## THE COMMON-ION EFFECT AND BUFFERS

**1.** What is a common ion and what is the common-ion effect?

**2.** Why can the dissociation of a weak base be ignored when calculating the pH of a solution that contains both a weak base and a strong base?

**3.** What is a buffer and how does it function?

**4.** Explain why the terms *appreciable* and *comparable* appear in the definition of a buffer.

**5.** Why is a solution that is 1.4 mM HF and 6.4 mM KF not a good buffer?

**6.** Why is a solution that is 1.3 M HF and 1.3 mM KF not a good buffer?

**7.** Explain why a solution of a strong acid and its conjugate base is not a buffer. Use a solution of HCl and KCl as an example.

**8.** Explain why a solution that is prepared by dissolving 0.1 mol of each of $KH_2PO_4$ and $K_3PO_4$ in 1 L of water is not a buffered solution.

**9.** Use Appendix C to determine the best acid/base pair to prepare buffers at the following pH's:

**a)** pH = 1.5 **b)** pH = 7.0 **c)** pH = 12.0

**10.** Select an acid-base pair from Appendix C that could be used to buffer a solution at each of the following pH's:

**a)** pH = 3.5 **b)** pH = 8.0 **c)** pH = 10.6

**11.** What is the pH of a solution that is 0.16 M $NH_3$ and 0.43 M $NH_4Cl$?

**12.** What is the pH of a solution that is 0.21 M $K_2HPO_4$ and 0.096 M $K_3PO_4$?

**13.** What is the pH of a solution made by dissolving 7.6 g $KNO_2$ to 750 mL of 0.11 M $HNO_2$?

**14.** What is the pH of a solution made by dissolving 8.5 g of $K_2CO_3$ and 6.9 g $KHCO_3$ in 500 mL of water?

**15.** How many grams of potassium acetate must be added to 2.5 L of 0.250 M acetic acid to prepare a pH = 4.26 buffer?

**16.** How many grams of ammonium chloride must be added to 0.75 L of 1.2 M ammonia to prepare a pH = 10.18 buffer?

**17.** How many milliliters of 6.0 M NaOH must be added to 0.50 L of 0.20 M $HNO_2$ to prepare a pH = 3.86 buffer?

**18.** How many milliliters of 3.5 M HCl must be added to 3.8 L of 0.18 M $K_2HPO_4$ to prepare a pH = 7.42 buffer?

## EQUILIBRIUM CONSTANTS FOR ACID BASE REACTIONS

**19.** Use the data in Appendix C to determine the equilibrium constants for the following reactions:

**a)** $NH_3(aq) + HCN(aq) \quad NH_4^{1+} + CN^{1-}$

**b)** $S^{2-} + HCN(aq) \rightleftharpoons HS^{1-} + CN^{1-}$

**c)** $F^{1-} + HCN(aq) \rightleftharpoons HF(aq) + CN^{1-}$

**20.** Use the data in Appendix C to determine the equilibrium constants for the following reactions:

**a)** $NH_3(aq) + H_3O^{1+} \rightleftharpoons NH_4^{1+} + H_2O$

**b)** $F^{1-} + H_2O \rightleftharpoons HF(aq) + OH^{1-}$

**c)** $HSO_3^{1-} + HS^{1-} \rightleftharpoons H_2S(aq) + SO_3^{2-}$

## MIXING PROBLEMS

**21.** What is $[SO_3^{2-}]$ in a solution prepared by mixing 25.0 mL of 0.100 M $H_2CO_3$ and 25.0 mL of 0.100 M $K_2SO_3$?

**22.** What is [HOCl] in a solution prepared by mixing 50.0 mL of 0.160 M KOCl and 50.0 mL of 0.160 M $NH_4Cl$?

**23.** What is $[F^{1-}]$ in a solution prepared by mixing 25 mL of 0.16 M HF and 42 mL of 0.086 M KCN?

**24.** What is $[NH_4^{1+}]$ prepared by mixing 75 mL of 0.34 M ammonia and 85 mL of 0.18 M acetic acid?

**25.** What is the pH of a solution made by mixing 5.0 mL of 1.2 M HCl and 3.0 mL of 0.88 M HBr?

**26.** What is the pH of a solution prepared by mixing 39 mL of 0.074 M $Ba(OH)_2$ and 57 mL of 0.11 M KOH?

**27.** What is the pH of a solution prepared by mixing 5.00 mL of 1.20 M HCl and 4.60 mL of 0.840 M NaOH?

**28.** What is the pH of a solution prepared by mixing 38.64 mL of 0.8862 M HCl and 53.66 mL of 0.7500 M NaOH?

**29.** Calculate the pH change that results when 10. mL of 3.0 M NaOH is added to 500. mL of each of the following solutions:

**a)** pure water **b)** 0.10 M $CH_3COO^{1-}$ **c)** 0.10 M $CH_3COOH$

**d)** a solution that is 0.10 M in each $CH_3COO^{1-}$ and $CH_3COOH$

**30.** Calculate the pH change that results when 10. mL of 3.0 M HCl is added to 500. mL of each of the solutions in Ex 29.

**31.** Calculate the pH change that results when 10. mL of 6.0 M HCl is added to 750. mL of each of the following solutions:

**a)** pure water **b)** 0.10 M $NH_4Cl$ **c)** 0.10 M $NH_3$

**d)** a solution that is 0.10 M in each $NH_4^{1+}$ and $NH_3$

**32.** Calculate the pH change that results when 10. mL of 6.0 M NaOH is added to each of the solutions described in Ex 31.

## TITRATIONS

**33.** Sketch the titration curve for the titration of 50 mL of 0.1 M HA ($K_a = 10^{-7}$) with 0.1 M NaOH. What are the initial pH, the pH at the midpoint of the titration, and the pH at the equivalence point?

**34.** Sketch the titration curve for the titration of 50 mL of 0.1 M $A^{1-}$ ($K_b = 10^{-7}$) with 0.1 M HCl. What are the initial pH, the pH at the midpoint of the titration, and the pH at the equivalence point?

**35.** What is the pH at each equivalence point in the titration of 25 mL of 0.080 M $H_3PO_4$ with 0.065 M NaOH?

**36.** What is the pH's at each equivalence points in the titration of 25 mL of 0.080 M $H_2CO_3$ with 0.10 M NaOH?

**37.** Consider the titration of 35.0 mL of 0.122 M ammonia with 0.0774 M HCl.

**a)** How many mL of HCl are required to reach the equivalence point?

**b)** What is the pH at the equivalence point? What indicator should be used for this titration?

**c)** What is the pH of the solution after addition of 15.0 mL of acid?

**d)** What is the pH of the solution after the addition of 65.0 mL of acid?

**38.** The $CO_2$ we breathe reacts with water in our blood to form the weak acid $H_2CO_3$. What mole ratio of $H_2CO_3/HCO_3^{1-}$ is required to obtain a pH of 7.40, the pH of blood? Use $K_a = 4.4\times10^{-8}$ for $H_2CO_3$.

**39.** 50.0 ml of 0.10 M HCl are required to titrate 10.0 ml of ammonia window cleaner to the end point.

**a)** What is the concentration of ammonia in the window cleaner?

**b)** What is the pH of the window cleaner if $K_b(NH_3) = 1.8\times10^{-5}$?

**c)** What is the pH at the equivalence point of the titration?

**d)** Which indicator in Table 7.4 would be the best to indicate the endpoint?

**40.** 5.182-g of a solid, weak, monoprotic acid is used to make a 100.0 mL solution. 25.00 mL of the resulting acid solution is then titrated with 0.09685 M NaOH. The pH after the addition of 20.00 mL of the base is 5.58, and the endpoint is reached after the addition of 47.92 mL of the base.

**a)** How many moles of acid were present in the 25.00 mL sample?

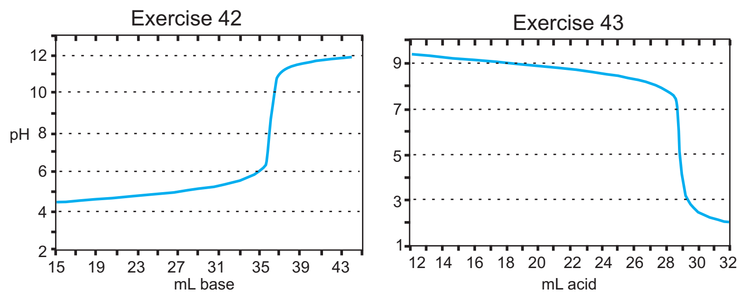
**b)** What is the molar mass of the acid?

**c)** What is the $pK_a$ of the acid?

**41.** A benzoic acid ($C_6H_5COOH$) sample was analyzed by dissolving 406.2 mg of the sample in 50 mL of water and titrating it with 0.06642 M NaOH.

**a)** What is the percent purity of the benzoic acid if the titration required 38.62 mL of base?

**b)** What is the $pK_a$ of benzoic acid if the pH of the titration was 4.46 after the addition of 25.00 mL of the base?




**42.** Use the portion of the titration curve for the titration of 50.00 mL of a weak acid with 0.122 M NaOH shown above left to determine the concentration and $pK_a$ of the weak acid.

**43.** Use the portion of the titration curve for the titration of 20.00 mL of a weak base with 0.143 M HCl shown above right to determine the concentration and $pK_b$ of the weak base.

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## COMPOSITION FROM pH

**44.** What are the concentrations of $C_6H_8O_6$, $C_6H_7O_6^{1-}$, and $C_6H_6O_6^{2-}$ in a solution prepared by adjusting a 0.065 M ascorbic acid solution to the following pH's?

**a)** 3.0 **b)** 5.0 **c)** 10.0 **d)** 12.0

**45.** What are the concentrations of hydrosulfuric acid and the hydrogen sulfate ion in a solution prepared by adjusting a 0.10 M $H_2S$ acid solution to the following pH's?

**a)** 5.0 **b)** 7.0 **c)** 10.0 **d)** 13.0

**46.** To what pH must a 0.15 M ascorbic acid solution be adjusted to obtain the following concentrations?

**a)** $[C_6H_6O_6^{2-}] = 0.040$ M

**b)** $[C_6H_7O_6^{1-}] = 0.15$ M

**c)** $[C_6H_6O_6^{2-}] = 2.2\times10^{-10}$ M

**47.** To what pH must a 0.10 M $H_2S$ solution be adjusted to obtain the following sulfide ion concentrations?

**a)** $[S^{2-}] = 0.085$ M

**b)** $[S^{2-}] = 1.0\times10^{-14}$ M

**c)** $[HS^{1-}] = 0.10$ M

**48.** NaOH is added to a 0.120 M phosphoric acid solution until the hydrogen phosphate ion concentration is 0.080 M, but the phosphate ion concentration is negligible. What is the pH of the solution?

**49.** HCl is added to a 0.140 M phosphate ion solution until the dihydrogen phosphate ion concentration is 0.075 M, but the hydrogen phosphate ion concentration is negligible. What is the pH?

## MISCELLANEOUS PROBLEMS

**50.** A tablet of aspirin ($HC_9H_7O_4$) is required to contain 325 mg of aspirin. The quality is analyzed by dissolving one tablet in 50 ml $H_2O$, then titrating the solution with 0.1000 M NaOH. If 16.05 ml of the NaOH solution are required to reach the endpoint, how many mg of aspirin are actually in the tested sample tablet? Does this product pass your inspection?

**51.** In molecular biology, phosphate buffers are normally utilized to maintain a physiological pH of 6.8 to 7.4. However for RNA isolation more acidic conditions (pH around 5.8) are often required for optimal enzymatic function.

**a)** Explain why an acetate buffer is preferred over a phosphate buffer for RNA isolation.

**b)** How many grams of sodium acetate should be dissolved in 500. mL of 0.112 M acetic acid to prepare a pH = 5.8 buffer?

**52.** Recall from Chapter 2, that the colligative concentration is extremely important in a cell. Thus, both the pH and the concentration of all components are important considerations when preparing a buffer. The concentration of all particles in solution is often termed the *osmolality* or (moles of particles)·kg solvent$^{-1}$. Using $NaH_2PO_4$ and $Na_2HPO_4$ and water, describe how to prepare a buffer with a pH = 7.21 and an osmolality of 300. mmol·kg$^{-1}$.