse any interaction.