1. What combination of substances will give a buffered solution that has a pH of 5.05? (Assume each pair of substances is dissolved in 5.0 L of water.)

\[ K_b \text{ for NH}_3 = 1.8 \times 10^{-5}; \ K_b \text{ for C}_5\text{H}_5\text{N} = 1.7 \times 10^{-9} \]

a) 1.0 mole NH\(_3\) and 1.5 mole NH\(_4\)Cl  
b) 1.5 mole NH\(_3\) and 1.0 mole NH\(_4\)Cl  
c) 1.0 mole C\(_5\)H\(_5\)N and 1.5 mole C\(_5\)H\(_5\)NHCl  
d) 1.5 mole C\(_5\)H\(_5\)N and 1.0 mole C\(_5\)H\(_5\)NHCl  
e) none of these

ANS: c) 1.0 mole C\(_5\)H\(_5\)N and 1.5 mole C\(_5\)H\(_5\)NHCl

2. You have solutions of 0.200 M HNO\(_2\) and 0.200 M KNO\(_2\) \((K_a \text{ for HNO}_2 = 4.00 \times 10^{-4})\). A buffer of pH 3.000 is needed. What volumes of HNO\(_2\) and KNO\(_2\) are required to make 1 liter of buffered solution?

a) 500 mL of each  
b) 286 mL HNO\(_2\); 714 mL KNO\(_2\)  
c) 413 mL HNO\(_2\); 587 mL KNO\(_2\)  
d) 714 mL HNO\(_2\); 286 mL KNO\(_2\)  
e) 587 mL HNO\(_2\); 413 mL KNO\(_2\)

ANS: d) 714 mL HNO\(_2\); 286 mL KNO\(_2\)

3. 15.0 mL of 0.50 M HCl is added to a 100.-mL sample of 0.200 M HNO\(_2\) \((K_a \text{ for HNO}_2 = 4.0 \times 10^{-4})\). What is the equilibrium concentration of NO\(_2^-\) ions?

a) \(1.1 \times 10^{-13}\) M  
b) \(6.5 \times 10^{-12}\) M  
c) \(7.5 \times 10^{-14}\) M  
d) \(1.7 \times 10^{-11}\) M  
e) none of these

ANS: a) \(1.1 \times 10^{-13}\) M

4. A solution contains 0.250 M HA \((K_a = 1.0 \times 10^{-6})\) and 0.45 M NaA. What is the pH after 0.10 mole of HCl is added to 1.00 L of this solution?

a) 3.17  
b) 3.23  
c) 6.00  
d) 10.77  
e) 10.83

ANS: c) 6.00
5. A weak acid, HF, is in solution with dissolved sodium fluoride, NaF. If HCl is added, which ion will react with the extra hydrogen ions from the HCl to keep the pH from changing?
   a) OH⁻
   b) Na⁺
   c) F⁻
   d) Na⁻
   e) none of these
   ANS:  c) F⁻

6. Which of the following is true for a buffered solution?
   a) The solution resists change in its [H⁺].
   b) The solution will not change its pH very much even if a concentrated acid is added.
   c) The solution will not change its pH very much even if a strong base is added.
   d) Any H⁺ ions will react with a conjugate base of a weak acid already in solution.
   e) all of these
   ANS:  e) all of these

7-8. The following questions refer to the following system: A 1.0-liter solution contains 0.25 M HF and 0.60 M NaF ($K_a$ for HF is $7.2 \times 10^{-4}$)

7. What is the pH of this solution?
   a) 1.4
   b) 3.5
   c) 4.6
   d) 2.8
   e) 0.94
   ANS:  b) 3.5

8. If one adds 0.30 liters of 0.020 M KOH to the solution what will be the change in pH?
   a) 0.0
   b) 0.2
   c) 0.4
   d) 0.5
   e) none of these
   ANS:  a) 0.0
9. Calculate the \([H^+]\) in a solution that is 0.10 M in NaF and 0.20 in HF. \((K_a = 7.2 \times 10^{-4})\)
   a) 0.20 M  
   b) 7.0 \times 10^{-4} M  
   c) 1.4 \times 10^{-3} M  
   d) 3.5 \times 10^{-4} M  
   e) none of these  
   ANS: c) 1.4 \times 10^{-3} M  
   PAGE: 15.2

10. Which of the following will not produce a buffered solution?
   a) 100 mL of 0.1 M Na\(_2\)CO\(_3\) and 50 mL of 0.1 M HCl  
   b) 100 mL of 0.1 M NaHCO\(_3\) and 25 mL of 0.2 M HCl  
   c) 100 mL of 0.1 M Na\(_2\)CO\(_3\) and 75 mL of 0.2 M HCl  
   d) 50 mL of 0.2 M Na\(_2\)CO\(_3\) and 5 mL of 1.0 M HCl  
   e) 100 mL of 0.1 M Na\(_2\)CO\(_3\) and 50 mL of 0.1 M NaOH  
   ANS: e) 100 mL of 0.1 M Na\(_2\)CO\(_3\) and 50 mL of 0.1 M NaOH  
   PAGE: 15.2

11. How many moles of HCl need to be added to 150.0 mL of 0.50M NaZ to have a solution with a pH of 6.50? \((K_a\) of HZ is 2.3 \times 10^{-5}). Assume negligible volume of the HCl.
   a) 6.8 \times 10^{-3}  
   b) 7.5 \times 10^{-2}  
   c) 5.0 \times 10^{-1}  
   d) 1.0 \times 10^{-3}  
   e) none of these  
   ANS: d) 1.0 \times 10^{-3}  
   PAGE: 15.2

12. Calculate the pH of a solution that is 0.5 M in HF \((K_a = 7.2 \times 10^{-4})\) and 0.6 M in NaF.
   a) 1.72  
   b) 3.32  
   c) 3.44  
   d) 5.53  
   e) 8.46  
   ANS: b) 3.22  
   PAGE: 15.2
13. Consider a solution consisting of the following two buffer systems:

\[
\begin{align*}
\text{H}_2\text{CO}_3 & \rightleftharpoons \text{HCO}_3^- + \text{H}^+ \quad pK_a = 6.4 \\
\text{H}_2\text{PO}_4^- & \rightleftharpoons \text{HPO}_4^{2-} + \text{H}^+ \quad pK_a = 7.2
\end{align*}
\]

At pH 6.4, which one of the following is true of the relative amounts of acid and conjugate base present?

a) \([\text{H}_2\text{CO}_3] > [\text{HCO}_3^-]\) and \([\text{H}_2\text{PO}_4^-] > [\text{HPO}_4^{2-}]\)

b) \([\text{H}_2\text{CO}_3] = [\text{HCO}_3^-]\) and \([\text{H}_2\text{PO}_4^-] > [\text{HPO}_4^{2-}]\)

c) \([\text{H}_2\text{CO}_3] = [\text{HCO}_3^-]\) and \([\text{HPO}_4^{2-}] > [\text{H}_2\text{PO}_4^-]\)

d) \([\text{HCO}_3^-] > [\text{H}_2\text{CO}_3]\) and \([\text{H}_2\text{PO}_4^-] > [\text{HPO}_4^{2-}]\)

e) \([\text{H}_2\text{CO}_3] > [\text{HCO}_3^-]\) and \([\text{H}_2\text{PO}_4^-] > [\text{HPO}_4^{2-}]\)

ANS: b) \([\text{H}_2\text{CO}_3] = [\text{HCO}_3^-]\) and \([\text{H}_2\text{PO}_4^-] > [\text{HPO}_4^{2-}]\)  PAGE: 15.2

14. For a solution equimolar in HCN and NaCN, which statement is false?

a) This is an example of the common ion effect.

b) The \([\text{H}^+]\) is larger than it would be if only the HCN was in solution.

c) The \([\text{H}^+]\) is equal to the \(K_a\).

d) Addition of more NaCN will shift the acid dissociation equilibrium of HCN to the left.

e) Addition of NaOH will increase [CN\(^-\)] and decrease [HCN].

ANS: b) The \([\text{H}^+]\) is larger than it would be if only the HCN was in solution.  PAGE: 15.2

15. Calculate the pH of a solution that is 2.00 M HF, 1.00 M NaOH, and 0.500 M NaF. (\(K_a\) is 7.2 x 10\(^{-4}\))

a) 3.14

b) 3.32

c) 3.02

d) 2.84

e) none of these

ANS: b) 3.32  PAGE: 15.2

16. Given 100.0 mL of a buffer that is 0.50 M in HOCl and 0.40 M in NaOCl, what is the pH after 10.0 mL of 1.0 M NaOH has been added? (\(K_a\) for HOCl = 3.5 x 10\(^{-8}\))

a) 6.45

b) 6.64

c) 7.36

d) 7.45

e) 7.55

ANS: e) 7.55  PAGE: 15.2
17. How many moles of solid NaF would have to be added to 1.0 L of 1.90 M HF solution to achieve a buffer of pH 3.35? Assume there is no volume change. ($K_a$ for HF = $7.2 \times 10^{-4}$)

   a) 3.1 
   b) 2.3 
   c) 1.6 
   d) 1.0 
   e) 4.9 

ANS: a) 3.1 

18. What is the pH of a solution that results when 0.010 mol HNO$_3$ is added to 500. mL of a solution that is 0.10 M in aqueous ammonia and 0.20 M in ammonium nitrate. Assume no volume change. ($K_b$ for NH$_3$ = $1.8 \times 10^{-5}$.)

   a) 8.00 
   b) 8.95 
   c) 5.05 
   d) 8.82 
   e) 2.00 

ANS: d) 8.82 

19. How many mmoles of HCl must be added to 100 mL of a 0.100 M solution of methylamine ($pK_b = 3.36$) to give a buffer having a pH of 10.0?

   a) 8.1 
   b) 18.7 
   c) 20.0 
   d) 41.5 
   e) 12.7 

ANS: a) 8.1 

20. Calculate the pH of a solution made by mixing 100.0 mL of 0.300 M NH$_3$ with 100.0 mL of 0.100 M HCl. ($K_b$ for NH$_3$ is $1.8 \times 10^{-5}$).

   a) 9.56 
   b) 4.44 
   c) 10.6 
   d) 3.40 
   e) none of these 

ANS: a) 9.56
21. Consider a solution of 2.0 M HCN and 1.0 M NaCN ($K_a$ for HCN = $6.2 \times 10^{-10}$). Which of the following statements is true?
   a) The solution is not a buffer because [HCN] is not equal to [CN⁻].
   b) The pH will be below 7.00 because the concentration of the acid is greater than that of the base.
   c) [OH⁻] > [H⁺]
   d) The buffer will be more resistant to pH changes from addition of strong acid than of strong base.
   e) All of these are false.

ANS: c) [OH⁻] > [H⁺]  

22. A solution contains 0.500 M HA ($K_a = 1.0 \times 10^{-8}$) and 0.250 M NaA. What is the [H⁺] after 0.10 mole of HCl(g) is added to 1.00 L of this solution?
   a) $1.4 \times 10^{-8}$ M
   b) $2.0 \times 10^{-8}$ M
   c) $2.5 \times 10^{-9}$ M
   d) $4.0 \times 10^{-8}$ M
   e) none of these

ANS: d) $4.0 \times 10^{-8}$ M  

23. Which of the following solutions will be the best buffer at a pH of 9.26? ($K_a$ for HC₂H₃O₂ is $1.8 \times 10^{-5}$, $K_b$ for NH₃ is $1.8 \times 10^{-5}$).
   a) 0.10 M HC₂H₃O₂ and 0.10 M NaC₂H₃O₂
   b) 5.0 M HC₂H₃O₂ and 5.0 M NaC₂H₃O₂
   c) 0.10 M NH₃ and 0.10 M NH₄Cl
   d) 5.0 M NH₃ and 5.0 M NH₄Cl
   e) 5.0 M HC₂H₃O₂ and 5.0 M NH₃

ANS: d) 5.0 M NH₃ and 5.0 M NH₄Cl  

24. One milliliter (1.00 mL) of acid taken from a lead storage battery is pipetted into a flask. Water and phenolphthalein indicator are added, and the solution is titrated with 0.50 M NaOH until a pink color appears; 12.0 mL are required. The number of grams of H₂SO₄ (formula weight = 98) present in one liter of the battery acid is (to within 5%):
   a) 240
   b) 290
   c) 480
   d) 580
   e) 750

ANS: b) 290  

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25. You are given 5.00 mL of an H_2SO_4 solution of unknown concentration. You divide the 5.00-mL sample into five 1.00-mL samples and titrate each separately with 0.1000 M NaOH. In each titration the H_2SO_4 is completely neutralized. The average volume of NaOH solution used to reach the endpoint is 15.3 mL. What was the concentration of H_2SO_4 in the 5.00-mL sample?

a) 1.53 M  
b) 0.306 M  
c) 0.765 M  
d) 1.53 \times 10^{-3} M  
e) 3.06 M

ANS: c) 0.765 M

26. What is the molarity of a sodium hydroxide solution if 25.0 mL of this solution reacts exactly with 22.30 mL of 0.253 M sulfuric acid?

a) 0.113 M  
b) 0.226 M  
c) 0.284 M  
d) 0.451 M  
e) 0.567 M

ANS: d) 0.451 M

27. If 25.0 mL of 0.451 M NaOH solution is titrated with 0.253 M H_2SO_4, the flask at the endpoint will contain (besides the indicator phenolphthalein) as the principal components:

a) sodium hydroxide, sulfuric acid, and water  
b) dissolved sodium sulfate and water  
c) sodium hydroxide, sodium sulfate, and water  
d) dissolved sodium sulfate, sulfuric acid, and water  
e) precipitated sodium sulfate and water

ANS: b) dissolved sodium sulfate and water

28. A 10-mL sample of tartaric acid is titrated to a phenolphthalein endpoint with 20. mL of 1.0 M NaOH. Assuming tartaric acid is diprotic, what is the molarity of the acid?

a) 2.0  
b) 1.0  
c) 4.0  
d) 10.  
e) impossible to determine

ANS: b) 1.0
29. What volume of water must be added to 10. mL of a pH 2.0 solution of HNO₃ in order to change the pH to 4.0?
   a) 10 mL
   b) 90 mL
   c) 1.0 × 10² mL
   d) 990 mL
   e) 99 mL

   ANS: d) 990 mL

30. If 25 mL of 0.75 M HCl are added to 100 mL of 0.25 NaOH, what is the final pH?
   a) 12.70
   b) 12.80
   c) 1.30
   d) 1.20
   e) 7.00

   ANS: a) 12.70

31. A 50.00-mL sample of 0.100 M KOH is titrated with 0.100 M HNO₃. Calculate the pH of the solution after the 52.00 mL of HNO₃ is added.
   a) 6.50
   b) 3.01
   c) 2.71
   d) 2.41
   e) none of these

   ANS: c) 2.71

32. A solution of hydrochloric acid of unknown concentration was titrated with 0.10 M NaOH. If a 100.-mL sample of the HCl solution required exactly 10. mL of the NaOH solution to reach the equivalence point, what was the pH of the HCl solution?
   a) 1.0
   b) 2.0
   c) 0.0
   d) 12.0
   e) -1.0

   ANS: b) 2.0
33–35. A titration of 200.0 mL of 1.00 M H₂A was done with 1.00 M NaOH. For the diprotic acid H₂A, \(K_{a1} = 2.5 \times 10^{-5}\), \(K_{a2} = 3.1 \times 10^{-9}\).

33. Calculate the pH before any 1.00 M NaOH has been added.
   a) 8.51
   b) 6.56
   c) 4.60
   d) 2.65
   e) 2.30
   **ANS:** e) 2.30  

34. Calculate the pH after 100.0 mL of 1.00 M NaOH have been added.
   a) 13.4
   b) 11.0
   c) 8.51
   d) 6.56
   e) 4.60
   **ANS:** e) 4.60  

35. Calculate the pH after 600.0 mL of 1.00 M NaOH have been added.
   a) 13.4
   b) 11.0
   c) 8.51
   d) 6.56
   e) 4.60
   **ANS:** a) 13.4  

36–38. Consider the titration of 300.0 mL of 0.500 M NH₃ (\(K_b = 1.8 \times 10^{-5}\)) with 0.500 M HNO₃.

36. After 150.0 mL of 0.500 M HNO₃ have been added, the pH of the solution is:
   a) 4.74
   b) 11.48
   c) 2.52
   d) 9.26
   e) none of these
   **ANS:** d) 9.26
37. How many milliliters of 0.500 M HNO₃ are required to reach the stoichiometric point of the reaction?
   a) 100. mL  
   b) 150. mL  
   c) 200. mL  
   d) 300. mL  
   e) none of these  
   **ANS:** d 300. mL  

38. At the stoichiometric point of this titration, the pH is:
   a) 2.67  
   b) 11.32  
   c) 4.93  
   d) 9.07  
   e) 7.00  
   **ANS:** c) 4.93  

39. Consider the titration of 500.0 mL of 0.200 M NaOH with 0.800 M HCl. How many milliliters of 0.800 M HCl must be added to reach a pH of 13.000?
   a) 55.6 mL  
   b) 24.6 mL  
   c) 18.5 mL  
   d) 12.9 mL  
   e) 4.32 mL  
   **ANS:** a) 55.6 mL  

40. What quantity of NaOH(s) must be added to 2.00 L of 0.500 M HCl to achieve a pH of 13.00? (Assume no volume change.)
   a) 0.200 mol  
   b) 1.200 mol  
   c) 1.00 x 10⁻¹³ mol  
   d) 1.500 mol  
   e) none of these  
   **ANS:** b) 1.200 mol  

41. A 50.0-mL sample of 0.10 M HNO₂ (Kₐ = 4.0 x 10⁻⁴) is titrated with 0.10 M NaOH. The pH after 25.0 mL of NaOH have been added is
   a) 7.00  
   b) 1.00  
   c) 12.50  
   d) 3.40  
   e) none of these  
   **ANS:** d) 3.40
42. The pH at the equivalence point of the titration of a strong acid with a strong base is:
   a) 3.9
   b) 4.5
   c) 7.0
   d) 8.2
   e) none of these
   ANS: c) 7.0

43. The pH at the equivalence point of a titration of a weak acid with a strong base will be
   a) less than 7.00.
   b) equal to 7.00.
   c) greater than 7.00.
   d) More data is needed to answer this question.
   ANS: c) greater than 7.00.

44. A 75.0-mL sample of 0.0500 M HCN (K_a = 6.2 \times 10^{-10}) is titrated with 0.500 M NaOH. What volume of 0.500 M NaOH is required to reach the stoichiometric point?
   a) 75.0 mL
   b) 7.50 mL
   c) 750. mL
   d) cannot determine without knowing the pH at the stoichiometric point
   e) none of these
   ANS: b) 7.50 mL

45. A 75.0-mL sample of 0.0500 M HCN (K_a = 6.2 \times 10^{-10}) is titrated with 0.500 M NaOH. What is the [H^+] in the solution after 3.0 mL of 0.50 M NaOH have been added?
   a) 1.0 \times 10^{-7} M
   b) 4.1 \times 10^{-10} M
   c) 5.2 \times 10^{-13} M
   d) 9.3 \times 10^{-10} M
   e) none of these
   ANS: d) 9.3 \times 10^{-10} M
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46. A student titrates an unknown weak acid, HA, to a pale pink phenolphthalein endpoint with 25.0 mL of 0.100 M NaOH. The student then adds 13.0 mL of 0.100 M HCl. The pH of the resulting solution is 4.7. Which of the following is true?
   a) At pH 4.7, half the conjugate base, A⁻, has been converted to HA.
   b) The pKₐ of the acid is 4.7.
   c) The pKₐ of the acid is less than 4.7.
   d) The pKₐ of the acid is greater than 4.7.
   e) More than one of these above is correct.

ANS: d) The pKₐ of the acid is greater than 4.7.  

47. How many moles of HCl(g) must be added to 1.0 L of 2.0 M NaOH to achieve a pH of 0.00? (Neglect any volume change.)
   a) 1.0 moles
   b) 2.0 moles
   c) 3.0 moles
   d) 10. moles
   e) none of these

ANS: c) 3.0 moles  

48. A 50.0-mL sample of a 1.50 M NaOH solution is titrated with a 2.00 M HCl solution. What will be the final volume of solution when the NaOH has been completely neutralized by the HCl?
   a) 87.5 mL
   b) 100.0 mL
   c) 90.0 mL
   d) 97.5 mL
   e) 89.0 mL

ANS: a) 87.5 mL

49. You have 75.0 mL of 0.10 HA. After adding 30.0 mL of 0.10 M NaOH, the pH is 5.50. What is the Kₐ value of HA?
   a) 1.0 x 10⁻¹⁰
   b) 2.1 x 10⁻⁶
   c) 1.0 x 10⁻⁴
   d) 1.3 x 10⁻⁶
   e) none of these

ANS: b) 2.1 x 10⁻⁶
50–51. Consider the titration of 100.0 mL of 0.10 M $\text{H}_2\text{A}$ ($K_{a1} = 1.5 \times 10^{-4}; K_{a2} = 8.0 \times 10^{-7}$) with 0.20 M NaOH.

50. Calculate the $[\text{H}^+]$ after 75.0 mL of 0.20 M NaOH has been added.
   a) $1.5 \times 10^{-4}$ M
   b) $1.1 \times 10^{-5}$ M
   c) $1.0 \times 10^{-13}$ M
   d) $8.0 \times 10^{-7}$ M
   e) none of these
   ANS: d) $8.0 \times 10^{-7}$ M

51. Calculate the volume of 0.20 M NaOH required to reach an $[\text{H}^+]$ of $6.0 \times 10^{-4}$ M.
   a) 0
   b) 10. mL
   c) 25. mL
   d) 50. mL
   e) 65. mL
   ANS: b) 10. mL

52. A 50.00-mL sample of a 1.00 M solution of the diprotic acid $\text{H}_2\text{A}$ ($K_{a1} = 1.0 \times 10^{-6}$ and $K_{a2} = 1.0 \times 10^{-10}$) is titrated with 2.00 M NaOH. How many mL of 2.00 M NaOH must be added to reach a pH of 10?
   a) 0
   b) 12.5 mL
   c) 25.0 mL
   d) 37.5 mL
   e) none of these
   ANS: d) 37.5 mL

53. Consider the titration of 100.0 mL of 0.100 M $\text{H}_2\text{A}$ ($K_{a1} = 1.50 \times 10^{-4}; K_{a2} = 1.00 \times 10^{-8}$). How many milliliters of 0.100 M NaOH must be added to reach a pH of 5.000?
   a) 41.9 mL
   b) 93.8 mL
   c) 100. mL
   d) 200. mL
   e) 60.0 mL
   ANS: b) 93.8 mL
54. A 100.0-mL sample of 0.500 M H₂A (diprotic acid) is titrated with 0.200 M NaOH. After 125.0 mL of 0.200 M NaOH has been added, the pH of the solution is 4.50. Calculate $K_{a1}$ for H₂A.

   a) 4.5
   b) $1.0 \times 10^{-7}$
   c) $3.2 \times 10^{-5}$
   d) not enough information to calculate
   e) none of these

   **ANS:** c) $3.2 \times 10^{-5}$

55–58. Consider the following information about the diprotic acid ascorbic acid (H₂As for short) (molar mass = 176.1).

\[
\begin{array}{c|c|c}
   & K_{a1} & pK_{a} \\
   H₂As & 7.9 \times 10^{-5} & 4.10 \\
   HAs⁻ & 1.6 \times 10^{-12} & 11.79 \\
\end{array}
\]

The titration curve for disodium ascorbate, Na₂As, with standard HCl is shown below:

55. What major species is (are) present at point III?

   a) As²⁻ and HAs⁻
   b) HAs⁻ only
   c) HAs⁻ and H₂As
   d) H₂As only
   e) H₂As and H⁺

   **ANS:** c) HAs⁻ and H₂As

56. What is the pH at point I (V₁/2 HCl added)?

   a) 4.10
   b) 7.95
   c) 11.79
   d) 12.39
   e) none of these

   **ANS:** c) 11.79
57. What is the pH at point III?
   a) 4.10
   b) 7.95
   c) 11.79
   d) 12.39
   e) none of these
   ANS: a) 4.10

58. Which of the following is a major species present at point IV?
   a) \( \text{H}_2\text{As} \)
   b) \( \text{HAs}^- \)
   c) \( \text{As}^{2-} \)
   d) \( \text{H}^+ \)
   e) none of these
   ANS: a) \( \text{H}_2\text{As} \)

59. A solution contains 10. mmol of \( \text{H}_3\text{PO}_4 \) and 5.0 mmol of \( \text{NaH}_2\text{PO}_4 \). How many milliliters of 0.10 M NaOH must be added to reach the second equivalence point of the titration of the \( \text{H}_3\text{PO}_4 \) with NaOH?
   a) 250
   b) 150
   c) \( 1.0 \times 10^2 \)
   d) 50
   e) \( 2.0 \times 10^2 \)
   ANS: a) 250

60. A solution contains 25 mmol of \( \text{H}_3\text{PO}_4 \) and 10. mmol of \( \text{NaH}_2\text{PO}_4 \). What volume of 2.0 M NaOH must be added to reach the second equivalence point of the titration of the \( \text{H}_3\text{PO}_4 \) with NaOH?
   a) 5.0 mL
   b) 12 mL
   c) 25 mL
   d) 30. mL
   e) 60. mL
   ANS: d) 30. mL
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61. A 100.-mL sample of a 0.10 M solution of H₃PO₄ is titrated with 0.20 M NaOH. What volume of base must be added to reach the third equivalence point?
   a) 50. mL
   b) 1.0 x 10²
   c) 150 mL
   d) 2.0 x 10²
   e) 250 mL

ANS:  c) 150 mL  PAGE: 15.4

62. For carbonic acid (H₂CO₃), Kₐ₁ = 4.30 x 10⁻⁷ and Kₐ₂ = 5.62 x 10⁻¹¹. Calculate the pH of a 0.50 M solution of Na₂CO₃.
   a) 3.33
   b) 2.03
   c) 10.67
   d) 11.97
   e) 8.31

ANS:  d) 11.97  PAGE: 15.4

63–64. A solution containing 10. mmol of CO₃²⁻ and 5.0 mmol of HCO₃⁻ is titrated with 1.0 M HCl.

63. What volume of HCl must be added to reach the first equivalence point?
   a) 5.0 mL
   b) 10. mL
   c) 15 mL
   d) 20. mL
   e) 25 mL

ANS:  b) 10. mL  PAGE: 15.4

64. What total volume of HCl must be added to reach the second equivalence point?
   a) 5.0 mL
   b) 10. mL
   c) 20. mL
   d) 25 mL
   e) 30. mL

ANS:  d) 25 mL  PAGE: 15.4
65. You dissolve 1.00 gram of an unknown diprotic acid in 200.0 mL of H₂O. This solution is just neutralized by 5.00 mL of a 1.00 M NaOH solution. What is the molar mass of the unknown acid?
   a) 25.0
   b) 50.0
   c) 200.
   d) 400.
   e) none of these
   ANS: d) 400.  PAGE: 15.4

66. A 5.95-g sample of an acid, H₂X, requires 45.0 mL of a 0.500 M NaOH solution for complete reaction (removing both protons). The molar mass of the acid is
   a) 132
   b) 178
   c) 264
   d) 529
   e) none of these
   ANS: d) 529  PAGE: 15.4

67. A 0.210-g sample of an acid (molar mass = 192 g/mol) is titrated with 30.5 mL of 0.108 M NaOH to a phenolphthalein endpoint. The formula of the acid is:
   a) HA
   b) H₂A
   c) H₃A
   d) H₄A
   e) not enough information given
   ANS: c) H₃A  PAGE: 15.4

68. Consider the titration of 100.0 mL of 0.250 M aniline (Kₘ = 3.8 × 10⁻¹⁰) with 0.500 M HCl. Calculate the pH of the solution at the stoichiometric point.
   a) -0.85
   b) 8.70
   c) 2.68
   d) 11.62
   e) none of these
   ANS: c) 2.68  PAGE: 15.4
69. Consider the titration of 100.0 mL of 0.250 M aniline \((K_b = 3.8 \times 10^{-10})\) with 0.500 M HCl. For calculating the volume of HCl required to reach a pH of 8.0, which of the following expressions is correct? \((x = \text{volume in mL of HCl required to reach a pH of 8.0})\)

\[ \frac{0.5x - (100)(0.25)}{100 + x} = \text{[aniline]} \]

b) \([H^+] = x\]

c) \(\frac{0.5x}{100 + x} = \text{[aniline]}\)

d) \(\frac{25 - 0.5x}{100 + x} - 10^{-6} = \text{[aniline]}\)

e) none of these

ANS: d) \(\frac{25 - 0.5x}{100 + x} - 10^{-6} = \text{[aniline]}\)  

70. A 100.0-mL sample of 0.2 M (CH₃)₃N \((K_b = 5.3 \times 10^{-5})\) is titrated with 0.2 M HCl. What is the pH at the equivalence point?

a) 9.9
b) 3.1
c) 10.3
d) 5.4
e) 7.0

ANS: d) 5.4

71. Calculate the pH at the equivalence point for the titration of 1.0 M ethylamine, C₂H₅NH₂, by 1.0 M perchloric acid, HClO₄, \((pK_b \text{ for C}_2\text{H}_5\text{NH}_2 = 3.25)\)

a) 6.05
b) 2.24
c) 5.53
d) 2.09
e) 5.38

ANS: c) 5.53

72. What volume of 0.0100 M NaOH must be added to 1.00 L of 0.0500 M HOCl to achieve a pH of 8.00? The \(K_a\) for HOCl is \(3.5 \times 10^{-8}\).

a) 1.0 L
b) 5.0 L
c) 1.2 L
d) 3.9 L
e) none of these

ANS: d) 3.9 L
73. Consider the following indicators and their pH ranges:

- Methyl orange 3.2–4.4
- Methyl red 4.8–6.0
- Bromothymol blue 6.0–7.6
- Phenolphthalein 8.2–10.0
- Alizarin yellow 10.1–12.0

Assume an indicator works best when the equivalence point of a titration comes in the middle of the indicator range. For which of the following titrations would methyl red be the best indicator?

- a) 0.100 M HNO₃ + 0.100 M KOH
- b) 0.100 M aniline \((K_b = 3.8 \times 10^{-10}) + 0.100 M HCl\)
- c) 0.100 M NH₃ \((K_b = 1.8 \times 10^{-5}) + 0.100 M HCl\)
- d) 0.100 M HF \((K_a = 7.2 \times 10^{-4}) + 0.100 M NaOH\)
- e) 0.100 M acetic acid \((K_a = 1.8 \times 10^{-5}) + 0.100 M NaOH\)

ANS: c) 0.100 M NH₃ \((K_b = 1.8 \times 10^{-5}) + 0.100 M HCl\)

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74. Which of the following is the net ionic equation for the reaction that occurs during the titration of nitrous acid with potassium hydroxide?

- a) \(HNO_2 + K^+ OH^- \rightarrow KNO_2 + H_2O\)
- b) \(HNO_2 + H_2O \rightarrow NO_2^- + H_3O^+\)
- c) \(HNO_2 + KOH \rightarrow K^+ + NO_2^- + H_2O\)
- d) \(HNO_2 + OH^- \rightarrow NO_2^- + H_2O\)
- e) \(H^+ + OH^- \rightarrow H_2O\)

ANS: d) \(HNO_2 + OH^- \rightarrow NO_2^- + H_2O\)

PAGE: 15.4

75. A 100. mL sample of 0.10 M HCl is mixed with 50. mL of 0.10 M NH₃. What is the resulting pH? \((K_b \text{ for } NH_3 = 1.8 \times 10^{-5})\)

- a) 12.52
- b) 3.87
- c) 1.30
- d) 7.85
- e) 1.48

ANS: e) 1.48

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76. In the titration of a weak acid HA with 0.100 M NaOH the stoichiometric point is known to occur at a pH value of approximately 10. Which of the following indicator acids would be best to use to mark the endpoint of this titration?
   a) indicator A, $K_a = 10^{-14}$
   b) indicator B, $K_a = 10^{-11}$
   c) indicator C, $K_a = 10^{-8}$
   d) indicator D, $K_a = 10^{-6}$
   e) none of these
   ANS: b) indicator B, $K_a = 10^{-11}$

77. In the titration of a weak acid, HA, with a sodium hydroxide solution the stoichiometric point occurs at pH = 9.5. Which of the following weak acid indicators would be best suited to mark the endpoint of this titration?
   a) HB, $K_a = 10^{-11}$
   b) HC, $K_a = 10^{-13}$
   c) HD, $K_a = 10^{-9}$
   d) HE, $K_a = 10^{-7}$
   ANS: a) HB, $K_a = 10^{-11}$

78. In the titration of a weak acid HA with 0.100 M NaOH, the stoichiometric point is known to occur at a pH value of approximately 11. Which of the following indicators would be best to use to mark the endpoint of this titration?
   a) an indicator with $K_a = 10^{-10}$
   b) an indicator with $K_a = 10^{-8}$
   c) an indicator with $K_a = 10^{-14}$
   d) an indicator with $K_a = 10^{-11}$
   e) an indicator with $K_a = 10^{-12}$
   ANS: e) an indicator with $K_a = 10^{-12}$

79. A certain indicator HIn has a $pK_a$ of 9.00 and a color change becomes visible when 7.00% of it is In-. At what pH is this color change visible?
   a) 10.2
   b) 3.85
   c) 6.15
   d) 7.88
   e) none of these
   ANS: d) 7.88

80–81. The following questions refer to a 2-liter buffered solution created from 0.31 M NH₃ ($K_b = 1.8 \times 10^{-5}$) and 0.26 M NH₄F.
80. What is the pH of this solution?
   a) 8.4
   b) 9.3
   c) 9.5
   d) 9.2
   e) 9.7

   **ANS:** b) 9.3  
   **PAGE:** 15.2

81. When 0.10 mol of H+ ions is added to the solution what is the pH?
   a) 8.4
   b) 9.6
   c) 9.4
   d) 9.2
   e) 9.7

   **ANS:** d) 9.2  
   **PAGE:** 15.2

82. Find the solubility (in mol/L) of lead chloride (PbCl2) at 25°C. $K_{sp} = 1.6 \times 10^{-5}$
   a) $1.6 \times 10^{-2}$
   b) 0.020
   c) $7.1 \times 10^{-5}$
   d) 2.1
   e) $9.3 \times 10^{-3}$

   **ANS:** a) $1.6 \times 10^{-2}$  
   **PAGE:** 15.6

83. Methyl orange is an indicator with a $K_a$ of $1 \times 10^{-4}$. Its acid form, HIn, is red, while its base form, In–, is yellow. At pH 6.0, the indicator will be
   a) red.
   b) orange.
   c) yellow.
   d) blue.
   e) not enough information

   **ANS:** c) yellow.  
   **PAGE:** 15.5
84. The two salts AgX and AgY have very similar solubilities in water. It is known that the salt AgX is much more soluble in acid than is AgY. What can be said about the relative strengths of the acids HX and HY?
   a) Nothing.
   b) HY is stronger than HX.
   c) HX is stronger than HY.
   d) The acids have equal strengths.
   e) Cannot be determined.
   **ANS:** b) HY is stronger than HX.  

85. Solubility Products ($K_{sp}$)
   - BaSO$_4$  $1.5 \times 10^{-9}$
   - CoS  $5.0 \times 10^{-22}$
   - PbSO$_4$  $1.3 \times 10^{-8}$
   - AgBr  $5.0 \times 10^{-13}$

   Which of the following compounds is the most soluble (in moles/liter)?
   a) BaSO$_4$
   b) CoS
   c) PbSO$_4$
   d) AgBr
   e) BaCO$_3$
   **ANS:** c) PbSO$_4$  

86. How many moles of Fe(OH)$_2$ [$K_{sp} = 1.8 \times 10^{-15}$] will dissolve in one liter of water buffered at pH = 12.00?
   a) $1.8 \times 10^{-11}$
   b) $1.8 \times 10^{-9}$
   c) $8.0 \times 10^{-6}$
   d) $5.0 \times 10^{-12}$
   e) $4.0 \times 10^{-8}$
   **ANS:** a) $1.8 \times 10^{-11}$  

87. How does the pH of a 0.20 M solution of NaHCO$_3$ compare to that of a 0.10 M solution of NaHCO$_3$?
   a) It is 2 times as high.
   b) It is half as much.
   c) It is the same.
   d) cannot be determined with the $K_a$ values
   e) none of these
   **ANS:** c) It is the same.  

PAGE: 15.6
88–91. You have a 250.0-mL sample of 1.00 M acetic acid ($K_a = 1.8 \times 10^{-5}$).

88. Assuming no volume change, how much NaOH must be added to make the best buffer?
   a) 5.0 g
   b) 10.0 g
   c) 15.0 g
   d) 20.0 g
   e) none of these
   **ANS:** a) 5.0 g

89. Calculate the pH of the best buffer.
   a) 7.00
   b) 4.74
   c) 3.14
   d) 2.37
   e) none of these
   **ANS:** b) 4.74

90. Calculate the pH after adding 0.0050 mol of NaOH to 1.0 liter of the best buffer.
   a) 7.05
   b) 2.41
   c) 3.54
   d) 4.78
   e) none of these
   **ANS:** d) 4.78

91. Calculate the pH after adding 0.0040 mol HCl to 1.0 liter of the best buffer.
   a) 4.72
   b) 2.35
   c) 3.12
   d) 6.98
   e) none of these
   **ANS:** a) 4.72

92–93. You have two buffered solutions. Buffered solution 1 consists of 5.0 M HOAc and 5.0 M NaOAc; buffered solution 2 is made of 0.050 M HOAc and 0.050 M NaOAc.
92. How do the pHs of the buffered solutions compare?
   a) The pH of buffered solution 1 is greater than that of buffered solution 2.
   b) The pH of buffered solution 2 is greater than that of buffered solution 1.
   c) The pH of buffered solution 1 is equal to that of buffered solution 2.
   d) Cannot be determined without the $K_a$ values.
   e) None of these (a-d).
   **ANS:** c) The pH of buffered solution 1 is equal to that of buffered solution 2.  
   **PAGE:** 15.2

93. Buffered solution 1 has a greater buffering capacity than buffered solution 2.
   **ANS:** True  
   **PAGE:** 15.3

94. You have two salts, AgX and AgY, with very similar $K_{sp}$ values. You know that $K_a$ for HX is much greater than $K_a$ for HY. Which salt is more soluble in acidic solution?
   a) AgX
   b) AgY
   c) They are equally soluble in acidic solution.
   d) Cannot be determined by the information given.
   e) None of these (a-d).
   **ANS:** b) AgY  
   **PAGE:** 15.6

95. You have a solution consisting of 0.10 M Cl$^-$ and 0.10 M CrO$_4^{2-}$. You add 0.10 M silver nitrate dropwise to this solution. Given that the $K_{sp}$ for Ag$_2$CrO$_4$ is $9.0 \times 10^{-12}$, and that for AgCl is $1.6 \times 10^{-10}$, which of the following will precipitate first?
   a) silver chloride
   b) silver chromate
   c) silver nitrate
   d) cannot be determined by the information given
   e) none of these
   **ANS:** a) silver chloride  
   **PAGE:** 15.7

96. Which of the following compounds has the lowest solubility in mol/L in water?
   a) Al(OH)$_3$ $K_{sp} = 2 \times 10^{-32}$
   b) CdS $K_{sp} = 1.0 \times 10^{-28}$
   c) PbSO$_4$ $K_{sp} = 1.3 \times 10^{-8}$
   d) Sn(OH)$_2$ $K_{sp} = 3 \times 10^{-27}$
   e) MgC$_2$O$_4$ $K_{sp} = 8.6 \times 10^{-5}$
   **ANS:** b) CdS $K_{sp} = 1.0 \times 10^{-28}$  
   **PAGE:** 15.6
97. The solubility of CaSO_4 in pure water at 0°C is 1 gram per liter. The value of the solubility product is
   a) 1 × 10^{-3}
   b) 7 × 10^{-2}
   c) 1 × 10^{-4}
   d) 5 × 10^{-5}

   **ANS:** d) 5 × 10^{-5}  
   **PAGE:** 15.6

98. The solubility of AgCl in water is _____ the solubility of AgCl in strong acid at the same temperature.
   a) greater than
   b) less than
   c) about the same as
   d) cannot be determined
   e) much different from

   **ANS:** c) about the same as  
   **PAGE:** 15.6

99. The molar solubility of PbI_2 is 1.5 x 10^{-3} M. Calculate the value of \( K_{sp} \) for PbI_2.
   a) 1.5 x 10^{-3}
   b) 2.3 x 10^{-6}
   c) 1.4 x 10^{-8}
   d) 3.4 x 10^{-9}
   e) none of these

   **ANS:** c) 1.4 x 10^{-8}  
   **PAGE:** 15.6

100. Calculate the concentration of chromate ion, CrO_4^{2-}, in a saturated solution of CaCrO_4.
   \( K_{sp} = 7.1 \times 10^{-4} \)
   a) 0.027 M
   b) 5.0 x 10^{-7} M
   c) 7.1 x 10^{-4} M
   d) 3.5 x 10^{-4} M
   e) 3.5 x 10^{-2} M

   **ANS:** a) 0.027 M  
   **PAGE:** 15.6

101. Calculate the concentration of the silver ion in a saturated solution of silver chloride, AgCl \( (K_{sp} = 1.6 \times 10^{-10}) \).
   a) 5.4 x 10^{-4}
   b) 1.3 x 10^{-5}
   c) 1.6 x 10^{-10}
   d) 8.0 x 10^{-11}
   e) none of these
102. The molar solubility of BaCO₃ (K_{sp} = 1.6 \times 10^{-9}) in 0.10 M BaCl₂ solution is:
   a) 1.6 \times 10^{-10}
   b) 4.0 \times 10^{-5}
   c) 7.4 \times 10^{-4}
   d) 0.10
   e) none of these

   **ANS:** e) none of these

103. It is observed that 7.5 mmol of BaF₂ will dissolve in 1.0 L of water. Use these data to calculate the values of K_{sp} for barium fluoride.
   a) 7.5 \times 10^{-3}
   b) 4.2 \times 10^{-7}
   c) 1.7 \times 10^{-6}
   d) 5.6 \times 10^{-5}
   e) 2.1 \times 10^{-12}

   **ANS:** c) 1.7 \times 10^{-6}

104. The K_{sp} of AgI is 1.5 \times 10^{-16}. Calculate the solubility in mol/L of AgI in a 0.30 M NaI solution.
   a) 1.7 \times 10^{-8}
   b) 0.30
   c) 2.6 \times 10^{-17}
   d) 8.5 \times 10^{17}
   e) 5.0 \times 10^{-16}

   **ANS:** e) 5.0 \times 10^{-16}

105. The molar solubility of AgCl (K_{sp} = 1.6 \times 10^{-10}) in 0.0020 M sodium chloride at 25°C is:
   a) 0.0020
   b) 1.3 \times 10^{-5}
   c) 8.0 \times 10^{-8}
   d) 1.7 \times 10^{-10}
   e) none of these

   **ANS:** c) 8.0 \times 10^{-8}

106. Silver chromate, Ag₂CrO₄, has a K_{sp} of 9.0 \times 10^{-12}. Calculate the solubility in mol/L of silver chromate.
   a) 1.3 \times 10^{-4} M
   b) 7.8 \times 10^{-5} M
   c) 9.5 \times 10^{-7} M
   d) 1.9 \times 10^{-12} M
   e) 9.8 \times 10^{-5} M
107. The solubility of mol/L of Ag₂CrO₄ is 1.3 × 10⁻⁴ M at 25°C. Calculate the $K_{sp}$ for this compound.
   a) 8.8 × 10⁻³
d) 4.7 × 10⁻¹³
   e) 2.3 × 10⁻¹³
   ANS: c) 8.8 × 10⁻¹²

108. Calculate the concentration of Al³⁺ in a saturated aqueous solution of Al(OH)₃ ($K_{sp} = 2 \times 10^{-32}$) at 25°C.
   a) 3 × 10⁻⁹
d) 3 × 10⁻¹⁷
e) none of these
   ANS: e) none of these

109. The solubility in mol/L of M(OH)₂ in 0.010 M KOH is 1.0 × 10⁻⁵ mol/L. What is the $K_{sp}$ for M(OH)₂?
   a) 1.0 × 10⁻⁹
c) 1.0 × 10⁻¹²
e) 1.0 × 10⁻²
   ANS: a) 1.0 × 10⁻⁹

110. The $K_{sp}$ of PbSO₄(s) is 1.3 × 10⁻⁸. Calculate the solubility (in mol/L) of PbSO₄(s) in a 0.0010 M solution of Na₂SO₄.
   a) 1.3 × 10⁻¹¹ M
c) 1.3 × 10⁻⁵ M
e) 1.4 × 10⁻⁴ M
   ANS: c) 1.3 × 10⁻⁵ M
111. The solubility of Cd(OH)_2 in water is $1.7 \times 10^{-5}$ mol/L at 25°C. The $K_{sp}$ value for Cd(OH)_2 is:
   a) $2.0 \times 10^{-14}$
   b) $4.9 \times 10^{-15}$
   c) $5.8 \times 10^{-10}$
   d) $2.9 \times 10^{-10}$
   e) none of these
ANS: a) $2.0 \times 10^{-14}$

112. The $K_{sp}$ for PbF_2 is $4.0 \times 10^{-8}$. If a 0.050 M NaF solution is saturated with PbF_2, what is the [Pb^{2+}] in solution?
   a) $3.8 \times 10^{-3}$ M
   b) $3.6 \times 10^{-4}$ M
   c) $5.4 \times 10^{-7}$ M
   d) $1.6 \times 10^{-5}$ M
   e) $2.7 \times 10^{-8}$ M
ANS: d) $1.6 \times 10^{-5}$ M

113. Chromate ion is added to a saturated solution of Ag₂CrO₄ to reach 0.10 M CrO₄²⁻. Calculate the final concentration of silver ion at equilibrium ($K_{sp}$ for Ag₂CrO₄ is $9.0 \times 10^{-12}$)
   a) $1.7 \times 10^{-6}$ M
   b) $9.5 \times 10^{-6}$ M
   c) $6.6 \times 10^{-6}$ M
   d) $5.5 \times 10^{-11}$ M
   e) $1.1 \times 10^{-13}$ M
ANS: b) $9.5 \times 10^{-6}$ M

114. The solubility of La(IO₃)_3 in a 0.10 M KIO₃ solution is $1.0 \times 10^{-7}$ mol/L. Calculate the $K_{sp}$ for La(IO₃)_3.
   a) $1.0 \times 10^{-8}$
   b) $2.7 \times 10^{-9}$
   c) $1.0 \times 10^{-10}$
   d) $2.7 \times 10^{-27}$
   e) none of these
ANS: c) $1.0 \times 10^{-10}$
115. In a solution prepared by adding excess PbI₂(s) \([K_{sp} = 1.4 \times 10^{-8}]\) to water, the \([I^-]\) at equilibrium is:

a) \(1.5 \times 10^{-3}\) mol/L  
b) \(2.4 \times 10^{-3}\) mol/L  
c) \(1.2 \times 10^{-3}\) mol/L  
d) \(8.4 \times 10^{-5}\) mol/L  
e) \(3.0 \times 10^{-3}\) mol/L  

ANS: e) \(3.0 \times 10^{-3}\) mol/L  

116. Which of the following salts shows the lowest solubility in water? \((K_{sp} \text{ values: } Ag_2S = 1.6 \times 10^{-49}; Bi_2S_3 = 1.0 \times 10^{-72}; HgS = 1.6 \times 10^{-54}; Mg(OH)_2 = 8.9 \times 10^{-12}; MnS = 2.3 \times 10^{-13})\)

a) Bi₂S₃  
b) Ag₂S  
c) MnS  
d) HgS  
e) Mg(OH)₂  

ANS: d) HgS  

117–118. The next two questions refer to the following: The solubility of silver phosphate \((Ag₃PO₄)\) at 25°C is \(1.6 \times 10^{-5}\) mol/L.

117. Determine the concentration of the Ag⁺ ion in a saturated solution.

a) \(1.6 \times 10^{-5}\) M  
b) \(3.2 \times 10^{-5}\) M  
c) \(4.8 \times 10^{-5}\) M  
d) \(6.4 \times 10^{-5}\) M  
e) \(7.6 \times 10^{-5}\) M  

ANS: c) \(4.8 \times 10^{-5}\) M  

118. What is the \(K_{sp}\) for the silver phosphate at 25°C?

a) \(7.7 \times 10^{-10}\)  
b) \(1.8 \times 10^{-18}\)  
c) \(8.6 \times 10^{-13}\)  
d) \(3.3 \times 10^{-13}\)  
e) none of these  

ANS: b) \(1.8 \times 10^{-18}\)
119. Barium carbonate has a measured solubility of $4.0 \times 10^{-5}$ at 25°C. Determine the $K_{sp}$.
   
   a) $5.3 \times 10^{-10}$  
   b) $6.1 \times 10^{-5}$  
   c) $9.1 \times 10^{-7}$  
   d) $1.2 \times 10^{-2}$  
   e) $1.6 \times 10^{-9}$  
   
   **ANS:** e) $1.6 \times 10^{-9}$  

120. A 300.0-mL saturated solution of copper(II) periodate (Cu(IO₄)₂) contains 0.44 grams of dissolved salt. Determine the $K_{sp}$.
   
   a) $6.1 \times 10^{-5}$  
   b) $67.2 \times 10^{-8}$  
   c) $9.2 \times 10^{-6}$  
   d) $1.4 \times 10^{-7}$  
   e) $3.7 \times 10^{-8}$  
   
   **ANS:** d) $1.4 \times 10^{-7}$  

121. The correct mathematical expression for finding the molar solubility $(S)$ of Sn(OH)₂ is:
   
   a) $2S² = K_{sp}$  
   b) $2S³ = K_{sp}$  
   c) $108S⁵ = K_{sp}$  
   d) $4S³ = K_{sp}$  
   e) $8S³ = K_{sp}$  
   
   **ANS:** d) $4S³ = K_{sp}$  

122. The [IO₃⁻] in a saturated solution of Ce(IO₃)₃ is $5.55 \times 10^{-3}$ M. Calculate the $K_{sp}$ for Ce(IO₃)₃.
   
   a) $3.16 \times 10^{-10}$  
   b) $1.03 \times 10^{-5}$  
   c) $2.56 \times 10^{-8}$  
   d) $3.51 \times 10^{-11}$  
   e) none of these  
   
   **ANS:** a) $3.16 \times 10^{-10}$  

123. Calculate the solubility of Ag₂CrO₄ [$K_{sp} = 9.0 \times 10^{-12}$] in a $1.0 \times 10^{-2}$ M AgNO₃ solution.
   
   a) $1.3 \times 10^{-4}$ mol/L  
   b) $2.3 \times 10^{-8}$ mol/L  
   c) $9.0 \times 10^{-8}$ mol/L  
   d) $9.0 \times 10^{-10}$ mol/L  
   e) none of these  
   
   **ANS:** c) $9.0 \times 10^{-8}$ mol/L  

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124. The solubility of Mg(OH)$_2$ ($K_{sp} = 8.9 \times 10^{-12}$) in 1.0 L of a solution buffered (with large capacity) at pH 10.0 is:
   a) $8.9 \times 10^9$ moles
   b) $8.9 \times 10^{-4}$ moles
   c) $8.9 \times 10^{-1}$ moles
   d) $8.9 \times 10^{-7}$ moles
   e) none of these

   **ANS:** b) $8.9 \times 10^{-4}$ moles

125. Calculate the solubility of Ca$_3$(PO$_4$)$_2$ (s) ($K_{sp} = 1.3 \times 10^{-32}$) in a 1.0 $\times$ $10^{-2}$ M Ca(NO$_3$)$_2$ solution.
   a) $5.7 \times 10^{-14}$ mol/L
   b) $6.2 \times 10^{-7}$ mol/L
   c) $1.6 \times 10^{-14}$ mol/L
   d) $3.16 \times 10^{-12}$ mol/L
   e) none of these

   **ANS:** a) $5.7 \times 10^{-14}$ mol/L

126. Calculate the solubility of Cu(OH)$_2$ in a solution buffered at pH = 8.50. ($K_{sp} = 1.6 \times 10^{-19}$)
   a) $1.6 \times 10^{-2}$ M
   b) $1.8 \times 10^{-7}$ M
   c) $1.6 \times 10^{-8}$ M
   d) $5.7 \times 10^{-10}$ M
   e) none of these

   **ANS:** c) $1.6 \times 10^{-8}$ M

127. Given the following $K_{sp}$ values

   
<table>
<thead>
<tr>
<th>Substance</th>
<th>$K_{sp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PbCrO$_4$</td>
<td>$2.0 \times 10^{-16}$</td>
</tr>
<tr>
<td>Pb(OH)$_2$</td>
<td>$1.2 \times 10^{-15}$</td>
</tr>
<tr>
<td>Zn(OH)$_2$</td>
<td>$4.5 \times 10^{-17}$</td>
</tr>
<tr>
<td>MnS</td>
<td>$2.3 \times 10^{-13}$</td>
</tr>
</tbody>
</table>

   which statement about solubility in mol/L in water is correct?
   a) PbCrO$_4$, Zn(OH)$_2$, and Pb(OH)$_2$ have equal solubilities in water.
   b) PbCrO$_4$ has the lowest solubility in water.
   c) The solubility of MnS in water will not be pH dependent.
   d) MnS has the highest molar solubility in water.
   e) A saturated PbCrO$_4$ solution will have a higher [Pb$^{2+}$] than a saturated Pb(OH)$_2$ solution.

   **ANS:** b) PbCrO$_4$ has the lowest solubility in water.
128. The concentration of OH\(^-\) in a saturated solution of Mg(OH)\(_2\) is 3.6 × 10\(^{-4}\) M. The K\(_{sp}\) of Mg(OH)\(_2\) is
   a) 1.3 × 10\(^{-7}\)
   b) 4.7 × 10\(^{-11}\)
   c) 1.2 × 10\(^{-11}\)
   d) 3.6 × 10\(^{-4}\)
   e) none of these
   ANS: e) none of these
   PAGE: 15.6

129. How many moles of CaF\(_2\) will dissolve in 3.0 liters of 0.050 M NaF solution? (K\(_{sp}\) for CaF\(_2\) = 4.0 × 10\(^{-11}\))
   a) 8.9 × 10\(^{-9}\)
   b) 8.0 × 10\(^{-8}\)
   c) 4.8 × 10\(^{-8}\)
   d) 2.7 × 10\(^{-8}\)
   e) none of these
   ANS: c) 4.8 × 10\(^{-8}\)
   PAGE: 15.6

130. Which of the following compounds has the lowest solubility in mol/L in water at 25°C?
   a) Ag\(_3\)PO\(_4\) \(K_{sp} = 1.8 \times 10^{-18}\)
   b) Sn(OH)\(_2\) \(K_{sp} = 5 \times 10^{-26}\)
   c) CdS \(K_{sp} = 3.6 \times 10^{-29}\)
   d) CaSO\(_4\) \(K_{sp} = 6.1 \times 10^{-5}\)
   e) Al(OH)\(_3\) \(K_{sp} = 2 \times 10^{-33}\)
   ANS: c) CdS \(K_{sp} = 3.6 \times 10^{-29}\)
   PAGE: 15.6

131. A 100.-mL sample of solution contains 10.0 mmol of Ca\(^{2+}\) ion. How many mmol of solid Na\(_2\)SO\(_4\) must be added in order to cause precipitation of 99.9% of the calcium as CaSO\(_4\)? The K\(_{sp}\) of CaSO\(_4\) is 6.1 × 10\(^{-5}\). Assume the volume remains constant.
   a) 17.4
   b) 10.0
   c) 61.0
   d) 71.0
   e) 2.00
   ANS: d) 71.0
   PAGE: 15.7
132. The $K_{sp}$ of Al(OH)$_3$ is $2 \times 10^{-32}$. At what pH will a 0.2 M Al$^{3+}$ solution begin to show precipitation of Al(OH)$_3$?
   a) 3.7
   b) 1.0
   c) 5.6
   d) 10.3
   e) 8.4
   ANS: a) 3.7

133–136. The following questions refer to the following system: 3.5 $\times$ 10$^2$ mL of 3.2 M Pb(NO$_3$)$_2$ and 2.0 $\times$ 10$^2$ mL of 0.020 M NaCl are added together. $K_{sp}$ for the lead chloride is 1.6 $\times$ 10$^{-5}$.

133. Determine the ion product.
   a) $1.1 \times 10^{-4}$
   b) $1.5 \times 10^{-2}$
   c) $7.8 \times 10^{-3}$
   d) $8.1 \times 10^{-4}$
   e) none of these
   ANS: a) $1.1 \times 10^{-4}$

134. Will precipitation occur?
   a) Yes
   b) No
   c) Maybe, it depends on the temperature.
   d) Maybe, it depends on the limiting reagent concentration.
   e) None of these.
   ANS: a) Yes

135. What is the limiting reagent in the formation of the lead chloride?
   a) Pb$^{2+}$
   b) Cl$^-$
   c) (NO$_3$)$^-$
   d) PbCl$_2$
   e) Pb(NO$_3$)$_2$
   ANS: b) Cl$^-$
136. Determine the equilibrium concentration of the chloride ion.
   a) $3.9 \times 10^{-4}$
   b) $8.0 \times 10^{-6}$
   c) $2.8 \times 10^{-3}$
   d) $6.1 \times 10^{-2}$
   e) none of these
ANS: c) $2.8 \times 10^{-3}$  

137. The $K_{sp}$ for BaF$_2$ is $2.4 \times 10^{-5}$. When 10 mL of 0.01 M NaF is mixed with 10 mL of 0.01 M Ba(NO$_3$)$_2$, will a precipitate form?
   a) No, because $Q$ is $1 \times 10^{-12}$ and since it is less than $K_{sp}$ no precipitate will form.
   b) Yes, because $Q$ is $1 \times 10^{-12}$ and since it is less than $K_{sp}$ a precipitate will form.
   c) No, because $Q$ is $1.25 \times 10^{-7}$ and since it is less than $K_{sp}$ no precipitate will form.
   d) Yes, because $Q$ is $1.25 \times 10^{-7}$ and since it is less than $K_{sp}$ a precipitate will form.
   e) none of these
ANS: c) No, because $Q$ is $1.25 \times 10^{-7}$ and since it is less than $K_{sp}$ no precipitate will form.  

138. How many moles of Ca(NO$_3$)$_2$ must be added to 1.0 L of a 0.100 M HF solution to begin precipitation of CaF$_2$(s)? For CaF$_2$, $K_{sp} = 4.0 \times 10^{-11}$.
   a) $5.8 \times 10^{-7}$
   b) $1.6 \times 10^{-9}$
   c) $7.0 \times 10^{-11}$
   d) $4.0 \times 10^{-9}$
   e) $6.3 \times 10^{-7}$
ANS: d) $4.0 \times 10^{-9}$  

139. Which of the following solid salts is more soluble in 1.0 M H$^+$ than in pure water?
   a) NaCl
   b) CaCO$_3$
   c) KCl
   d) AgCl
   e) KNO$_3$
ANS: b) CaCO$_3$  

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140. A solution contains 0.018 moles each of I⁻, Br⁻, and Cl⁻. When the solution is mixed with 200 mL of 0.24 M AgNO₃, how much AgCl(s) precipitates out?

\[
\begin{align*}
K_{sp} \text{ AgI} & = 1.5 \times 10^{-16} \\
K_{sp} \text{ AgBr} & = 5.0 \times 10^{-13} \\
K_{sp} \text{ AgCl} & = 1.6 \times 10^{-10}
\end{align*}
\]

a) 0.0 g  
b) 1.7 g  
c) 2.6 g  
d) 3.3 g  
e) 5.0 g

ANS: b) 1.7 g  

141. A 50.0-mL sample of 0.100 M Ca(NO₃)₂ is mixed with 50.00 mL of 0.200 M NaF. When the system has come to equilibrium, which of the following sets of conditions will hold? The \( K_{sp} \) for CaF₂ is 4.0 \( \times \) 10⁻¹¹.

<table>
<thead>
<tr>
<th>Moles Solid CaF₂ Formed</th>
<th>([\text{Ca}^{2+}]) (M)</th>
<th>([\text{F}^-]) (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1: 5.0 ( \times ) 10⁻³</td>
<td>3.5 ( \times ) 10⁻⁴ M</td>
<td>7.0 ( \times ) 10⁻⁴ M</td>
</tr>
<tr>
<td>Option 2: 5.0 ( \times ) 10⁻³</td>
<td>3.4 ( \times ) 10⁻⁹ M</td>
<td>0.05 M</td>
</tr>
<tr>
<td>Option 3: 5.0 ( \times ) 10⁻³</td>
<td>2.2 ( \times ) 10⁻⁴ M</td>
<td>4.3 ( \times ) 10⁻⁴ M</td>
</tr>
<tr>
<td>Option 4: 5.0 ( \times ) 10⁻³</td>
<td>3.5 ( \times ) 10⁻⁴ M</td>
<td>4.3 ( \times ) 10⁻⁴ M</td>
</tr>
<tr>
<td>Option 5: 10.0 ( \times ) 10⁻³</td>
<td>1.3 ( \times ) 10⁻⁵ M</td>
<td>1.3 ( \times ) 10⁻⁵ M</td>
</tr>
</tbody>
</table>

a) Option 1  
b) Option 2  
c) Option 3  
d) Option 4  
e) Option 5

ANS: c) Option 3  

142. Silver acetate (AgC₂H₃O₂) is a sparingly soluble salt with \( K_{sp} = 1.9 \times 10^{-3} \). Consider a saturated solution in equilibrium with the solid salt. Compare the effects on the solubility of adding to the solution either the acid HNO₃ or the base NH₃.

a) Either substance would decrease the solubility.  
b) NH₃ would increase the solubility, but HNO₃ would decrease it.  
c) NH₃ would increase the solubility, but HNO₃ would have virtually no effect.  
d) Either substance would increase the solubility.  
e) NH₃ would decrease the solubility, but HNO₃ would increase it.

ANS: d) Either substance would increase the solubility.
143. The $K_{sp}$ for Mn(OH)$_2$ is $2.0 \times 10^{-13}$. At what pH will Mn(OH)$_2$ begin to precipitate from a solution in which the initial concentration of Mn$^{2+}$ is 0.10 M?

a) 6.47  
b) 13.3  
c) 5.85  
d) 7.03  
e) 8.15

**ANS:** e) 8.15

144. The concentration of Mg$^{2+}$ in seawater is 0.052 M. At what pH will 99% of the Mg$^{2+}$ be precipitated as the hydroxide? ($K_{sp}$ for Mg(OH)$_2 = 8.9 \times 10^{-12}$)

a) 8.35  
b) 9.22  
c) 6.50  
d) 10.12  
e) 4.86

**ANS:** d) 10.12

145. Sodium chloride is added slowly to a solution that is 0.010 M in Cu$^+$, Ag$^+$, and Au$^+$. The $K_{sp}$ values for the chloride salts are $1.9 \times 10^{-7}$, $1.6 \times 10^{-10}$, and $2.0 \times 10^{-13}$, respectively. Which compound will precipitate first?

a) CuCl(s)  
b) AgCl(s)  
c) AuCl(s)  
d) All will precipitate at the same time.  
e) Cannot be determined.

**ANS:** c) AuCl(s)

146. A 0.012-mol sample of Na$_2$SO$_4$ is added to 400 mL of each of two solutions. One solution contains $1.5 \times 10^{-3}$ M BaCl$_2$; the other contains $1.5 \times 10^{-3}$ M CaCl$_2$. Given that $K_{sp}$ for BaSO$_4 = 1.5 \times 10^{-9}$ and $K_{sp}$ for CaSO$_4 = 6.1 \times 10^{-5}$:

a) BaSO$_4$ would precipitate but CaSO$_4$ would not.  
b) CaSO$_4$ would precipitate but BaSO$_4$ would not.  
c) Both BaSO$_4$ and CaSO$_4$ would precipitate.  
d) Neither BaSO$_4$ nor CaSO$_4$ would precipitate.  
e) Not enough information is given to determine if precipitation would occur.

**ANS:** a) BaSO$_4$ would precipitate but CaSO$_4$ would not.
147. Which of the following solid salts is more soluble in 1.0 M H+ than in pure water?
   a) NaCl
   b) KCl
   c) FePO₄
   d) AgCl
   e) KNO₃

   ANS: c) FePO₄

148. Which of the following solid salts should be more soluble in 1.0 M NH₃ than in water?
   a) Na₂CO₃
   b) KCl
   c) AgBr
   d) KNO₃
   e) none of these

   ANS: c) AgBr

149. The overall $K_f$ for the complex ion Ag(NH₃)²⁺ is 1.7 × 10⁷. The $K_{sp}$ for AgI is 1.5 × 10⁻¹⁶. What is the molar solubility of AgI in a solution that is 2.0 M in NH₃?
   a) 1.5 × 10⁻⁹
   b) 1.3 × 10⁻³
   c) 1.0 × 10⁻⁴
   d) 5.8 × 10⁻¹²
   e) 8.4 × 10⁻⁵

   ANS: c) 1.0 × 10⁻⁴

150. If 30 mL of 5.0 × 10⁻⁴ M Ca(NO₃)₂ are added to 70 mL of 2.0 × 10⁻⁴ M NaF, will a precipitate occur? ($K_{sp}$ of CaF₂ = 4.0 × 10⁻¹¹)
   a) No, because the ion product is greater than $K_{sp}$.
   b) Yes, because the ion product is less than $K_{sp}$.
   c) No, because the ion product is less than $K_{sp}$.
   d) Not enough information is given.
   e) Yes, because the ion product is greater than $K_{sp}$.

   ANS: c) No, because the ion product is less than $K_{sp}$.
151. Given the following values of equilibrium constants:

\[
\begin{align*}
\text{Cu(OH)}_2(s) & \rightleftharpoons \text{Cu}^{2+}(aq) + 2\text{OH}^-(aq) \quad K_{sp} = 1.6 \times 10^{-19} \\
\text{Cu(NH}_3\text{)}_4^{2+} & \rightleftharpoons \text{Cu}^{2+}(aq) + 4\text{NH}_3(aq) \quad K = 1.0 \times 10^{-13}
\end{align*}
\]

What is the value of the equilibrium constant for the reaction:

\[
\text{Cu(OH)}_2(s) + 4\text{NH}_3(aq) \rightleftharpoons \text{Cu(NH}_3\text{)}_4^{2+}(aq) + 2\text{OH}^-(aq)
\]

a) \(1.6 \times 10^{-19}\)  

b) \(6.2 \times 10^{31}\)  

c) \(1.6 \times 10^{-6}\)  

d) \(1.6 \times 10^{-32}\)  

e) \(1.0 \times 10^{13}\)

ANS: c) \(1.6 \times 10^{-6}\)  

152–154. A 50.0-mL sample of \(2.0 \times 10^{-4}\) M CuNO\(_3\) is added to 50.0 mL of 4.0 M NaCN.

\[
\text{Cu}^+ \text{ reacts with } \text{CN}^- \text{ to form the complex ion } \text{Cu(CN)}_3^{2-}:
\]

\[
\text{Cu(CN)}_3^{2-} \rightleftharpoons \text{Cu}^+ + 3\text{CN}^- \quad K = 1.0 \times 10^{-9}
\]

152. The concentration of \(\text{CN}^-\) at equilibrium is

a) \(4.0\) M  

b) \(2.0\) M  

c) \(1.0\) M  

d) \(6.0 \times 10^{-4}\) M  

e) none of these

ANS: b) \(2.0\) M  

153. The concentration of \(\text{Cu}^+\) at equilibrium is

a) \(2.0 \times 10^{-4}\) M  

b) \(1.0 \times 10^{-4}\) M  

c) \(1.2 \times 10^{-14}\) M  

d) \(5.0 \times 10^{-14}\) M  

e) none of these

ANS: c) \(1.2 \times 10^{-14}\) M  

154. Calculate the solubility of CuBr(s) (\(K_{sp} = 1.0 \times 10^{-5}\)) in 1.0 L of 1.0 M NaCN.

a) \(1.0\) mol/L  

b) \(1.0 \times 10^{-6}\) mol/L  

c) \(0.33\) mol/L  

d) \(1.0 \times 10^7\) mol/L  

e) none of these

ANS: c) \(0.33\) mol/L
155–156. Consider a solution made by mixing 500.0 mL of 4.0 M NH₃ and 500.0 mL of 0.40 M AgNO₃. Ag⁺ reacts with NH₃ to form AgNH₃⁺ and Ag(NH₃)₂⁺:

\[
\begin{align*}
\text{Ag}^+ + \text{NH}_3 & \rightleftharpoons \text{AgNH}_3^+ & K_1 = 2.1 \times 10^3 \\
\text{AgNH}_3^+ + \text{NH}_3 & \rightleftharpoons \text{Ag(NH}_3)_2^+ & K_2 = 8.2 \times 10^3
\end{align*}
\]

155. The concentration of Ag(NH₃)₂⁺ at equilibrium is:

a) 2.0 M  
b) 0.40 M  
c) 0.20 M  
d) 1.0 \times 10^{-3} M  
e) none of these

ANS: c) 0.20 M

156. The concentration of Ag⁺ at equilibrium is:

a) 2.0 M  
b) 1.2 \times 10^{-8} M  
c) 4.5 \times 10^{-9} M  
d) 1.6 M  
e) none of these

ANS: c) 4.5 \times 10^{-9} M

157–160. The following questions refer to the following system: 500.0 mL of 0.020 M Mn(NO₃)₂ are mixed with 1.0 L of 1.0 M Na₂C₂O₄. The oxalate ion, C₂O₄²⁻, acts as a ligand to form a complex ion with the Mn²⁺ ion with a coordination number of two.

\[
\begin{align*}
\text{Mn}^{2+} + \text{C}_2\text{O}_4^{2-} & \rightleftharpoons \text{MnC}_2\text{O}_4 & K_1 = 7.9 \times 10^3 \\
[\text{Mn(C}_2\text{O}_4)_2]^{2-} & \rightleftharpoons \text{MnC}_2\text{O}_4 + \text{C}_2\text{O}_4^{2-} & K_2 = 1.26 \times 10^{-2}
\end{align*}
\]

157. What is the equilibrium constant for the following formation:

\[
\text{Mn}^{2+} + 2\text{C}_2\text{O}_4^{2-} \rightleftharpoons [\text{Mn(C}_2\text{O}_4)_2]^{2-}
\]

a) 1.0  
b) 3.7 \times 10^2  
c) 2.1 \times 10^{-1}  
d) 6.3 \times 10^5  
e) none of these

ANS: d) 6.3 \times 10^5
158. Find the equilibrium concentration of the \([\text{Mn(C}_2\text{O}_4\text{)}_2]\text{]^{2–}}\) ion.
   a) \(9.2 \times 10^{-5}\) M
   b) 0.01 M
   c) \(2.5 \times 10^{-8}\)
   d) \(1.3 \times 10^{-4}\)
   e) \(6.7 \times 10^{-3}\)
   **ANS:** e) \(6.7 \times 10^{-3}\)  
   **PAGE:** 15.8

159. Find the equilibrium concentration of the Mn(C\(_2\)O\(_4\)) ion.
   a) \(9.2 \times 10^{-5}\) M
   b) 0.01 M
   c) \(2.5 \times 10^{-8}\)
   d) \(1.3 \times 10^{-4}\)
   e) \(6.7 \times 10^{-3}\)
   **ANS:** d) \(1.3 \times 10^{-4}\)  
   **PAGE:** 15.8

160. Find the equilibrium concentration of the Mn\(^{2+}\) ion.
   a) \(9.2 \times 10^{-5}\) M
   b) 0.01 M
   c) \(2.5 \times 10^{-8}\)
   d) \(1.3 \times 10^{-4}\)
   e) \(6.7 \times 10^{-3}\)
   **ANS:** c) \(2.5 \times 10^{-8}\)  
   **PAGE:** 15.8

161. Calculate the molar concentration of uncomplexed \(\text{Zn}^{2+}\) in a solution that contains 0.20 mole of \(\text{Zn(NH}_3\text{)}_4^{2+}\) per liter and 0.0116 M \(\text{NH}_3\) at equilibrium? The overall \(K_i\) for \(\text{Zn(NH}_3\text{)}_4^{2+}\) is \(3.8 \times 10^9\).
   a) \(2.9 \times 10^{-3}\) M
   b) \(8.8 \times 10^{-3}\) M
   c) \(6.7 \times 10^{-4}\) M
   d) \(2.0 \times 10^{-13}\) M
   e) none of these
   **ANS:** a) \(2.9 \times 10^{-3}\) M  
   **PAGE:** 15.8
162. The cation $M^{2+}$ reacts with $NH_3$ to form a series of complex ions as follows:

\[
\begin{align*}
M^{2+} + NH_3 &\rightleftharpoons M(NH_3)^{2+} \quad K_1 = 10^2 \\
M(NH_3)^{2+} + NH_3 &\rightleftharpoons M(NH_3)_{2}^{2+} \quad K_2 = 10^3 \\
M(NH_3)_{2}^{2+} + NH_3 &\rightleftharpoons M(NH_3)_{3}^{2+} \quad K_3 = 10^2
\end{align*}
\]

A $1.0 \times 10^{-3}$ mol sample of $M(NO_3)_2$ is added to 1.0 L of 15.0 M $NH_3$ ($K_b = 1.8 \times 10^{-5}$). Choose the dominant species in this solution.

a) $M^{2+}$  

b) $M(NH_3)^{2+}$  

c) $M(NH_3)_{2}^{2+}$  

d) $M(NH_3)_{3}^{2+}$

ANS: d) $M(NH_3)_{3}^{2+}$  

PAGE: 15.8

163. The $K_f$ for the complex ion $Ag(NH_3)_2^+$ is $1.7 \times 10^7$. The $K_{sp}$ for $AgCl$ is $1.6 \times 10^{-10}$. Calculate the molar solubility of $AgCl$ in 1.0 M $NH_3$.

a) $5.2 \times 10^{-2}$  

b) $4.7 \times 10^{-2}$  

c) $2.9 \times 10^{-3}$  

d) $1.3 \times 10^{-5}$  

e) $1.7 \times 10^{-10}$

ANS: b) $4.7 \times 10^{-2}$  

PAGE: 15.8