1. Which of the following aqueous mixtures would be a buffer system?
   A) HCl, NaCl
   B) HNO₃, NaN₃
   C) H₃PO₄, H₂PO₄⁻
   D) H₂SO₄, CH₃COOH
   E) NH₃, NaOH

2. Which, if any, of the following aqueous mixtures would be a buffer system?
   A) CH₃COOH, NaH₂PO₄
   B) H₂CO₃, HCO₃⁻
   C) H₂PO₄⁻, HCO₃⁻
   D) HSO₄⁻, HSO₃⁻
   E) None of the above will be a buffer solution.

3. Equal volumes of the following pairs of solutions are mixed. Which pair will produce a buffer solution?
   A) 0.10 mol L⁻¹ HCl and 0.05 mol L⁻¹ NaOH
   B) 0.10 mol L⁻¹ HCl and 0.15 mol L⁻¹ NH₃
   C) 0.10 mol L⁻¹ HCl and 0.05 mol L⁻¹ NH₃
   D) 0.10 mol L⁻¹ HCl and 0.20 mol L⁻¹ CH₃COOH
   E) 0.10 mol L⁻¹ HCl and 0.20 mol L⁻¹ NaCl

4. Which one of the following aqueous solutions, when mixed with an equal volume of 0.10 mol L⁻¹ aqueous NH₃, will produce a buffer solution?
   A) 0.10 mol L⁻¹ HCl
   B) 0.20 mol L⁻¹ HCl
   C) 0.10 mol L⁻¹ CH₃COOH
   D) 0.050 mol L⁻¹ NaOH
   E) 0.20 mol L⁻¹ NH₄Cl
5. Which one of the following pairs of 0.100 mol L\(^{-1}\) solutions, when mixed, will produce a buffer solution?
   A) 50. mL of aqueous CH\(_3\)COOH and 25. mL of aqueous HCl
   B) 50. mL of aqueous CH\(_3\)COOH and 100. mL of aqueous NaOH
   C) 50. mL of aqueous NaOH and 25. mL of aqueous HCl
   D) 50. mL of aqueous CH\(_3\)COONa and 25. mL of aqueous NaOH
   E) 50. mL of aqueous CH\(_3\)COOH and 25. mL of aqueous CH\(_3\)COONa

6. Which of the following has the highest buffer capacity?
   A) 0.10 \( M \) H\(_2\)PO\(_4\)-/0.10 \( M \) HPO\(_4^{2-}\)
   B) 0.50 \( M \) H\(_2\)PO\(_4\)-/0.10 \( M \) HPO\(_4^{2-}\)
   C) 0.10 \( M \) H\(_2\)PO\(_4\)-/0.50 \( M \) HPO\(_4^{2-}\)
   D) 0.50 \( M \) H\(_2\)PO\(_4\)-/0.50 \( M \) HPO\(_4^{2-}\)
   E) They all have the same buffer capacity.

7. A buffer is to be prepared by adding solid sodium acetate to 0.10 \( M \) CH\(_3\)COOH. Which of the following concentrations of sodium acetate will produce the most effective buffer?
   A) 3.0 \( M \) CH\(_3\)COONa
   B) 2.5 \( M \) CH\(_3\)COONa
   C) 2.0 \( M \) CH\(_3\)COONa
   D) 1.5 \( M \) CH\(_3\)COONa
   E) 0.50 \( M \) CH\(_3\)COONa

8. A phosphate buffer (H\(_2\)PO\(_4\)-/HPO\(_4^{2-}\)) has a pH of 8.3. Which of the following changes will cause the pH to increase?
   A) dissolving a small amount of Na\(_2\)HPO\(_4\)
   B) dissolving a small amount of NaH\(_2\)PO\(_4\)
   C) adding a small amount of dilute hydrochloric acid
   D) adding a small amount of dilute phosphoric acid
   E) making the buffer more concentrated by removing some water
9. What is the \([\text{H}_3\text{O}^+]\) in a buffer that consists of 0.30 \(M\) HCOOH and 0.20 \(M\) HCOONa? 

For HCOOH, \(K_a = 1.7 \times 10^{-4}\)

A) \(1.1 \times 10^{-4} \, M\)
B) \(2.6 \times 10^{-4} \, M\)
C) \(4.3 \times 10^{-4} \, M\)
D) \(6.7 \times 10^{-5} \, M\)
E) none of the above

10. What is the \(pK_a\) for the acid HA if a solution of 0.65 \(M\) HA and 0.85 \(M\) NaA has a pH of 4.75? 

A) < 4.00
B) 4.63
C) 4.87
D) 5.02
E) > 5.50

11. What is the \([\text{H}_3\text{O}^+]\) in a solution that consists of 0.15 \(M\) \(\text{C}_2\text{N}_2\text{H}_8\) (ethylenediamine) and 0.35 \(M\) \(\text{C}_2\text{N}_2\text{H}_6\text{Cl}\)? \(K_b = 4.7 \times 10^{-4}\)

A) \(2.0 \times 10^{-3} \, M\)
B) \(1.1 \times 10^{-1} \, M\)
C) \(6.3 \times 10^{-9} \, M\)
D) \(2.1 \times 10^{-10} \, M\)
E) \(5.0 \times 10^{-11} \, M\)

12. What will be the effect of adding 0.5 mL of 0.1 \(M\) NaOH to 100 mL of an acetate buffer in which \([\text{CH}_3\text{COOH}] = [\text{CH}_3\text{COO}^-] = 0.5 \, M\)?

A) The pH will increase slightly.
B) The pH will increase significantly.
C) The pH will decrease slightly.
D) The pH will decrease significantly.
E) Since it is a buffer solution, the pH will not be affected.
13. A solution is prepared by adding 100 mL of 0.2 M hydrochloric acid to 100 mL of 0.4 M sodium formate. Is this a buffer solution, and if so, what is its pH?
   A) It is a buffer, pH > $pK_a$ of formic acid.
   B) It is a buffer, pH < $pK_a$ of formic acid.
   C) It is a buffer, pH = $pK_a$ of formic acid.
   D) It is a buffer, pH = $pK_b$ of sodium formate.
   E) Since hydrochloric acid is a strong acid, this is not a buffer.

14. Assuming that the total volume does not change after 0.200 g of KCl is added to 1.0 L of a saturated aqueous solution of AgCl, calculate the number of moles of Ag$^+$ ion in the solution after equilibrium has been reestablished. For AgCl, $K_{sp} = 1.8 \times 10^{-10}$.
   A) $1.8 \times 10^{-10}$ mol Ag$^+$
   B) $9.0 \times 10^{-10}$ mol Ag$^+$
   C) $9.0 \times 10^{-9}$ mol Ag$^+$
   D) $6.7 \times 10^{-8}$ mol Ag$^+$
   E) $1.3 \times 10^{-5}$ mol Ag$^+$

15. Barium sulfate (BaSO$_4$) is a slightly soluble salt, with $K_{sp} = 1.1 \times 10^{-10}$. What mass of Ba$^{2+}$ ions will be present in 1.0 L of a saturated solution of barium sulfate?
   A) < $10^{-7}$ g
   B) $1.0 \times 10^{-5}$ g
   C) 0.0014 g
   D) 0.0024 g
   E) > 0.05 g

16. When a strong acid is titrated with a strong base, the pH at the equivalence point
   A) is greater than 7.0.
   B) is equal to 7.0.
   C) is less than 7.0, but is not 3.5.
   D) is equal to the $pK_a$ of the acid.
   E) is equal to 3.5.
17. Calculate the solubility of silver chromate, $\text{Ag}_2\text{CrO}_4$, in $0.005 \ M \text{Na}_2\text{CrO}_4$. $K_{sp} = 2.6 \times 10^{-12}$
   
   A) $1.4 \times 10^{-4} \ M$
   B) $3.4 \times 10^{-5} \ M$
   C) $1.1 \times 10^{-5} \ M$
   D) $1.6 \times 10^{-6} \ M$
   E) $< 1.0 \times 10^{-6} \ M$

18. Calculate the solubility of lead(II) iodide, $\text{PbI}_2$, in $0.025 \ M \text{KI}$. $K_{sp} = 7.9 \times 10^{-9}$
   
   A) $4.5 \times 10^{-2} \ M$
   B) $2.8 \times 10^{-2} \ M$
   C) $8.9 \times 10^{-5} \ M$
   D) $5.0 \times 10^{-5} \ M$
   E) $1.3 \times 10^{-5} \ M$

19. A lab technician adds 0.015 mol of KOH to 1.00 L of 0.0010 $M \text{Ca(NO}_3\text{)}_2$. $K_{sp} = 6.5 \times 10^{-6}$ for $\text{Ca(OH)}_2$. Which of the following statements is correct?
   
   A) Calcium hydroxide precipitates until the solution is saturated.
   B) The solution is unsaturated and no precipitate forms.
   C) The concentration of calcium ions is reduced by the addition of the hydroxide ions.
   D) One must know $K_{sp}$ for calcium nitrate to make meaningful predictions on this system.
   E) The presence of KOH will raise the solubility of $\text{Ca(NO}_3\text{)}_2$.

20. Write the ion product expression for magnesium fluoride, $\text{MgF}_2$.
   
   A) $[\text{Mg}^{2+}][\text{F}^-]^2$
   B) $[\text{Mg}^{2+}][\text{F}^-]$
   C) $[\text{Mg}^{2+}][\text{F}^-]^2$
   D) $\frac{1}{[\text{Mg}^{2+}][\text{F}^-]}$
   E) $\frac{1}{[\text{Mg}^{2+}][\text{F}^-]^2}$
21. Which of the following substances has the greatest solubility in water?
   A) MgCO₃, $K_{sp} = 3.5 \times 10^{-8}$
   B) NiCO₃, $K_{sp} = 1.3 \times 10^{-7}$
   C) AgI₂O₅, $K_{sp} = 3.1 \times 10^{-8}$
   D) CuBr, $K_{sp} = 5.0 \times 10^{-9}$
   E) AgCN, $K_{sp} = 2.2 \times 10^{-16}$

22. The solubility of calcium chromate is $1.56 \times 10^{-3}$ g/100 mL of solution. What is the $K_{sp}$ for CaCrO₄?
   A) $2.4 \times 10^{-4}$
   B) $1.5 \times 10^{-5}$
   C) $7.6 \times 10^{-6}$
   D) $1.0 \times 10^{-8}$
   E) $< 1.0 \times 10^{-8}$

23. Calculate the solubility of strontium fluoride, SrF₂, in pure water. $K_{sp} = 2.6 \times 10^{-9}$
   A) $1.4 \times 10^{-3} \, M$
   B) $3.4 \times 10^{-4} \, M$
   C) $8.7 \times 10^{-4} \, M$
   D) $5.1 \times 10^{-5} \, M$
   E) $< 1.0 \times 10^{-5} \, M$

24. Calculate the solubility of barium carbonate, BaCO₃, in pure water. $K_{sp} = 2.0 \times 10^{-9}$
   A) $1.3 \times 10^{-3} \, M$
   B) $3.2 \times 10^{-5} \, M$
   C) $2.2 \times 10^{-5} \, M$
   D) $4.5 \times 10^{-5} \, M$
   E) $4.0 \times 10^{-18} \, M$
25. When a strong acid is titrated with a weak base, the pH at the equivalence point
   A) is greater than 7.0
   B) is equal to 7.0.
   C) is less than 7.0.
   D) is equal to the $pK_a$ of the acid.
   E) is equal to the $pK_b$ of the base.

26. The solubility of lead(II) chloride is 0.45 g/100 mL of solution. What is the $K_{sp}$ of PbCl₂?
   A) $4.9 \times 10^{-2}$
   B) $1.7 \times 10^{-5}$
   C) $8.5 \times 10^{-6}$
   D) $4.2 \times 10^{-6}$
   E) $< 1.0 \times 10^{-6}$

27. A change in pH will significantly affect the solubility of which, if any, of the following compounds?
   A) BaF₂
   B) CuCl
   C) CuBr
   D) AgI
   E) None of the solubilities will be significantly affected.

28. A saturated solution of calcium hydroxide, Ca(OH)₂, is in contact with excess solid Ca(OH)₂. Which of the following statements correctly describes what will happen when aqueous HCl (a strong acid) is added to this mixture, and system returns to equilibrium?
   (For Ca(OH)₂, $K_{sp} = 6.5 \times 10^{-6}$)
   A) The solubility of Ca(OH)₂ will be unchanged.
   B) The OH⁻ concentration will decrease and the Ca²⁺ concentration will increase.
   C) The OH⁻ concentration will increase and the Ca²⁺ concentration will decrease.
   D) The concentrations of both Ca²⁺ and OH⁻ will increase.
   E) The solubility of Ca(OH)₂ will decrease.
29. The solubility of aluminum hydroxide in water ______________ when dilute nitric acid is added to it.
   A) increases
   B) decreases
   C) does not change
   D) first increases, then decreases
   E) first decreases, then increases

30. A buffer is prepared by adding 300.0 mL of 2.0 M NaOH to 500.0 mL of 2.0 M CH₃COOH. What is the pH of this buffer? \( K_a = 1.8 \times 10^{-5} \)
   A) 4.57
   B) 4.52
   C) 4.87
   D) 4.92
   E) 4.97

31. A 25.0-mL sample of 0.10 M C₂H₃NH₂ (ethylamine) is titrated with 0.15 M HCl. What is the pH of the solution after 9.00 mL of acid have been added to the amine? \( K_b = 6.5 \times 10^{-4} \)
   A) 11.08
   B) 10.88
   C) 10.74
   D) 10.55
   E) 10.49

32. A 20.0-mL sample of 0.30 M HBr is titrated with 0.15 M NaOH. What is the pH of the solution after 40.3 mL of NaOH have been added to the acid?
   A) 2.95
   B) 3.13
   C) 10.87
   D) 11.05
   E) 13.14
33. A 50.0-mL sample of 0.50 \( M \) HCl is titrated with 0.50 \( M \) NaOH. What is the pH of the solution after 28.0 mL of NaOH have been added to the acid?
A) 0.85
B) 0.75
C) 0.66
D) 0.49
E) 3.8

34. If 10.0 g of NaF and 20.0 g of HF are dissolved in water to make one liter of solution, what will the pH be? For HF, \( K_a = 6.8 \times 10^{-4} \).
A) 7.13
B) 2.54
C) 1.57
D) 3.17
E) 4.86

35. What is the pH of a solution that consists of 0.50 \( M \) \( \text{H}_2\text{C}_6\text{H}_6\text{O}_6 \) (ascorbic acid) and 0.75 \( M \) \( \text{NaHC}_6\text{H}_6\text{O}_6 \) (sodium ascorbate)? For ascorbic acid, \( K_a = 6.8 \times 10^{-5} \).
A) 3.76
B) 3.99
C) 4.34
D) 4.57
E) 5.66

36. A formic acid buffer containing 0.50 \( M \) HCOOH and 0.50 \( M \) HCOONa has a pH of 3.77. What will the pH be after 0.010 mol of NaOH has been added to 100.0 mL of the buffer?
A) 3.67
B) 3.78
C) 3.81
D) 3.85
E) 3.95
37. A solution is prepared by adding 500 mL of 0.3 $M$ NaClO to 500 mL of 0.4 $M$ HClO. What is the pH of this solution?
A) The pH will be greater than the $pK_a$ of hypochlorous acid.
B) The pH will be less than the $pK_a$ of hypochlorous acid.
C) The pH will be equal to the $pK_a$ of hypochlorous acid.
D) The pH will equal the $pK_b$ of sodium hypochlorite.
E) The pH will be none of the above.

38. Buffer solutions with the component concentrations shown below were prepared. Which of them should have the highest pH?
A) $[\text{H}_2\text{PO}_4^-] = 0.50 \, M, \, [\text{HPO}_4^{2-}] = 0.50 \, M$
B) $[\text{H}_2\text{PO}_4^-] = 1.0 \, M, \, [\text{HPO}_4^{2-}] = 1.0 \, M$
C) $[\text{H}_2\text{PO}_4^-] = 1.0 \, M, \, [\text{HPO}_4^{2-}] = 0.50 \, M$
D) $[\text{H}_2\text{PO}_4^-] = 0.50 \, M, \, [\text{HPO}_4^{2-}] = 1.0 \, M$
E) $[\text{H}_2\text{PO}_4^-] = 0.75 \, M, \, [\text{HPO}_4^{2-}] = 1.0 \, M$

39. The salts $X(\text{NO}_3)_2$ and $Y(\text{NO}_3)_2$ (where $X^-$ and $Y^-$ are metal ions) are dissolved in water to give a solution which is 0.1 $M$ in each of them. Which of the answers gives the concentration of chloride ions will precipitate the most $Y\text{Cl}_2$ without precipitating any $X\text{Cl}_2$?

Given $K_{sp}$ values: $X\text{Cl}_2, \, 2 \times 10^{-5} \quad Y\text{Cl}_2, \, 1 \times 10^{-10}$
A) $1 \, M$ $\text{Cl}^-$
B) $0.1 \, M$ $\text{Cl}^-$
C) $0.01 \, M$ $\text{Cl}^-$
D) $0.001 \, M$ $\text{Cl}^-$
E) $0.0001 \, M$ $\text{Cl}^-$
40. The salts X(NO$_3$)$_2$ and Y(NO$_3$)$_2$ (where X$^+$ and Y$^+$ are metal ions) are dissolved in water to

give a solution which is 0.1 M in each of them. Using the $K_{sp}$ values listed below, decide

which aqueous reagent, if any, will definitely precipitate X$^+$ before precipitating Y$^+$ from

solution.

Given $K_{sp}$ values:

XCl$_2$, 1 x 10$^{-5}$  YCl$_2$, 1 x 10$^{-10}$  X(OH)$_2$, 1 x 10$^{-10}$  Y(OH)$_2$, 1 x 10$^{-5}$

A) 1 M NaCl
B) 1 M HCl
C) 1 M HNO$_3$
D) 1 M NaOH
E) None of the above reagents will accomplish the precipitation.

41. The lab technician Anna Lytic adds 2.26 mol KOH to 1.00 L of 0.5 M Al(NO$_3$)$_3$. What is

the concentration of aluminum ions after the aluminum nitrate has reacted with the

potassium hydroxide? $K_f$ = 3.0 x 10$^{33}$ for Al(OH)$_4^-$

A) 1.8 x 10$^{-7}$ M
B) 9.1 x 10$^{-18}$ M
C) 1.0 x 10$^{-21}$ M
D) 3.3 x 10$^{-34}$ M
E) 7.1 x 10$^{-35}$ M

42. An acetate buffer has a pH of 4.40. Which of the following changes will cause the pH to
decrease?

A) dissolving a small amount of solid sodium acetate
B) adding a small amount of dilute hydrochloric acid
C) adding a small amount of dilute sodium hydroxide
D) dissolving a small amount of solid sodium chloride
E) diluting the buffer solution with water
43. A popular buffer solution consists of carbonate (CO$_3^{2-}$) and hydrogen carbonate (HCO$_3^-$) conjugate acid-base pair. Which, if any, of the following such buffers has the highest buffer capacity?

A) 0.9 M CO$_3^{2-}$ and 0.1 M HCO$_3^-$
B) 0.1 M CO$_3^{2-}$ and 0.9 M HCO$_3^-$
C) 0.5 M CO$_3^{2-}$ and 0.5 M HCO$_3^-$
D) 0.1 M CO$_3^{2-}$ and 0.1 M HCO$_3^-$
E) They all have the same buffer capacity.