Chapter 2: Water

Matching

A) hydrogen bond
B) rotational
C) H_3PO_4
D) $H_2PO_4^-$
E) HPO_4^{2-}
F) disordered
G) positive entropy
H) negative entropy
I) higher electronegativity
J) insoluble
K) tetrahedral arrangement
L) acid
M) base
N) only partially ionized

1. Translational and ______ thermal motion causes liquid water molecules to reorient approximately every 10^{-12} seconds.

Ans: B
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

2. The 104.5° bond angle in the water molecule is the result of the ______ of electron orbitals around oxygen.

Ans: K
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

3. The polarity of the O–H bond is caused by the ______ of oxygen relative to that of hydrogen.

Ans: I
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

4. For the ______ represented by D–H····A, the donor D is weakly acidic and the acceptor A is weakly basic.

Ans: A
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

5. Octane molecules dispersed in water tend to aggregate because that allows water molecules to be more ______.

Ans: F
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

6. The insolubility of nonpolar molecules in water is due to the large ______, which is the result of water molecules forming an ordered network surrounding nonpolar molecules.

Ans: H
Level of Difficulty: Moderate
Section: 2.1.C
Learning objective: **Physical Properties of Water**

7. A strong acid is completely ionized in water, whereas a weak acid is ______.

Ans: N
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

8. Phosphate (pK_1 = 2.15, pK_2 = 6.82, and pK_3 = 12.38) will be mostly in the HPO_4^{2-} form at pH 7.2. At pH 5.82 it is mostly in the ______ form.

Ans: D
Level of Difficulty: Moderate
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

9. A solution containing a weak acid (pK = 7.5) and its conjugate base at pH of 8.5 has a good capacity to buffer the addition of ______.

Ans: L
Level of Difficulty: Moderate
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

10. A phosphate buffer solution at pH = pK_1 = 2.15 would have equal amounts of phosphate in the ______ form and the $H_2PO_4^-$ form.

Ans: C
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

Multiple Choice

11. Rank the following interactions in order of increasing strength (start with the weakest interaction).
A) ionic interactions, hydrogen bonds, London dispersion forces, covalent bonds
B) London dispersion forces, hydrogen bonds, ionic interactions, covalent bonds
C) London dispersion forces, ionic interactions, hydrogen bonds, covalent bonds
D) covalent bonds, London dispersion forces, ionic interactions, hydrogen bonds
E) hydrogen bonds, London dispersion forces, ionic interactions, covalent bonds

Ans: B
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

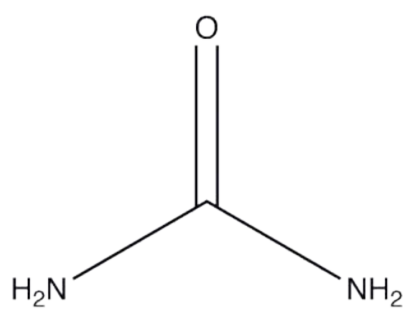
12. The strongest *noncovalent* interactions are
A) ionic interactions.
B) hydrogen bonds.
C) dipole-dipole interactions.
D) London dispersion forces.
E) van der Waals forces.

Ans: A
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

13. Hydrogen bonds within liquid water
A) are attractions between protons and oxygen nuclei.
B) are attractions between two hydrogen atoms.
C) are attractions between protons and hydroxide ions.
D) are ion-induced dipole attractions.
E) are dipole-dipole attractions.

Ans: E
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

14. Urea is a water-soluble product of nitrogen metabolism. How many hydrogen bonds can one urea molecule donate to surrounding water molecules?



A) 2
B) 3
C) 4
D) 5
E) 6

Ans: C
Level of Difficulty: Moderate
Section: 2.1.A
Learning objective: **Physical Properties of Water**

15. Methanol can act both as a H-bond donor and as a H-bond acceptor. What is the maximal number of H-bonds a single molecule of methanol can form with surrounding water molecules.

A) 1
B) 2
C) 3
D) 4
E) 5

Ans: C
Level of Difficulty: Moderate
Section: 2.1.A
Learning objective: **Physical Properties of Water**

16. In a hydrogen bond between a water molecule and another biomolecule
A) a hydrogen ion on the water molecule forms an ionic bond with a hydride ion on the other molecule.
B) the partial charge on a hydrogen of the water molecule interacts with the partial charge on a hydrogen of the other molecule.
C) the hydrogen bond will typically form between a hydrogen atom of the water molecule and either a nitrogen, sulfur, or oxygen atom of the other molecule.
D) a hydrogen on the water molecule forms a covalent bond with a hydrogen atom on the other molecule.
E) the hydrogen atom is located between an oxygen atom of the water and a carbon atom of the other molecule.

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

17. Which of the following statements about water is <u>not true</u>?
A) It has a high dielectric constant.
B) It dissolves salts and polar substances.
C) It can form two hydrogen bonds per water molecule.
D) It packs in a hexagonal (honeycomb) shaped lattice when the temperature falls below 0°C.
E) In the liquid state it is only 15% less hydrogen bonded than in the solid state at 0°C.

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

18. Which of the following statements about water is <u>not true</u>?
A) The electron-rich oxygen atom of one water molecule can interact with the electron-poor proton on another water molecule to form a hydrogen bond.
B) Liquid water is only 15% less hydrogen bonded than ice.
C) Water is a nonpolar molecule that with a bent molecular geometry.
D) Water can form highly ordered, cage-like, structures around nonpolar molecules.
E) Water is a key player in the energetics of hydrophobic interactions.

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

19. Which of the following statements about water is incorrect?
A) Water is an excellent solvent for polar molecules.
B) Pure water has a concentration of approximately 55.5 M.
C) Cations are solvated by shells of water molecules oriented with their hydrogen atoms pointed toward the ions.
D) Nonpolar molecules do not dissolve in water, but form a separate phase.
E) <u>Amphiphilic</u> detergents often form micelles with the polar groups on the outside exposed to water (solvent) and the nonpolar groups sequestered in the interior.

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

20. Which of the following statements about water is <u>incorrect?</u>
A) It is a small, polar molecule with a low dielectric constant.
B) It has a marked dipole moment.
C) It is largely hydrogen bonded, although any single H-bond exists only for a very short period of time ($\sim 10^{-12}$ s).
D) Acid-base reactions are very fast due to the mobility of hydronium ions in water which is a consequence of the ability of individual protons to “jump” from one water molecule to another.
E) It has a bent geometry with each O─H bond approximately 0.958 Å long and with an O─H bond energy of approximately 460 kJ/mol.

Ans: A
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

21. Ice
A) is a crystal of water molecules packed in an open structure stabilized by hydrogen bonds.
B) is less dense than liquid water.
C) contains 17% more hydrogen bonds then water.
D) All of the statements above are true.
E) None of the statements above are true.

Ans: D
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

22. Covalent C─C and C─H bonds have bond strengths that are approximately ____ times higher than those of H-bonds.
A) 2
B) 5
C) 10
D) 20
E) 100

Ans: D
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

23. The boiling point of water is 264°C higher than the boiling point of methane because
A) the molecular mass of methane is much lower than that of water.
B) methane molecules tend to avoid contact with each other.
C) water molecules are connected to each other by H-bonds.
D) methane molecules do not undergo London dispersion forces.
E) all of the above

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

24. _____ is exceptionally soluble in water due to the formation of hydrogen bonds.
A) NaCl
B) Benzene
C) Sodium palmitate
D) Ethanol
E) Oxygen

Ans: D
Level of Difficulty: Easy
Section: 2.1.B
Learning objective: **Physical Properties of Water**

25. Molecules such as methanol and ethanol are very soluble in water because
A) they tend to avoid contact with each other.
B) they contain C─H groups that donate H-bonds to water.
C) they contain C─H groups that accept H-bonds from water
D) they contain O─H groups that can form multiple H-bonds with water.
E) they do not form intermolecular H-bonds

Ans: D
Level of Difficulty: Easy
Section: 2.1.B
Learning objective: **Physical Properties of Water**

26. Hydrophobic interactions between nonpolar molecules
A) result from the tendency of water to maximize contact with nonpolar molecules.
B) are the result of strong attractions between nonpolar molecules.
C) are the result of strong repulsion between water and nonpolar molecules.
D) depend on strong permanent dipoles in the nonpolar molecules.
E) require the presence of surrounding water molecules.

Ans: E
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

27. Fatty acids such as palmitate and oleate are usually characterized as
A) hydrophobic.
B) hydrophilic.
C) polar.
D) water soluble.
E) amphiphilic.

Ans: E
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

28. Amphiphilic molecules
A) have both oxidizing and reducing groups.
B) are micelles.
C) have chromophores in two different wavelength regions.
D) have both acidic and basic groups.
E) have both hydrophilic and hydrophobic groups.

Ans: E
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

29. Which of the following statements about hydrophobic interactions is <u>not true</u>?
A) They are caused by hydrophobic molecules interacting strongly with each other.
B) They are the driving force for micelle formation.
C) When nonpolar molecules come in contact with water, a highly-ordered shell of water molecules forms at the interface between the nonpolar molecules and water. A hydrophobic interaction is caused by the desire of water molecules to regain the entropy lost during this organization around the nonpolar substance by excluding the substance from interaction with water molecules.
D) They are entropy driven.
E) They are the main driving force for protein folding into three dimensional structures.

Ans: A
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

30. Which of the following is the best explanation for the hydrophobic effect?
A) It is caused by an affinity of hydrophobic groups for each other.
B) It is caused by the affinity of water for hydrophobic groups.
C) It is an entropic effect, caused by the desire of water molecules to increase their entropy by forming highly ordered structures around the hydrophobic groups.
D) It is an entropic effect, caused by the desire of water molecules to increase their entropy by excluding hydrophobic groups, which they must otherwise surround with highly ordered structures.
E) It is an entropic effect caused by the desire of hydrophobic groups to increase their entropy by associating with other hydrophobic groups.

Ans: D
Level of Difficulty: Difficult
Section: 2.1.C
Learning objective: **Physical Properties of Water**

31. In the energetics of transferring hydrocarbons from water to nonpolar solvents, the factor $T\Delta S$ is commonly
A) negative.
B) positive.
C) unmeasurable.
D) unimportant.
E) assumed to be zero.

Ans: B
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

32. Globules of up to several thousand amphiphilic molecules arranged with the hydrophilic groups on the surface and the hydrophobic groups buried in the center that form in water are called
A) micelles.
B) liposomes.
C) vacuoles.
D) bilayer membranes.
E) none of the above

Ans: A
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

33. Sheets composed of two layers of amphipathic molecules arranged with the hydrophilic groups on the surface and the hydrophobic groups buried in the center that form in water are called
A) micelles.
B) liposomes.
C) vacuoles.
D) bilayer membranes.
E) none of the above

Ans: D
Level of Difficulty: Easy
Section: 2.1.C
Learning objective: **Physical Properties of Water**

34. Physical properties that depend on the amounts of various species, rather than the identities of those species, are called
A) osmotic properties.
B) hydrophobic properties.
C) London dispersion forces.
D) aggregate properties.
E) colligative properties.

Ans: E
Level of Difficulty: Easy
Section: 2.1.B
Learning objective: **Physical Properties of Water**

35. Osmotic pressure is a function of
A) humidity.
B) solute size.
C) solute concentration.
D) van der Waals forces.
E) solute vapor pressure.

Ans: C
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

36. K_w, the ionization constant of water, is _____ at _____.
A) 10^{-7}; 25°C
B) 10^{7}; 25K
C) 10^{14}; 25°C
D) 10^{-14}; 25°C
E) 10^{-14}; 0°C

Ans: D
Level of Difficulty: Easy
Section: 2.1.A
Learning objective: **Physical Properties of Water**

37. Weak acids
A) are only partially ionized in an aqueous solution.
B) give solutions with a high pH.
C) do not provide hydronium ions.
D) are almost insoluble in water.
E) are of no value in a buffering system.

Ans: A
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

38. A solution is made by mixing 0.05 mL of 1.0 M HCl with 999.95 mL of pure water. Calculate the pH of the resulting solution (assume the total volume is 1.0 L).
A) 2.7
B) 4.3
C) 9.7
D) 7.0
E) 5.0

Ans: B
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

39. The pH of coffee is 5.6. The pH of grapefruit juice is 2.6. This means that the proton concentration in coffee is
A) a thousand times higher than in grapefruit juice.
B) a thousand times lower than in grapefruit juice.
C) 3000 times lower than in grapefruit juice.
D) 3 times the proton concentration of grapefruit juice.
E) 3000 times higher than in grapefruit juice.

Ans: B
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

40. A solution is made by mixing 1.0 mL of 1.0 M acetic acid (pK = 4.76, K_a = 1.74 x 10^{-5}) with one 999 mL of pure water. Calculate the pH of the resulting solution (assume the total volume is 1.0 L).
A) 10.1
B) 3.0
C) 1.0
D) 3.9
E) 1.32

Ans: D
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

41. You mix 999 mL pure water and 1 mL of 2.0 M NaOH. Calculate the pH of the resulting solution. (assume the total volume is 1.0 L).
A) 0.3
B) 0.7
C) 2.7
D) 11.3
E) 13.7

Ans: D
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

42. The pH of a 0.1 M solution of sodium acetate would be
A) basic, because of the acetate ion reacts with water to form acetic acid and OH^-.
B) acidic, because the acetate ion is acidic.
C) acidic, because the acetate ion forms acetic acid.
D) neutral, because salts are neither acidic nor basic.
E) basic, because the Na^+ ionizes and combines with OH^-.

Ans: A
Level of Difficulty: Easy
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

43. Phosphoric acid is a polyprotic acid, with p*K* values of 2.14, 6.86, and 12.38. Which ionic form predominates at pH 9.3?
A) H_3PO_4
B) $H_2PO_4^{1-}$
C) HPO_4^{2-}
D) PO_4^{3-}
E) none of the above

Ans: C
Level of Difficulty: Moderate
Section: 2.2.B
Learning objective: **Chemical Properties of Water**

44. To make a phosphate buffer at pH 6.82 starting with one liter of 10 mM phosphoric acid (p*K*s are 2.15, 6.82, and 12.38), you could add
A) 5 millimoles of HCl.
B) 20 millimoles of K^+.
C) 25 millimoles of HCl.
D) 15 millimoles of KOH.
E) You can't make a buffer by adding HCl or KOH.

Ans: E
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

45. You mix equal volumes of 0.05 M NaH_2PO_4 and 0.05 M Na_2HPO_4 (pK's for phosphoric acid are 2.15, 6.82 and 12.38). Which of the following best describes the resulting solution?
A) pH 2.15 and poorly buffered
B) pH 2.15 and well buffered
C) pH 6.82 and well buffered
D) pH 12.38 and well buffered
E) pH 6.82 and poorly buffered

Ans: C
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

46. To make an acetate buffer at pH 4.76 starting with 500 mL of 0.1 M sodium acetate (pK acetic acid = 4.76), you could add
A) 0.1 mol of NaOH.
B) 0.2 mol of HCl.
C) 0.025 mol of HCl.
D) 0.1 mol of HCl.
E) You can't make a buffer by adding HCl or NaOH.

Ans: C
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

47. The pK_1 of citric acid is 3.09. What is the citric acid : monosodium citrate ratio in a 1.0 M citric acid solution with a pH of 2.09?
A) 10:1
B) 1:1
C) 1:10
D) 10:11
E) 1:11

Ans: A
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

48. The pKs of succinic acid are 4.21 and 5.64. How many grams of monosodium succinate (FW = 140 g/mol) and disodium succinate (FW = 162 g/mol) must be added to 1 L of water to produce a solution with a pH 5.28 and a total solute concentration of 100 mM? (Assume the total volume remains 1 liter, answer in grams monosodium succinate, grams disodium succinate, respectively.)
A) 11.3 g, 4.2 g
B) 9.7 g, 4.9 g
C) 4.9 g, 9.7 g
D) 14.9 g, 1.1 g
E) 1.1 g, 14.9 g

Ans: B
Level of Difficulty: Moderate
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

49. What is the approximate pK_a of a weak acid HA if a solution 0.1 M HA and 0.3 M A^- has a pH of 6.5?
A) 5.8
B) 6.0
C) 6.2
D) 6.4
E) 6.6

Ans: B
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

50. A graduate student at SDSU wants to measure the activity of a particular enzyme at pH 4.0. To buffer her reaction, she will use a buffer system based on one of the acids listed below, which acid is most appropriate for the experiment?
A) Formic acid (K_a 1.78×10^{-4})
B) MES (K_a 8.13×10^{-7})
C) PIPES (K_a 1.74×10^{-7})
D) Tris (K_a 8.32×10^{-9})
E) Piperidine (K_a 7.58×10^{-12})

Ans: A
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

51. The pH at the midpoint in the titration of an acid with a base is
A) equal to the p*K* of the corresponding acid.
B) equal to the p*K* of the corresponding base.
C) equal to 14 minus the p*K* of the corresponding acid.
D) equal to 14 plus the p*K* of the corresponding base.
E) none of the above

Ans: A
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

52. The capacity of a buffer to resist changes in pH upon addition of protons or hydroxide ions depends on
A) the pK_a of the weak acid in the buffer.
B) the pH of the buffer.
C) the total concentration of the weak acid and its conjugate base in the buffer.
D) all of the above
E) none of the above

Ans: D
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

53. The pH of blood is affected by
A) the reaction of CO_2 with H_2O to form carbonic acid.
B) the ionization of aqueous carbonic acid to hydronium ions and the bicarbonate anions.
C) the decrease of the blood pH due to the production of hydronium ions.
D) the excretion of bicarbonate and ammonium ions from the kidneys.
E) all of the above

Ans: E
Level of Difficulty: Easy
Section: 2.2.C
Learning objective: **Chemical Properties of Water**

Short answer

54. Biological processes can be best understood in the context of water.
a. What effect does water have on the noncovalent interactions between either charged or polar groups/molecules?
b. Why is this effect important with respect to biochemical processes?

Ans: a. Water reduces the strength of those interactions.
b. Water reduces the strength of polar and ionic interactions. This makes those interactions reversible and life is based on reversible interaction between biomolecules.
Level of Difficulty: Difficult
Section 2.1.B
Learning objective: **Physical Properties of Water**

55. The hydrophobic effect is an important driving force for protein folding and for the assembly of molecules into cellular structures.
a. Give the definition of the hydrophobic effect
b. What are amphiphilic (amphipathic) molecules?
c. Which cellular structures are composed of many amphipathic molecules that are driven together under the influence of the hydrophobic effect?

Ans: a. It is defined as the tendency of water to minimize contact with hydrophobic substances.
b. Molecules with both polar and nonpolar regions
c. Cellular membranes meet these criteria.
Level of Difficulty: Moderate
Section 2.1.C
Learning objective: **Physical Properties of Water**

56. Intracellular fluids and the fluids surrounding cells in multicellular organisms are full of dissolved substances, including nucleotides, amino acids, proteins and ions. The total concentration of substances determines the colligative properties of a fluid. Osmosis is one of several such colligative properties.
a. Give the definition of osmosis.
b. Eukaryotic cells are aqueous solutions surrounded by semipermeable membranes. Consequently, incubation of a cell in a solution of lower osmotic pressure would cause the cell to swell up and burst. Discuss two solutions that have developed during evolution to solve this problem.

Ans: a. Osmosis is the movement of solvent (water) through a semipermeable membrane from a region of high concentration to a region of low concentration (with concentration referring to the concentration of water).
b. Plant cells are surrounded by a rigid cell wall that prevents the cell from expanding and therefore water from flowing into the cell. Animals surround their cells with a solution that has the same osmotic pressure as is found inside their cells. As a consequence there is no flow of water into or out of these cells.
Level of Difficulty: Difficult
Section 2.1.D
Learning objective: **Physical Properties of Water**

57. Solutions that contain a mixture of a weak acid and its conjugate base are known to resist changes in pH.
a. Calculate the pH of 1.0 L of an aqueous solution containing 75 mmol of MES ($pK_a = 6.09$) and 25 mmol of its conjugate base.
b. How much of a 5.0 M NaOH solution do you need to add to raise the pH to 6.09?

Ans: a. $pH = pK_a + \log [A^-]/[HA] \Rightarrow$
$pH = 6.09 + \log 25\text{ mM}/75\text{ mM} = 6.09 - 0.48 = 5.61$
b. $pH = pK_a + \log [A^-]/[HA]$
At pH = 6.09, $6.09 = 6.09 + \log [A^-]/[HA] \Rightarrow$
$\log [A^-]/[HA] = 0 \Rightarrow [A^-]/[HA] = 1 \Rightarrow [A^-] = [HA]$
You know that $[A^-] + [HA] = 100$ mM, substitute $[A^-] = [HA]$ in this equation $\Rightarrow 2 \times [A^-] = 100$ mM $\Rightarrow [A^-] = [HA] = 50$ mM.
You start with 1.0 L of a buffer containing 25 mmol A^- and 75 mM HA. To change the pH to 6.09, 25 mmol of HA has to be converted to A^-. This is done by adding 25 mmol of NaOH. The NaOH solution is 5.0 M $\Rightarrow 25 \times 10^{-3}$ mol/5.0 mol $\times 1.0\ L^{-1} = 5.0 \times 10^{-3}$ L or 5.0 mL
Level of Difficulty: Difficult
Section 2.2.B
Learning objective: **Chemical Properties of Water**

58. A buffer contains 0.010 mol of lactic acid (pK_a = 3.86) and 0.050 mol sodium lactate per liter of aqueous solution.
a. Calculate the pH of this buffer.
b. Calculate the pH after 5.0 mL of 0.50 M HCl is added to 1 liter of the buffer (assume the total volume will be 1005 mL).

Ans: a. pH = pK_a + log [A$^-$]/[HA] ⇒
pH = 3.86 + log 50 mM/10 mM = 3.86 + 0.70 = 4.56
b. Add 5.0 × 10^{-3} L × 0.50 mol/L HCl = 2.5 x 10^{-3} mol or 2.5 mmol HCl added
50 mmol lactate + 2.5 mmol H^+ = 47.5 mmol lactate + 2.5 mmol lactic acid ⇒ after adding 2.5 mmol HCl there is 47.5 mmol of lactate and 12.5 mmol of lactic acid ⇒ pH = 3.86 + log 47.5 mmol × (1005 mL)$^{-1}$/12.5 mmol × (1005 mL)$^{-1}$ = 3.86 + log 47.5/12.5 = 3.86 + 0.58 = 4.44
Level of Difficulty: Difficult
Section 2.2.B
Learning objective: **Chemical Properties of Water**

59. The pK_a of carbonic acid is 6.35. A solution is made by combining 50 mL 1.0 M carbonic acid, 2.0 mL 5.0 M KOH and 448 mL pure water (assume the total volume is 500 mL). Calculate the pH of the resulting solution.

Ans: 50 × 10^{-3} L × 1.0 mol/L carbonic acid = 50 × 10^{-3} mol or 50 mmol carbonic acid. 2 × 10^{-3} × 5.0 mol/L KOH = 10 × 10^{-3} mol or 10 mmol KOH. 50 mmol carbonic acid + 10 mmol OH^- = 40 mmol carbonic acid and 10 mmol bicarbonate (and 10 mmol water). pH = pK_a + log [A$^-$]/[HA] = 6.35 + log 10 mmol × (500 mL)$^{-1}$/40 mmol × (500 mL)$^{-1}$ = 6.35 + log 10/40 = 6.35 – 0.60 = 5.75
Level of Difficulty: Difficult
Section 2.2.B
Learning objective: **Chemical Properties of Water**

60. You prepare a solution by mixing 50 mL 0.10 M sodium acetate and 150 mL 1.0 M acetic acid (pK_a 4.76).
a. Calculate the pH of this solution.
b. Can this solution be used effectively as a buffer (explain your answer)?

Ans: a. 50 × 10^{-3} L × 0.10 mol/L acetate = 5.0 × 10^{-3} mol or 5.0 mmol acetate
150 × 10^{-3} × 1.0 mol/L acetic acid = 150. × 10^{-3} mol or 150 mmol acetic acid. The total volume equals 200 mL (assuming additive volumes).
pH = pK_a + log [A$^-$]/[HA] = 4.76 + log 5 mmol × (200 mL)$^{-1}$/150 mmol × (200 mL)$^{-1}$ = 4.76 + log 5/150 = 4.76−1.48 = 3.28
b. No, because the pH (3.28) is more than 1 unit from the pK_a (4.76).
Level of Difficulty: Difficult
Section 2.2.B
Learning objective: **Chemical Properties of Water**