

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 ₂ O and OH ⁻ |
| (c) H ₂ S 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 ₂ CO ₃ and HCO ₃ ⁻ |
- 17-7. Knowing that HF is a stronger acid than H₃CCOOH, determine, if possible, in which direction the following equilibrium lies.
- $$\text{HF(aq)} + \text{H}_3\text{CCOO}^-\text{(aq)} \rightleftharpoons \text{F}^-\text{(aq)} + \text{H}_3\text{CCOOH(aq)}$$
- | |
|--|
| (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 H₂S is a stronger acid than HCN, determine, if possible, in which direction the following equilibrium lies.
- $$\text{HCN(aq)} + \text{HS}^-\text{(aq)} \rightleftharpoons \text{CN}^-\text{(aq)} + \text{H}_2\text{S(aq)}$$
- | |
|--|
| (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.
- $$\text{HSO}_4^-(\text{aq}) + \text{NO}_2^-(\text{aq}) \rightleftharpoons \text{SO}_4^{2-}(\text{aq}) + \text{HNO}_2(\text{aq})$$
- (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.
- $$2 \text{HS}^-(\text{aq}) \rightleftharpoons \text{S}^{2-}(\text{aq}) + \text{H}_2\text{S}(\text{aq})$$
- (a) equilibrium lies to the left
(b) equilibrium lies to the right
(c) equilibrium is perfectly balanced left and right
- 17-11. At 50 °C the water ionization constant, K_w , is 5.48×10^{-14} . What is $[\text{H}_3\text{O}^+]$ in neutral water at 50 °C?
- (a) $1.00 \times 10^{-7} \text{ M}$ (b) $2.34 \times 10^{-7} \text{ M}$
(c) $5.48 \times 10^{-7} \text{ M}$ (d) $2.74 \times 10^{-7} \text{ M}$
- 17-12. At 10 °C the water ionization constant, K_w , is 2.9×10^{-15} . What is $[\text{H}_3\text{O}^+]$ in neutral water at 10 °C?
- (a) $4.44 \times 10^{-6} \text{ M}$ (b) $1.00 \times 10^{-7} \text{ M}$
(c) $1.70 \times 10^{-7} \text{ M}$ (d) $5.39 \times 10^{-8} \text{ M}$
- 17-13. We have a 0.00100 M solution of NaOH at 25 °C. What is $[\text{H}_3\text{O}^+]$ in this solution?
- (a) $1.00 \times 10^{-3} \text{ M}$ (b) $1.00 \times 10^{-11} \text{ M}$
(c) $1.00 \times 10^{-7} \text{ M}$ (d) 7.00 M
- 17-14. We add 0.535 g of NaOH to 100.0 mL of water at 25 °C. What is $[\text{H}_3\text{O}^+]$ in this solution?
- (a) 0.134 M (b) $1.34 \times 10^{13} \text{ M}$
(c) $7.48 \times 10^{-14} \text{ M}$ (d) $6.87 \times 10^{-12} \text{ M}$
- 17-15. We dilute 1.00 mL of 1.00 M HCl solution to 100.0 mL. What is $[\text{OH}^-]$ in this solution at 25 °C?
- (a) $1.00 \times 10^{12} \text{ M}$ (b) 0.010 M
(c) $7.00 \times 10^{-4} \text{ M}$ (d) $1.00 \times 10^{-12} \text{ M}$
- 17-16. We have a $5.43 \times 10^{-4} \text{ M}$ solution of HNO_3 at 25 °C. What is $[\text{OH}^-]$ in this solution?
- (a) $1.84 \times 10^{-11} \text{ M}$ (b) $5.43 \times 10^{-10} \text{ M}$
(c) $5.43 \times 10^{-4} \text{ M}$ (d) $3.67 \times 10^{-8} \text{ M}$
- 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 °C?
- (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 °C?
- (a) 3.64 (b) 3.12
(c) 10.88 (d) 10.36
- 17-19. We have a 4.63×10^{-4} M solution of HCl. What is the pH of this solution at 25 °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 °C?
- (a) -0.35 (b) 3.47
(c) 10.53 (d) 0.35
- 17-21. We have a 5.82×10^{-10} M solution of HCl. What is the pH of this solution at 25 °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 °C?
- (a) 1.08 (b) -1.08
(c) 12.00 (d) 1.55
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BEGIN MATERIAL ON WEAK ACIDS AND BASES

- 17-23. What is $[\text{H}_3\text{O}^+]$ in a 0.10 M solution of HCN at 25 °C? (K_a for HCN = 4.0×10^{-10})
- (a) 1.58×10^{-9} M (b) 2.00×10^{-5} M
(c) 6.32×10^{-6} M (d) 4.00×10^{-11} M
- 17-24. What is $[\text{H}_3\text{O}^+]$ in a 0.034 M solution of HF at 25 °C? (K_a for HF = 7.2×10^{-4})
- (a) 4.60×10^{-3} M (b) 4.95×10^{-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 °C? (K_a for CH_3COOH = 1.8×10^{-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 °C? (K_a for H_2S = 1.00×10^{-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 °C? (K_a for HNO_2 = 4.5×10^{-4})
- (a) 2.91 (b) 4.50
(c) 2.22 (d) 2.99
- 17-28. What is $[\text{OH}^-]$ in a 0.10 M solution of NaCN at 25 °C? (K_b for CN^- = 2.5×10^{-5})
- (a) 5.00×10^{-3} M (b) 6.37×10^{-12} M
(c) 1.57×10^{-3} M (d) 4.67×10^{-5} M

- 17-29. What is $[\text{OH}^-]$ in a 0.050 M solution of NH_3 at 25 °C? ($K_b \text{ NH}_3 = 1.8 \times 10^{-5}$)
- (a) 4.24×10^{-3} M (b) 6.86×10^{-12} M
(c) 9.40×10^{-4} M (d) 0.22 M
- 17-30. What is the pH of a 0.52 M solution of NaCH_3COO at 25 °C? (K_b for $\text{CH}_3\text{COO}^- = 5.6 \times 10^{-10}$)
- (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 °C? (K_b for $\text{F}^- = 1.4 \times 10^{-11}$)
- (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 °C? (K_b for $\text{ClO}^- = 2.9 \times 10^{-7}$)
- (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 °C. What is the pH of the solution? (K_b for $\text{CN}^- = 2.5 \times 10^{-5}$)
- (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 °C. What is K_a for this acid?
- (a) 7.56×10^{-4} (b) 2.29×10^{-8}
(c) 4.46×10^{-5} (d) 1.15×10^{-7}
- 17-35. A 0.040 M solution of an acid, HA , has a pH of 3.02 at 25 °C. What is K_a for this acid?
- (a) 2.28×10^{-5} (b) 2.39×10^{-2}
(c) 5.68×10^{-4} (d) 2.34×10^{-5}
- 17-36. A 0.020 M solution of an acid, HA , has a pH of 2.70 at 25 °C. What is K_a for this acid?
- (a) 2.21×10^{-4} (b) 4.55×10^{-8}
(c) 1.99×10^{-4} (d) 2.00×10^{-3}
- 17-37. A 0.045 M solution of a base, B , has a pH of 9.20 at 25 °C. What is K_b for this base?
- (a) 8.85×10^{-18} (b) 5.58×10^{-9}
(c) 1.40×10^{-8} (d) 3.56×10^{-5}
- 17-38. We make a 0.10 M solution of the diprotic acid, H_2CO_3 , at 25 °C. What is $[\text{CO}_3^{2-}]$ in the solution? ($K_{a1} = 4.2 \times 10^{-7}$ and $K_{a2} = 4.8 \times 10^{-11}$)
- (a) 4.2×10^{-7} M (b) 2.0×10^{-4} M
(c) 4.8×10^{-11} M (d) 2.2×10^{-6} M

- 17-39. We make a 0.20 M solution of the diprotic acid, H_2S , at 25 °C. What is $[\text{S}^{2-}]$ in the solution? ($K_{a1} = 1.0 \times 10^{-7}$ and $K_{a2} = 1.3 \times 10^{-13}$)
- (a) 1.3×10^{-13} M (b) 1.6×10^{-7} M
 (c) 1.0×10^{-7} M (d) 1.4×10^{-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 $[\text{Ni}(\text{NH}_3)_4]^{2+} = 5.6 \times 10^8$ K_f for $[\text{Cd}(\text{NH}_3)_4]^{2+} = 1.0 \times 10^7$
 K_f for $[\text{Cu}(\text{NH}_3)_4]^{2+} = 6.8 \times 10^{12}$ K_f for $[\text{Zn}(\text{NH}_3)_4]^{2+} = 2.9 \times 10^9$
- (a) Ni^{2+} (b) Cd^{2+}
 (c) Cu^{2+} (d) Zn^{2+}
- 17-42. Calculate $[\text{Cd}^{2+}]$ in a solution that was originally 0.01 M Cd^{2+} and 2.0 M NH_3 . (K_f for $[\text{Cd}(\text{NH}_3)_4]^{2+} = 1.0 \times 10^7$)
- (a) 0.01 M (b) 4.6×10^{-6} M
 (c) 8.2×10^{-8} M (d) 6.8×10^{-11} M
- 17-43. Calculate $[\text{Ni}^{2+}]$ in a solution that was originally 0.10 M Ni^{2+} and 2.0 M NH_3 . (K_f for $[\text{Ni}(\text{NH}_3)_4]^{2+} = 5.6 \times 10^8$)
- (a) 2.7×10^{-10} M (b) 0.10 M
 (c) 1.60 M (d) 8.7×10^{-6} M
- 17-44. Calculate $[\text{Cu}^{2+}]$ in a solution that was originally 0.10 M Cu^{2+} and 1.0 M NH_3 . (K_f for $[\text{Cu}(\text{NH}_3)_4]^{2+} = 6.8 \times 10^{12}$)
- (a) 6.8×10^{-12} M (b) 1.1×10^{-12} M
 (c) 0.60 M (d) 3.2×10^3 M
- 17-45. We make up 0.10 M solutions of $[\text{Cd}(\text{CN})_4]^{2-}$, $[\text{Ni}(\text{CN})_4]^{4-}$, $[\text{Ag}(\text{CN})_2]^-$, and $[\text{Fe}(\text{CN})_6]^{2-}$. Which of the following metal ions is highest in concentration?
- K_f for $[\text{Cd}(\text{CN})_4]^{2-} = 1.3 \times 10^{17}$ K_f for $[\text{Ni}(\text{CN})_4]^{2-} = 1.0 \times 10^{31}$
 K_f for $[\text{Ag}(\text{CN})_2]^- = 5.6 \times 10^{18}$ K_f for $[\text{Fe}(\text{CN})_6]^{2-} = 7.7 \times 10^{36}$
- (a) Cd^{2+} (b) Ni^{2+}
 (c) Ag^+ (d) Fe^{2+}

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

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

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

$$K_f \text{ for } [\text{Ag}(\text{CN})_2]^- = 5.6 \times 10^{18}$$

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

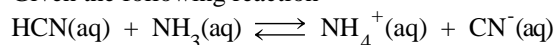
(a) Cd^{2+}

(b) Ni^{2+}

(c) Ag^+

(d) Fe^{2+}

17-47. Given the following reaction



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

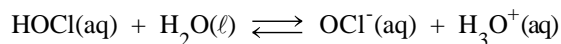
(a) acid

(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) $\text{Al}(\text{NO}_3)_3$	_____
(v) KNO_3	_____
(vi) $\text{Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$	_____

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.



(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?

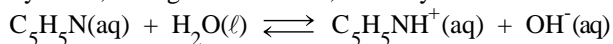
(a) 2.30×10^{-5}

(b) 5.25×10^{-10}

(c) 1.53×10^{-3}

(d) 3.50×10^{-8}

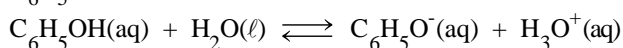
17-50. Pyridine, an organic molecule, is a very common weak base.



Assume you have a 0.0213 M aqueous solution of pyridine, $\text{C}_5\text{H}_5\text{N}$. The K_b value for the compound is 1.5×10^{-9} .

- (i) What is the concentration of OH^- in the solution?
- | | |
|-------------------------------------|--------------------------------------|
| (a) $2.13 \times 10^{-2} \text{ M}$ | (b) $5.65 \times 10^{-6} \text{ M}$ |
| (c) $1.77 \times 10^{-9} \text{ M}$ | (d) $3.20 \times 10^{-11} \text{ M}$ |
- (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 $\text{C}_6\text{H}_5\text{O}^-$ on ionization.



- (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 $(\text{NH}_4)_2\text{S}$	_____

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

	pH	$[\text{OH}^-]$	$[\text{H}_3\text{O}^+]$
(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}

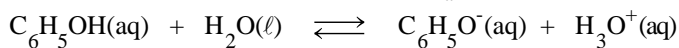
- 17-54. What are the pH and ion concentrations in a solution of 0.10 M sodium formate, NaCHO_2 ? K_b for the formate ion, HCO_2^- is 5.6×10^{-11} .

	pH	$[\text{Na}^+]$	$[\text{CHO}_2^-]$	$[\text{OH}^-]$
(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} .

	$[\text{H}_3\text{O}^+]$	$[\text{OH}^-]$	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, $\text{C}_6\text{H}_5\text{OH}$, in 500. mL of water is 5.90. What is the value of K_a for the acid?



- | | | | |
|-----|-----------------------|-----|-----------------------|
| (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 | | |