Chapter 2 Water, Weak Bonds, and the Generation of Order Out of Chaos

Matching Questions

Use the following to answer questions 1–10:

Choose the correct answer from the list below. Not all of the answers will be used.
a) ionic bonds or salt bridges
b) Brownian motion
c) hydrophobic
d) hydrogen
e) polar
f) nonpolar
g) van der Waals
h) entropy
i) ion product of water
j) amphipathic
k) positive
l) dielectric constant
m) negative

1. _____________: The type of bond found between an oxygen on one water molecule and hydrogen on a different water molecule.
   Ans: d
   Section: 2.2

2. Movement of particles due to the random fluctuations of energy content of the environment is known as _____________.
   Ans: b
   Section: 2.1

3. Electrostatic interactions between atoms with opposite electrical charges are also called _____________.
   Ans: a
   Section: 2.3

4. Water weakens the electrostatic interaction of ions due to its high _____________.
   Ans: l
   Section: 2.3

5. The distance when two atoms no longer repulse each other yet have the strongest attraction is known as the_____________ contact distance.
   Ans: g
   Section: 2.3

6. ____________: Thermodynamic force that drives hydrophobic interactions.
   Ans: h
   Section: 2.4

7. ____________: A molecule with two distinctive chemical properties or characteristics.
   Ans: j
   Section: 2.4

8. Which type of amino acid is responsible for increasing entropy as a protein folds?
   Ans: f
   Section: 2.4

9. ____________: The charge on acetic acid when the pH is more than one pH unit above the pK_a.
   Ans: m
   Section: 2.5

10. ____________: The charge of an amino group when the pH is one pH unit below the pK_a.
    Ans: k
    Section: 2.5

Fill-in-the-Blank Questions

11. Molecules that are readily soluble in water are considered ___.
    Ans: polar Section 2.2

12. The force that is quantified by Coulomb's law is called ___.
    Ans: ionic or electrostatic interaction Section 2.3

13. A solvent with a low dielectric constant would be a ___ solvent for salts.
    Ans: poor Section 2.3

14. The transient force, which while weak, still has a large impact on how macromolecules interact is the ___.
    Ans: van der Waals interaction Section 2.3

15. Hydrophobic molecules are driven together by ___, not because they have an affinity for each other.
    Ans: entropy Section 2.4

16. Lipids that interact with both the water and the hydrophobic regions of the membrane are considered ___.
    Ans: amphipathic Section 2.4

17. An acid ionizes to form a proton and its ___.
    Ans: base or conjugate base Section 2.5

18. When the pH is more than two pH units above the pK_a of a carboxyl group, the acid is ___.
Ans: unprotonated Section 2.5

19. Buffers are critical in maintaining proper ___ levels in biological systems.
Ans: pH Section 2.5

20. The source of the key buffering component of blood is ___.
Ans: carbon dioxide Section 2.5

Multiple-Choice Questions

21. What is the H^+ concentration in a urine sample that has a pH of 6?
A) 10^{-6} M
B) 10^{-8} M
C) 10^{6} M
D) 10^{-14} M
E) 8 M
Ans: A Section: 2.5

22. Which of the following is considered a noncovalent bond?
A) electrostatic interactions
B) hydrogen bonds
C) van der Waals interactions
D) All of the above.
E) None of the above.
Ans: D Section: 2.3

23. What charged group(s) is/are present in glycine at a pH of 7?
A) $–NH_3^+$
B) $–COO^-$
C) $–NH_2^+$
D) A and B
E) A, B, and C
Ans: D Section: 2.5

24. Water can form hydrogen bonds with the ____________ of another molecule.
A) carbonyl groups
B) amine groups
C) aromatic rings
D) alcohol groups
E) A, B, and D
Ans: E Sections: 2.3 & 2.4

25. What pairs of atoms in nucleotide bases are involved in hydrogen bonds?
    A) N–H and C═O
    B) N–H and S–H
    C) O–H and P–O
    D) All of the above.
    E) None of the above.
    Ans: A Section: 2.3

26. Typical van der Waals energies are about:
    A) 4–20 kJ/mol.
    B) 2–4 kJ/mol.
    C) 200 kJ/mol.
    D) All of the above.
    E) None of the above.
    Ans: B Section: 12.3

27. What two properties of water are important for biological interactions?
    A) the polarity of water
    B) the density of water
    C) the cohesive properties of water
    D) A and C
    E) B and C
    Ans: D Section: 2.2

28. List atoms commonly found in biological molecules that are often hydrogen-bond acceptors.
    A) carbon
    B) oxygen
    C) nitrogen
    D) B and C
    E) All of the above.
    Ans: D Section: 2.3

29. What happens to nonpolar molecules in water?
    A) They dissolve independently.
    B) They aggregate together.
    C) They precipitate.
    D) All of the above.
    E) None of the above.
    Ans: B Section: 2.3

30. What is the $[A^-]/[HA]$ ratio when the weak acid is in a solution one pH unit above its pK_a?
    A) 1:1
    B) 1:10
    C) 10:1
    D) 2:1
    E) None of the above.
    Ans: C Section 2.3

31. What are the primary chemical components present in a phosphate buffer at pH 7.4?
A) H_3PO_4 and PO_4^{-3}
B) $H_2PO_4^-$ and PO_4^{-3}
C) HPO_4^{-2} and PO_4^{-3}
D) $H_2PO_4^-$ and HPO_4^{-2}
E) H_3PO_4 and HPO_4^{-2}
Ans: D Section 2.5

32. What is the concentration of acetic acid in 250 ml of a 100 mM acetate buffer at pH 4.76?
A) 250 mM
B) 100 mM
C) 50 mM
D) 75 mM
E) There is not enough information to tell.
Ans: C Section 2.5

33. Climate scientists are concerned with the ongoing decrease in the pH of the Earth's oceans. Based on what you know about weak acid/base equilibria, which of the following would contribute to ocean acidification?
A) An increase in phosphate containing fertilizers from river runoff causes a shift in phosphoric acid equilibrium.
B) An increase in atmospheric CO_2 causes a shift in carbonic acid equilibrium.
C) An increase in atmospheric SO_2 emissions causes a shift in sulfuric acid equilibrium.
D) All of the above.
E) None of the above.
Ans: B Section: 2.5

34. Citric acid is an important intermediate in glucose metabolism and is synthesized in mitochondrial matrix. The three pK_a values for each of the carboxylic acids are 3.1, 4.8, and 6.4. What would the charge be on a citrate molecule formed in the mitochondrial matrix where the pH is 7.8?
A) +3
B) +2
C) -3
D) -2
E) None of the above.
Ans: C Section 2.5

35. A student observes that when an unknown molecule is added to water, it forms micelles. What can this student infer about this phenomenon?
A) The unknown molecule is amphipathic.
B) The micelle formation is driven by the resulting decrease in entropy of water.
C) The unknown molecule forms many van der Waals interactions with water.
D) Micelle formation is driven by the hydrophilic effect.
E) All of the above.
Ans: A Section 2.4

Short-Answer Questions

36. Using Coulomb's law, describe how water is an ideal solvent for the ions found in cells?
Ans: The force that attracts two oppositely charged ions is measured by a constant a kq_1q_2 divided by the dielectric constant of the solvent × R. This means that a solvent such as water, with a high dielectric constant, will result in a lowered attractive force between two ions dissolved in water.
Section: 2.3

37. What is the significance of hydrogen bonding in biochemical structures such as DNA?
Ans: The bonds are weak enough to be easily disrupted; yet when many are present in large numbers, they provide the stabilization necessary for larger structures such as DNA.
Section: 2.3

38. What is an electrostatic interaction? Give an example.
Ans: It is the attractive force of two oppositely charged atoms. Salts (such as NaCl) are a common example.
Section: 2.3

39. How is water able to be a solvent for so many biological molecules?
Ans: Many biological molecules have polar characteristics. Water is extremely polar and it is capable of competing with other polar molecules by weakening their electrostatic and hydrogen bonds. The oxygen can act as a hydrogen-bond acceptor, and the hydrogen can act as a donor.
Section: 2.2

40. What is the net effect of many van der Waals interactions?
Ans: At the interface of two large molecules, the numerous van der Waals interactions can substantially affect and stabilize the interaction.
Section: 2.3

41. How is protein folding driven?
Ans: Nonpolar amino acids associate with each other, forming the interior of folded proteins. This causes an increase in the entropy of water and thermodynamically drives protein folding.
Section: 2.4

42. If noncovalent bonds are so much weaker than covalent bonds, how do they stabilize large biochemical structures?
    Ans: There is stability in numbers.
    Section: Introduction

43. What thermodynamic and free-energy changes participate in protein folding?
    Ans: A combination of hydrogen bonds and van der Waals forces affect enthalpy and the entropy associated with hydrophobic interactions.
    Section: 2.4

44. How do hydrophobic interactions aid in membrane formation?
    Ans: Hydrophobic interaction causes the nonpolar tails to aggregate and form the interior of the membrane. This results in a net release of heat and a favorable change in the system enthalpy.
    Section: 2.4

45. Give examples of key functional groups found in biochemistry.
    Ans: hydrophobic, hydroxyl, aldehyde, keto, carboxyl, amino, phosphoryl, sulfhydryl
    Section: 2.5, Table 2.1

46. Draw a titration curve for the ionization of acetic acid.
    Ans: The curve should look like Figure 2.12.
    Section: 2.5

47. Why are conjugate acid–base pairs so important in biological systems?
    Ans: The conjugate acid–base pairs in biological systems act as buffers. Many metabolic activities release protons, and these can combine with the conjugate base and so have little effect on the pH.
    Section: 2.5

48. Tris buffers are commonly used in biochemistry labs because they buffer within the physiological range of 7.1 to 9.1 due to a pK_a of 8.1. To demonstrate the buffering capacity of Tris buffer, your biochemistry lab teaching assistant has given you one liter of a 0.1 M Tris buffer at pH 7.4. Add 2 mL of 1M HCl to this buffer and calculate what the new pH will be.

Ans: Use the Henderson-Hasselbalch equation to determine the ratio of conjugate base to weak acid of the original solution.
$7.4 = 8.1 + \log [A^-]/[HA]$
$-0.7 = \log [A^-]/[HA]$
$0.20/1 = [A^-]/[HA]$
0.20/1.20 = 0.17 = % of buffer A^- = 0.17 (0.1M) = 0.017M A^- .
1.0.1.20 = 0.83 = % of buffer HA = 0.83(0.1M) = 0.083 M HA
Next determine the $[H^+]$ added based on the amount and concentration of the HCl.
$[HCl] = [H^+] = (0.002\ L)\ (1.0\ M)/1.002\ L) = .002\ M$
New $[A^-]$ = 0.017 M – 0.002 M = 0.015M A^-
New [HA] = 0.083 M + 0.02 M = 0.085M HA
Using the Henderson-Hasselbalch equation, recalculate the new pH.
$pH = 8.1 + \log (0.015)/0.08 = 7.35$

Section: 2.5