

**ACID-BASE TERMS AND A REVIEW OF ACID-BASE THEORY FROM CAMS CHAPTER 12**

1. Define a conjugate acid-base pair.
2. Indicate the conjugate acid for each of the following:  
a)  $\text{OH}^{1-}$     b)  $\text{NO}_2^{1-}$     c)  $\text{NH}_2^{1-}$     d)  $\text{PO}_4^{3-}$     e)  $\text{HSO}_3^{1-}$
3. Indicate the conjugate base for each of the following:  
a)  $\text{OH}^{1-}$     b)  $\text{H}_2\text{O}_2$     c)  $\text{H}_2\text{PO}_4^{1-}$     d)  $\text{H}_3\text{O}^{1+}$     e)  $\text{H}_2\text{SO}_3$
4. Define a Lewis acid and a Brønsted acid. Give an example of a Lewis acid that is not a Brønsted acid.
5. Are all Brønsted bases also Lewis bases? Explain.
6. What distinguishes a weak acid from a strong one?
7. Which of the following are Brønsted bases?  
a) NaOH    b) NaCl    c)  $\text{CH}_3\text{OH}$     d) KCN    e)  $\text{KH}_2\text{PO}_4$
8. Which of the following are Brønsted acids?  
a) HClO    b)  $\text{CaH}_2$     c)  $\text{CH}_3\text{CO}_2\text{H}$     d)  $\text{KHSO}_3$     e)  $\text{NH}_4\text{Cl}$
9. Explain how the reaction  $\text{Ag}^{1+} + \text{Cl}^{1-} \rightarrow \text{AgCl}$  is a Lewis acid-base reaction. Is it also a Brønsted acid-base reaction? Explain.
10. Write Brønsted acid-base reactions or indicate *no reaction* if  $K \ll 1$ .  
a) Hydrochloric acid and aqueous sodium hydroxide are mixed.  
b) Aqueous potassium fluoride is added to perchloric acid.  
c) Aqueous  $\text{NH}_4\text{Cl}$  is added to aqueous  $\text{KHSO}_4$ .  
d) Aqueous ammonia is added to hydrofluoric acid.  
e)  $\text{HNO}_2$  is added to aqueous KF.
11. Write Brønsted acid-base reactions or indicate *no reaction* if  $K \ll 1$ .  
a) Aqueous sodium sulfate is added to hydrobromic acid.  
b) Aqueous  $\text{NH}_4\text{Cl}$  and aqueous KF are mixed.  
c) Aqueous NaCN is added to a large excess of sulfurous acid.  
d) Acetic acid and aqueous sodium hypochlorite are mixed.  
e) Hydrogen sulfide is bubbled into water.
12. Explain why  $\text{HClO}_4$  is a strong acid, but HClO is a weak acid.
13. Explain why HCl is a strong acid, but HF is a weak acid.
14. What is the predominate phosphorus containing species in a solution prepared by adding sodium phosphate to an excess of carbonic acid?
15. What is the predominate phosphorus containing species in a solution prepared by adding phosphoric acid to a large excess of ammonia?
16. Define *amphiprotic*. Identify the amphiprotic species in Exercises 2 & 3.
17. What is an *autoionization* reaction? Write the chemical equation for the autoionization of ammonia.  $\text{H}_3\text{O}^{1+}$  and  $\text{OH}^{1-}$  are the strongest acid and base that can exist in aqueous solutions because water reacts with any acids or bases that are stronger than these acids. This is known as the *leveling effect*. What are the strongest acid and base that can exist in liquid ammonia?

In the remaining exercises, assume a temperature of 25 °C if none is given; that is, assume that  $K_w = 1.0 \times 10^{-14}$  if no temperature is given.

### THE p-SCALE

18. Determine the hydronium and hydroxide ion concentrations in the following solutions:

- a) rainwater; pH = 5.3    b) household ammonia; pH = 11.9  
c) vinegar; pH = 2.7    d) seawater; pH = 7.6

19. Determine the hydronium and hydroxide ion concentrations in the following solutions:

- a) detergent; pH = 10.3    b) stomach acid; pH = 2.4  
c) beer; pH = 4.2    d) milk of magnesia; pH = 10.5

20. Determine the  $pK_a$  of each of the following acids:

- a) Hypoiodous acid     $\text{HIO}$      $K_a = 2.3 \times 10^{-11}$   
b) Iodic acid     $\text{HIO}_3$      $K_a = 0.16$

21. Determine the  $pK_a$  of each of the following acids:

- a) Tartaric acid     $\text{H}_2\text{C}_4\text{H}_4\text{O}_6$      $K_a = 1.0 \times 10^{-3}$   
b) Boric acid     $\text{H}_3\text{BO}_3$      $K_a = 5.8 \times 10^{-10}$

22. Determine the  $K_a$  of each of the following acids:

- a) Phenol     $\text{C}_6\text{H}_5\text{OH}$      $pK_a = 10.00$   
b) Ascorbic acid     $\text{H}_2\text{C}_6\text{H}_6\text{O}_6$      $pK_a = 4.10$

23. Determine the  $K_a$  of each of the following acids:

- a) Hypobromous acid     $\text{HOBr}$      $pK_a = 8.64$   
b) Saccharin     $\text{HNC}_7\text{H}_4\text{SO}_3$      $pK_a = 11.68$

24. What is the  $pK_b$  of the conjugate base of each acid in Exercise 20?

25. What is the  $pK_b$  of the conjugate base of each acid in Exercise 21?

26. Determine the pH of solutions with the following pOH's:

- a) 12.32    b) 1.86    c) 4.37

27. What is the  $K_a$  of an acid whose conjugate base has the following  $pK_b$ ?

- a) 8.37    b) 12.66    c) 0.22

### AUTOIONIZATION AND pH

28. Determine the pH and pOH of solutions with the following hydronium ion concentrations:

- a)  $3.4 \times 10^{-6}$  M    b)  $4.7 \times 10^{-3}$  M    c)  $8.8 \times 10^{-10}$  M

29. Determine the pH and pOH of solutions with the following hydroxide ion concentrations:

- a)  $7.5 \times 10^{-8}$  M    b)  $3.9 \times 10^{-4}$  M    c)  $1.0 \times 10^{-12}$  M

30. What is the pH of  $1.0 \times 10^{-8}$  M HCl at 25 °C? Hint: At such a low acid concentration water is the primary source of  $\text{H}_3\text{O}^{1+}$  in the solution.

31. The solubility of  $\text{Al}(\text{OH})_3$  in water is  $2.9 \times 10^{-9}$  M at 25 °C. What is the pH of a saturated solution of  $\text{Al}(\text{OH})_3$  at 25 °C? Hint: What is the primary source of hydroxide ion in the solution?

32. The pH of water at 100 °C is 6.13. What is the value of  $K_w$  at 100 °C?

**Exercises 33-36 deal with solutions at 37 °C, the temperature of the human body.  $K_w = 2.42 \times 10^{-14}$  at this temperature.**

33. What is pH of a neutral solution at 37 °C?

34. What is the  $K_b$  of a base if  $K_a = 5.0 \times 10^{-10}$  at 37 °C for its conjugate acid?

35. What is the  $pK_b$  of a base if the  $pK_a$  of its conjugate acid is 5.21 at 37 °C?

36. The hydroxide ion concentration in a weak base solution at 37 °C is 0.024. What is the pH of the solution?

### STRONG ACIDS AND STRONG BASES

37. What is the pH of each of the following aqueous solutions?

a) 0.066 M HCl      b) 0.21 M KOH      c) 0.11 M Ba(OH)<sub>2</sub>

38. What is the pH of each of the following aqueous solutions?

a) 0.57 M NaOH      b)  $1.3 \times 10^{-4}$  M HNO<sub>3</sub>      c) 2.1 M KOH

39. To what volume must 5.0 mL of 6.0 M HCl be diluted to prepare a solution with pH = 1.22?

40. How much water must be added to 25 mL of an HCl solution with a pH = 2.46 to make a pH = 4.00 solution? Assume the volumes are additive.

41. What volume of HCl gas measured at 300. K and 1 atm is required to prepare 5.0 L of hydrochloric acid with a pH of 3.84?

41. 512 mL of HCl gas at 300. K and 886 torr is dissolved in water. What is the pH of the resulting solution if the total volume is 653 mL?

43. How many grams of Ba(OH)<sub>2</sub> would have to be dissolved in water to prepare 500.0 mL of a pH = 9.80 solution?

44. To what volume should 2.6 mL of 0.11 M NaOH be diluted in order to make a pH = 12.00 solution?

### WEAK ACIDS

45. What is the 5% rule?

46. Use the 5% rule to determine if the equilibrium concentration of the acid can be approximated by its makeup concentration.

a) 2.0 M HF      b)  $2.0 \times 10^{-4}$  M H<sub>2</sub>S      c) 0.10 M HNO<sub>2</sub>

47. Use the 5% rule to determine if the equilibrium concentration of the acid can be approximated by its makeup concentration.

a) 0.80 M cyanic acid (HCNO, pK<sub>a</sub> = 3.46)

b)  $4.4 \times 10^{-3}$  M hydrazoic acid (HN<sub>3</sub>, pK<sub>a</sub> = 4.6)

c) 3.0 M arsenic acid (H<sub>3</sub>AsO<sub>4</sub>, pK<sub>a</sub> = 2.26)

48. Calculate the pH of a 0.25 M phenol (C<sub>6</sub>H<sub>5</sub>OH, K<sub>a</sub> =  $1.0 \times 10^{-10}$ ), which is often used as an antiseptic.

49. What is the pH of vinegar, a 4.5% solution of acetic acid? Assume the density of the solution is 1.0 g·mL<sup>-1</sup>.

50. The pH of a 0.030 M benzoic acid solution is 2.85. What are K<sub>a</sub> and pK<sub>a</sub> of benzoic acid? What are K<sub>b</sub> and pK<sub>b</sub> of the benzoate ion?

51. What is the hypochlorite ion concentration in a 0.14 M solution of HOCl? What is the pH of the solution?

52. What is the fluoride ion concentration in 2.0 M HF?

53. What is the pH of 0.044 M HF?

54. What is the phosphate ion concentration in 0.066 M H<sub>3</sub>PO<sub>4</sub>?

55. What is the K<sub>a</sub> of chloroacetic acid, ClCH<sub>2</sub>COOH, if a 0.085-M solution has a pH of 2.00?

56. What is the K<sub>a</sub> of an acid if a 0.21-M solution is 3.4% dissociated?

57. What is the pK<sub>a</sub> of iodic acid if the iodate ion concentration in a 0.066-M solution of HIO<sub>3</sub> is 0.050 M?

58. What is the percent dissociation of 0.048 M propanoic acid (pK<sub>a</sub> = 4.86)?

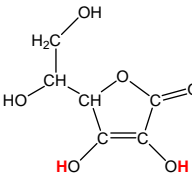
59. What is the percent dissociation of 0.26 M uric acid (pK<sub>a</sub> = 3.89)?

60. What is the percent dissociation of 0.15 M iodic acid (pK<sub>a</sub> = 0.77)?

61. What mass of ammonium chloride is required to prepare 500. mL of a solution with a pH of 4.62?

62. What mass of potassium hydrogensulfate is required to make 350. mL of a solution with a pH of 2.50?

## POLYPROTIC ACIDS

63. Vitamin C is ascorbic acid,  $\text{H}_2\text{C}_6\text{H}_6\text{O}_6$ , . Calculate the pH,  $[\text{C}_6\text{H}_8\text{O}_6]$ ,  $[\text{C}_6\text{H}_7\text{O}_6^{1-}]$  and  $[\text{C}_6\text{H}_5\text{O}_6^{2-}]$  in a 0.075-M solution of ascorbic acid.

64. Oxalic acid ( $\text{H}_2\text{C}_2\text{O}_4$ ) is a diprotic acid with two carboxylic acid group that occurs naturally in some plants. Calculate the pH and the concentrations of all species present in a 0.25-M solution.
65. What are concentrations of all species in a 0.16-M solution of malonic acid ( $\text{H}_2\text{C}_3\text{H}_2\text{O}_4$ )?  $K_1 = 1.5 \times 10^{-3}$  and  $K_2 = 2.0 \times 10^{-6}$

## WEAK BASES &amp; BASIC SALTS

66. Calculate the pH of a 0.50-M solution of pyridine ( $\text{C}_5\text{H}_5\text{N}$ ,  $K_b = 1.7 \times 10^{-9}$ ).
67. Industrial bleach is 15%  $\text{NaClO}$  by mass. What is the hypochlorous acid concentration in industrial bleach? Household bleach is a 5.25% solution of  $\text{NaOCl}$ . What is its pH? Assume a density of  $1.0 \text{ g} \cdot \text{mL}^{-1}$  for each solution.
68. What are the  $\text{HF}$  concentration and pH of 0.32 M  $\text{KF}$ ?
69. What are the  $\text{NH}_4^{1+}$  concentration and pH of a 0.16-M solution of  $\text{NH}_3$ ?
70. The pH of a 0.068-M solution of methyl amine ( $\text{CH}_3\text{NH}_2$ ) is 11.72. What are the  $K_b$  and  $\text{p}K_b$  of methylamine? What are the  $K_a$  and  $\text{p}K_a$  of the methylammonium ion?
71. The pH of 0.083 M aniline ( $\text{C}_6\text{H}_5\text{NH}_2$ ) is 8.76. What are its  $K_b$  and  $\text{p}K_b$ ?
72. How many grams of  $\text{KCN}$  are required to prepare 250. mL of a  $\text{pH} = 11.15$  solution?
73. What percent of the ammonia molecules in a 0.12-M solution have reacted to produce ammonium ions?
74. What percent of the acetate ions in a 0.060-M solution of potassium acetate react to produce acetic acid molecules?
75. What are the concentrations of all phosphorus containing species in 0.084 M  $\text{K}_3\text{PO}_4$ ? What is the pH of the solution?
76. What are the concentrations of all carbon-containing species in 0.041 M  $\text{K}_2\text{CO}_3$ ?

## SALTS

77. Define the term *salt*. Give an example of a neutral, a basic, and an acidic salt.
78. Explain why all anions are not bases in water. Give examples of two anions that are not bases for different reasons.
79. Indicate whether each salt is acidic, basic, or neutral.
- |                            |                            |                            |
|----------------------------|----------------------------|----------------------------|
| a) $\text{K}_2\text{SO}_4$ | b) $\text{K}_2\text{SO}_3$ | c) $\text{KHSO}_4$         |
| d) $\text{K}_2\text{CO}_3$ | e) $\text{KClO}$           | d) $\text{NH}_4\text{ClO}$ |
80. Indicate whether each salt is acidic, basic, or neutral.
- |                          |                                 |                                 |
|--------------------------|---------------------------------|---------------------------------|
| a) $\text{NH}_4\text{F}$ | b) $\text{NH}_4\text{HSO}_4$    | c) $(\text{NH}_4)_3\text{PO}_4$ |
| d) $\text{KNO}_3$        | e) $(\text{NH}_4)_2\text{CO}_3$ | f) $\text{NaF}$                 |
81. What is the pH of each of the following salt solutions?
- |                                  |                         |                           |
|----------------------------------|-------------------------|---------------------------|
| a) 0.12 M $\text{NH}_4\text{Cl}$ | b) 0.096 M $\text{KCN}$ | c) 0.10 M $\text{KHSO}_3$ |
|----------------------------------|-------------------------|---------------------------|
82. What is the pH of each of the following salt solutions?
- |                        |                                     |                                     |
|------------------------|-------------------------------------|-------------------------------------|
| a) 0.12 M $\text{KCl}$ | b) 0.086 M $\text{KH}_2\text{PO}_4$ | c) 0.088 M $\text{Na}_2\text{SO}_3$ |
|------------------------|-------------------------------------|-------------------------------------|