Chapter 17
THE CHEMISTRY OF ACIDS AND BASES

17-1. Under the Brønsted concept of acids and bases, a base is:
(a) a proton donor (b) a proton acceptor
(c) a hydroxide donor (d) an electron pair donor

17-2. Under the Brønsted concept of acids and bases, an acid is:
(a) a proton donor (b) a proton acceptor
(c) an electron pair donor (d) an electron pair acceptor

17-3. Under the Lewis concept of acids and bases, a base is:
(a) a proton donor (b) a proton acceptor
(c) an electron pair acceptor (d) an electron pair donor

17-4. Under the Lewis concept of acids and bases, an acid is:
(a) a proton donor (b) a proton acceptor
(c) an electron pair donor (d) an electron pair acceptor

17-5. Which of the following is NOT an acid-base conjugate pair?
(a) HCN and CN^- (b) H_2O and OH^-
(c) H_2S and OH^- (d) NH_4^+ and NH_3

17-6. Which of the following is NOT an acid-base conjugate pair?
(a) HClO and Cl^- (b) HNO_2 and NO_2^-
(c) HF and F^- (d) H_2CO_3 and HCO_3^-

17-7. Knowing that HF is a stronger acid than H_3CCOOH, determine, if possible, in which direction the following equilibrium lies.

$$HF(aq) + H_3CCOO^-(aq) \rightleftharpoons F^-(aq) + H_3CCOOH(aq)$$

(a) equilibrium lies to the left
(b) equilibrium lies to the right
(c) equilibrium is perfectly balanced left and right
(d) cannot be determined

17-8. Knowing that H_2S is a stronger acid than HCN, determine, if possible, in which direction the following equilibrium lies.

$$HCN(aq) + HS^-(aq) \rightleftharpoons CN^-(aq) + H_2S(aq)$$

(a) equilibrium lies to the left
(b) equilibrium lies to the right
(c) equilibrium is perfectly balanced left and right
(d) cannot be determined

17-9. The HSO_4^- ion is a stronger acid than HNO_2. Determine, if possible, in which direction the following equilibrium lies.

$HSO_4^-(aq) + NO_2^-(aq) \rightleftharpoons SO_4^{2-}(aq) + HNO_2(aq)$

(a) equilibrium lies to the left
(b) equilibrium lies to the right
(c) equilibrium is perfectly balanced left and right
(d) cannot be determined

17-10. Knowing that H_2S is a stronger acid than HS^-, determine, if possible, in which direction the following equilibrium lies.

$2\ HS^-(aq) \rightleftharpoons S^{2-}(aq) + H_2S(aq)$

(a) equilibrium lies to the left
(b) equilibrium lies to the right
(c) equilibrium is perfectly balanced left and right

17-11. At 50 ^oC the water ionization constant, K_w, is 5.48×10^{-14}. What is $[H_3O^+]$ in neutral water at 50 ^oC?

(a) 1.00×10^{-7} M (b) 2.34×10^{-7} M
(c) 5.48×10^{-7} M (d) 2.74×10^{-7} M

17-12. At 10 ^oC the water ionization constant, K_w, is 2.9×10^{-15}. What is $[H_3O^+]$ in neutral water at 10 ^oC?

(a) 4.44×10^{-6} M (b) 1.00×10^{-7} M
(c) 1.70×10^{-7} M (d) 5.39×10^{-8} M

17-13. We have a 0.00100 M solution of NaOH at 25 ^oC. What is $[H_3O^+]$ in this solution?

(a) 1.00×10^{-3} M (b) 1.00×10^{-11} M
(c) 1.00×10^{-7} M (d) 7.00 M

17-14. We add 0.535 g of NaOH to 100.0 mL of water at 25 ^oC. What is $[H_3O^+]$ in this solution?

(a) 0.134 M (b) 1.34×10^{13} M
(c) 7.48×10^{-14} M (d) 6.87×10^{-12} M

17-15. We dilute 1.00 mL of 1.00 M HCl solution to 100.0 mL. What is $[OH^-]$ in this solution at 25 ^oC?

(a) 1.00×10^{12} M (b) 0.010 M
(c) 7.00×10^{-4} M (d) 1.00×10^{-12} M

17-16. We have a 5.43×10^{-4} M solution of HNO_3 at 25 ^oC. What is $[OH^-]$ in this solution?

(a) 1.84×10^{-11} M (b) 5.43×10^{-10} M
(c) 5.43×10^{-4} M (d) 3.67×10^{-8} M

17-17. We have 500. mL of a solution that contains 0.0854 g of NaOH. What is the pH of this solution at 25 ^oC?

(a) 2.36 (b) 11.63
(c) 2.67 (d) 11.33

17-18. We have 300. mL of a solution that contains 0.0128 g of KOH. What is the pH of this solution at 25 ^{o}C?

(a) 3.64 (b) 3.12
(c) 10.88 (d) 10.36

17-19. We have a 4.63 x 10^{-4} M solution of HCl. What is the pH of this solution at 25 ^{o}C?

(a) 3.33 (b) 10.67
(c) 4.00 (d) 4.63

17-20. We have a 0.45 M solution of HNO_3. What is the pH of this solution at 25 ^{o}C?

(a) -0.35 (b) 3.47
(c) 10.53 (d) 0.35

17-21. We have a 5.82 x 10^{-10} M solution of HCl. What is the pH of this solution at 25 ^{o}C?

(a) 4.76 (b) 9.23
(c) 7.00 (d) 2.45

17-22. Concentrated HCl is 12 M. What is the pH of concentrated HCl at 25 ^{o}C?

(a) 1.08 (b) -1.08
(c) 12.00 (d) 1.55

BEGIN MATERIAL ON WEAK ACIDS AND BASES

17-23. What is [H_3O^+] in a 0.10 M solution of HCN at 25 ^{o}C? (K_a for HCN = 4.0 x 10^{-10})

(a) 1.58 x 10^{-9} M (b) 2.00 x 10^{-5} M
(c) 6.32 x 10^{-6} M (d) 4.00 x 10^{-11} M

17-24. What is [H_3O^+] in a 0.034 M solution of HF at 25 ^{o}C? (K_a for HF = 7.2 x 10^{-4})

(a) 4.60 x 10^{-3} M (b) 4.95 x 10^{-3} M
(c) 0.034 M (d) 0.027 M

17-25. What is the pH of a 0.350 M solution of CH_3COOH at 25 ^{o}C? (K_a for CH_3COOH = 1.8 x 10^{-5})

(a) 7.00 (b) 11.4
(c) 0.0025 (d) 2.60

17-26. What is the pH of a 0.155 M solution of H_2S at 25 ^{o}C? (K_a for H_2S =1.00 x 10^{-7})

(a) 13.39 (b) 3.90
(c) 3.50 (d) 2.88

17-27. What is the pH of a 0.00335 M solution of HNO_2 at 25 ^{o}C? (K_a for HNO_2 = 4.5 x 10^{-4})

(a) 2.91 (b) 4.50
(c) 2.22 (d) 2.99

17-28. What is [OH^-] in a 0.10 M solution of NaCN at 25 ^{o}C? (K_b for CN^- = 2.5 x 10^{-5})

(a) 5.00 x 10^{-3} M (b) 6.37 x 10^{-12} M
(c) 1.57 x 10^{-3} M (d) 4.67 x 10^{-5} M

17-29. What is $[OH^-]$ in a 0.050 M solution of NH_3 at 25 ^oC? (K_b NH_3 = 1.8 x 10^{-5})

(a) 4.24 x 10^{-3} M (b) 6.86 x 10^{-12} M
(c) 9.40 x 10^{-4} M (d) 0.22 M

17-30. What is the pH of a 0.52 M solution of $NaCH_3COO$ at 25 ^oC? (K_b for CH_3COO^- = 5.6 x 10^{-10})

(a) 9.23 (b) 4.77
(c) 9.37 (d) 10.21

17-31. What is the pH of a 0.144 M solution of NaF at 25 ^oC? (K_b for F^- = 1.4 x 10^{-11})

(a) 8.15 (b) 5.84
(c) 9.12 (d) 7.00

17-32. What is the pOH of a 0.338 M solution of NaClO at 25 ^oC? (K_b for ClO^- = 2.9 x 10^{-7})

(a) 3.27 (b) 3.50
(c) 10.73 (d) 10.50

17-33. We add 12.0 g of NaCN to 500. mL of water at 25 ^oC. What is the pH of the solution? (K_b for CN^- = 2.5 x 10^{-5})

(a) 2.46 (b) 5.83
(c) 11.5 (d) 12.8

17-34. A 0.20 M solution of an acid, HA, has a pH of 3.82 at 25 ^oC. What is K_a for this acid?

(a) 7.56 x 10^{-4} (b) 2.29 x 10^{-8}
(c) 4.46 x 10^{-5} (d) 1.15 x 10^{-7}

17-35. A 0.040 M solution of an acid, HA, has a pH of 3.02 at 25 ^oC. What is K_a for this acid?

(a) 2.28 x 10^{-5} (b) 2.39 x 10^{-2}
(c) 5.68 x 10^{-4} (d) 2.34 x 10^{-5}

17-36. A 0.020 M solution of an acid, HA, has a pH of 2.70 at 25 ^oC. What is K_a for this acid?

(a) 2.21 x 10^{-4} (b) 4.55 x 10^{-8}
(c) 1.99 x 10^{-4} (d) 2.00 x 10^{-3}

17-37. A 0.045 M solution of a base, B, has a pH of 9.20 at 25 ^oC. What is K_b for this base?

(a) 8.85 x 10^{-18} (b) 5.58 x 10^{-9}
(c) 1.40 x 10^{-8} (d) 3.56 x 10^{-5}

17-38. We make a 0.10 M solution of the diprotic acid, H_2CO_3, at 25 ^oC. What is $[CO_3^{2-}]$ in the solution? (K_{a1} = 4.2 x 10^{-7} and K_{a2} = 4.8 x 10^{-11})

(a) 4.2 x 10^{-7} M (b) 2.0 x 10^{-4} M
(c) 4.8 x 10^{-11} M (d) 2.2 x 10^{-6} M

17-39. We make a 0.20 M solution of the diprotic acid, H_2S, at 25 ^oC. What is $[S^{2-}]$ in the solution? (K_{a1} = 1.0 x 10^{-7} and K_{a2} = 1.3 x 10^{-13})

(a) 1.3 x 10^{-13} M (b) 1.6 x 10^{-7} M
(c) 1.0 x 10^{-7} M (d) 1.4 x 10^{-4} M

17-40. Water cannot function as which one of the following?

(a) a Brønsted acid (b) a Brønsted base
(c) a Lewis acid (d) a Lewis base

QUESTIONS ON FORMATION CONSTANTS

17-41. We place 0.00010 moles of $NiCl_2$, $CdCl_2$, $ZnCl_2$, and $CuCl_2$ in 1.00 L of a 0.10 M NH_3 solution. Which of these metal ions is lowest in concentration in the solution?

K_f for $[Ni(NH_3)_4]^{2+}$ = 5.6 x 10^8 K_f for $[Cd(NH_3)_4]^{2+}$ = 1.0 x 10^7
K_f for $[Cu(NH_3)_4]^{2+}$ = 6.8 x 10^{12} K_f for $[Zn(NH_3)_4]^{2+}$ = 2.9 x 10^9

(a) Ni^{2+} (b) Cd^{2+}
(c) Cu^{2+} (d) Zn^{2+}

17-42. Calculate $[Cd^{2+}]$ in a solution that was originally 0.01 M Cd^{2+} and 2.0 M NH_3. (K_f for $[Cd(NH_3)_4]^{2+}$ = 1.0 x 10^7)

(a) 0.01 M (b) 4.6 x 10^{-6} M
(c) 8.2 x 10^{-8} M (d) 6.8 x 10^{-11} M

17-43. Calculate $[Ni^{2+}]$ in a solution that was originally 0.10 M Ni^{2+} and 2.0 M NH_3. (K_f for $[Ni(NH_3)_4]^{2+}$ = 5.6 x 10^8)

(a) 2.7 x 10^{-10} M (b) 0.10 M
(c) 1.60 M (d) 8.7 x 10^{-6} M

17-44. Calculate $[Cu^{2+}]$ in a solution that was originally 0.10 M Cu^{2+} and 1.0 M NH_3. (K_f for $[Cu(NH_3)_4]^{2+}$ = 6.8 x 10^{12})

(a) 6.8 x 10^{-12} M (b) 1.1 x 10^{-12} M
(c) 0.60 M (d) 3.2 x 10^3 M

17-45. We make up 0.10 M solutions of $[Cd(CN)_4]^{2-}$, $[Ni(CN)_4]^{4-}$, $[Ag(CN)_2]^-$, and $[Fe(CN)_6]^{2-}$. Which of the following metal ions is highest in concentration?

K_f for $[Cd(CN)_4]^{2-}$ = 1.3 x 10^{17} K_f for $[Ni(CN)_4]^{2-}$ = 1.0 x 10^{31}
K_f for $[Ag(CN)_2]^-$ = 5.6 x 10^{18} K_f for $[Fe(CN)_6]^{2-}$ = 7.7 x 10^{36}

(a) Cd^{2+} (b) Ni^{2+}
(c) Ag^+ (d) Fe^{2+}

17-46. We make up 0.10 M solutions of $[Cd(CN)_4]^{2-}$, $[Ni(CN)_4]^{2-}$, $[Ag(CN)_2]^-$, and $[Fe(CN)_6]^{2-}$. Which of the following metal ions is lowest in concentration?

K_f for $[Cd(CN)_4]^{2-} = 1.3 \times 10^{17}$ K_f for $[Ni(CN)_4]^{2-} = 1.0 \times 10^{31}$

K_f for $[Ag(CN)_2]^- = 5.6 \times 10^{18}$ K_f for $[Fe(CN)_6]^{2-} = 7.7 \times 10^{36}$

(a) Cd^{2+} (b) Ni^{2+}

(c) Ag^+ (d) Fe^{2+}

17-47. Given the following reaction

$HCN(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + CN^-(aq)$

The Brønsted acid on the left is

(a) HCN (b) NH_3

and its conjugate base is

(a) NH_4^+ (b) CN^-

The ammonium ion would be classified as a Brønsted

(a) acid (b) base

17-48. You are given 0.1 M aqueous solutions of the compounds below. In each case, tell whether the solution will have a pH of 7, a pH less than 7, or a pH greater than 7.

	Substance	**pH of Solution (=7, <7, or >7)**
(i)	H_3PO_4	_____
(ii)	K_2CO_3	_____
(iii)	$NaHSO_4$	_____
(iv)	$Al(NO_3)_3$	_____
(v)	KNO_3	_____
(vi)	$Mg(C_2H_3O_2)_2$	_____

17-49. The molecule HOCl is both a weak Brønsted acid and an oxidizing agent. As an acid it gives the base OCl^- on ionization.

$HOCl(aq) + H_2O(\ell) \rightleftharpoons OCl^-(aq) + H_3O^+(aq)$

(i) If the pH of a 0.015 M solution of the acid is 4.64, what is the concentration of the hypochlorite ion, OCl^-, in solution?

(a) 4.37×10^{-4} (b) 2.29×10^{-5}

(c) 4.37×10^{4} (d) 4.38×10^{-10}

(ii) What is the value of K_a for the acid?

(a) 2.30×10^{-5} (b) 5.25×10^{-10} (c) 1.53×10^{-3} (d) 3.50×10^{-8}

17-50. Pyridine, an organic molecule, is a very common weak base.

$C_5H_5N(aq) + H_2O(\ell) \rightleftharpoons C_5H_5NH^+(aq) + OH^-(aq)$

Assume you have a 0.0213 M aqueous solution of pyridine, C_5H_5N. The K_b value for the compound is 1.5×10^{-9}.

(i) What is the concentration of OH^- in the solution?

(a) 2.13×10^{-2} M (b) 5.65×10^{-6} M

(c) 1.77×10^{-9} M (d) 3.20×10^{-11} M

(ii) What is the pH of the solution?

(a) 12.33 (b) 8.75

(c) 5.25 (d) 10.50

17-51. The molecule phenol is a weak Brønsted acid often used in disinfectants. As an acid it gives the base $C_6H_5O^-$ on ionization.

$C_6H_5OH(aq) + H_2O(\ell) \rightleftharpoons C_6H_5O^-(aq) + H_3O^+(aq)$

(i) If the pH of a 0.015 M solution of the acid is 5.86, what is the concentration of the hydronium ion, H_3O^+, in solution?

(a) 1.50×10^{-1} (b) 7.24×10^{-9}

(c) 1.38×10^{-6} (d) 5.86×10^{-6}

(ii) What is the value of K_a for the acid?

(a) 1.50 (b) 1.3×10^{-10}

(c) 2.29×10^{-9} (d) 9.20×10^{-5}

17-52. For each solution below, tell if the pH is less than 7, equal to 7, or greater than 7.

	SOLUTION	**pH**
(i)	0.10 M HNO_3	_____
(ii)	0.012 M KOH	_____
(iii)	0.15 M acetic acid	_____
(iv)	0.56 M Na_2CO_3	_____
(v)	0.45 M KBr	_____
(vi)	0.15 M $(NH_4)_2S$	_____

17-53. What are the pH and the ion concentrations in a solution of 0.0015 M NaOH?

	pH	**$[OH^-]$**	**$[H_3O^+]$**
(a)	11.18	6.7×10^{-3}	1.5×10^{-12}
(b)	2.82	1.5×10^{-3}	6.7×10^{-12}
(c)	11.18	1.5×10^{-3}	6.7×10^{-12}
(d)	1.50	3.16×10^{-13}	3.16×10^{-2}

17-54. What are the pH and ion concentrations in a solution of 0.10 M sodium formate, $NaCHO_2$? K_b for the formate ion, HCO_2^- is 5.6×10^{-11}.

	pH	**$[Na^+]$**	**$[CHO_2^-]$**	**$[OH^-]$**
(a)	5.63	0.10	0.10	2.4×10^{-6}
(b)	8.37	0.10	0.10	2.4×10^{-6}
(c)	8.22	0.050	0.050	1.7×10^{-6}
(d)	5.63	0.10	0.10	4.2×10^{-9}

17-55. If you have a 0.15 M solution of Na_2CO_3, what are the concentrations of H_3O^+ and OH^- and what is the pH of the solution? K_b for CO_3^{2-} is 2.1×10^{-4}.

	$[H_3O^+]$	**$[OH^-]$**	**pH**
(a)	5.61×10^{-3}	1.78×10^{-12}	5.61
(b)	1.78×10^{-12}	5.61×10^{-3}	11.75
(c)	5.61×10^{-3}	1.78×10^{-12}	11.75
(d)	1.78×10^{-12}	5.61×10^{-3}	5.61

17-56. The pH of a solution made by dissolving 0.588 g of the weak organic acid phenol, C_6H_5OH, in 500. mL of water is 5.90. What is the value of K_a for the acid?

$$C_6H_5OH(aq) + H_2O(\ell) \rightleftharpoons C_6H_5O^-(aq) + H_3O^+(aq)$$

(a) 5.0×10^{-15} (b) 2.5×10^{-10}
(c) 1.0×10^{-4} (d) 1.3×10^{-10}

ANSWERS — CHAPTER 17

1.	b	11.	b	21.	c
2.	a	12.	d	22.	b
3.	d	13.	b	23.	c
4.	d	14.	c	24.	a
5.	c	15.	d	25.	d
6.	a	16.	a	26.	b
7.	b	17.	b	27.	d
8.	a	18.	c	28.	c
9.	b	19.	a	29.	c
10.	a	20.	d	30.	a
31.	a	41.	c	51.	c, b
32.	b	42.	d	52.	<7, >7, <7, >7, =7, >7
33.	c	43.	a	53.	c
34.	d	44.	b	54.	b
35.	d	45.	a	55.	b
36.	a	46.	b	56.	d
37.	b	47.	a, b, a		
38.	c	48.	<7, >7, <7, <7, =7, >7		
39.	a	49.	b, d		
40.	c	50.	b, b		