12.E: Acids and Bases

The following questions are related to the material covered in this chapter. For additional discussion on each topic, also check the links included in each heading.

12.2.1: Arrhenius Acids and Bases

1. Define *Arrhenius acid*.
2. Define *Arrhenius base*.
3. What are some general properties of Arrhenius acids?
4. What are some general properties of Arrhenius bases?
5. Identify each substance as an Arrhenius acid, an Arrhenius base, or neither.
   a. NaOH
   b. C_2H_5OH
   c. H_3PO_4
6. Identify each substance as an Arrhenius acid, an Arrhenius base, or neither.
   a. $C_6H_{12}O_6$
   b. HNO_2
   c. $Ba(OH)_2$
7. Write the balanced chemical equation for the neutralization reaction between KOH and $H_2C_2O_4$. What is the salt?
8. Write the balanced chemical equation for the neutralization reaction between $Sr(OH)_2$ and H_3PO_4. What is the salt?
9. Write the balanced chemical equation for the neutralization reaction between HCl and $Fe(OH)_3$. What is the salt?
10. Write the balanced chemical equation for the neutralization reaction between H_2SO_4 and $Cr(OH)_3$. What is the salt?
11. $CaCl_2$ would be the product of the reaction of what acid and what base?
12. $Zn(NO_3)_2$ would be product of the reaction of what acid and what base?
13. $BaSO_4$ would be product of the reaction of what acid and what base?
14. Na_3PO_4 would be product of the reaction of what acid and what base?

Answers

1. a compound that increases the H^+ concentration in water
2.
3. sour taste, react with metals, and turn litmus red
4.
5. a. Arrhenius base
   b. neither
   c. Arrhenius acid
6.
7. $2KOH + H_2C_2O_4 \rightarrow 2H_2O + K_2C_2O_4$; $K_2C_2O_4$
8.
9. $3HCl + Fe(OH)_3 \rightarrow 3H_2O + FeCl_3$; $FeCl_3$
10.
11. HCl and $Ca(OH)_2$
12.
13. H_2SO_4 and $Ba(OH)_2$

12.2.1: Brønsted-Lowry Acids and Bases

Exercise 12.E.1

1. Define *Brønsted-Lowry acid*. How does it differ from an Arrhenius acid?
2. Define *Brønsted-Lowry base*. How does it differ from an Arrhenius base?
3. Write the dissociation of hydrogen bromide in water as a Brønsted-Lowry acid-base reaction and identify the proton donor and proton acceptor.
4. Write the dissociation of nitric acid in water as a Brønsted-Lowry acid-base reaction and identify the proton donor and proton acceptor.
5. Pyridine (C_5H_5N) acts as a Brønsted-Lowry base in water. Write the hydrolysis reaction for pyridine and identify the Brønsted-Lowry acid and Brønsted-Lowry base.
6. The methoxide ion (CH_3O^-) acts as a Brønsted-Lowry base in water. Write the hydrolysis reaction for the methoxide ion and identify the Brønsted-Lowry acid and Brønsted-Lowry base.
7. Identify the Brønsted-Lowry acid and Brønsted-Lowry base in this chemical equation.

   $H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$

8. Identify the Brønsted-Lowry acid and Brønsted-Lowry base in this chemical equation.

   $H_2C_2O_4 + 2F^- \rightarrow 2HF + C_2O_4^{2-}$

9. Predict the products of this reaction, assuming it undergoes a Brønsted-Lowry acid-base reaction.

   $HC_2H_3O_2 + C_5H_5N \rightarrow ?$

10. Predict the products of this reaction, assuming it undergoes a Brønsted-Lowry acid-base reaction.

    $(C_2H_5)_3N + H_2O \rightarrow ?$

11. What is the conjugate acid of H_2O? of NH_3?
12. What is the conjugate acid of $H_2PO_4^-$? of NO_3^-?
13. What is the conjugate base of HSO_4^-? of H_2O?
14. What is the conjugate base of H_3O^+? of H_2SO_4?
15. Identify the conjugate acid-base pairs in this reaction.

    $HSO_4^- + PO_4^{3-} \rightarrow SO_4^{2-} + HPO_4^{2-}$

16. Identify the conjugate acid-base pairs in this reaction.

    $HClO_3 + (C_2H_5)_3N \rightarrow ClO_3^- + (C_2H_5)_3NH^+$

17. Identify the conjugate acid-base pairs in this reaction.

    $NH_3 + C_6H_5O^- \rightarrow C_6H_5OH + NH_2^-$

18. Identify the conjugate acid-base pairs in this reaction.

    $C_5H_5NH^+ + C_2O_4^{2-} \rightarrow C_5H_5N + HC_2O_4^-$

nswers

1. A Brønsted-Lowry acid is a proton donor. It does not necessarily increase the H^+ concentration in water.
2.
3. $HBr + H_2O \rightarrow H_3O^+ + Br^-$; PD: HBr; PA: H_2O
4.
5. $C_5H_5N + H_2O \rightarrow C_5H_5NH^+ + OH^-$; PD: H_2O; PA: C_5H_5N
6.
7. BL acid: H_3PO_4; BL base: OH^-
8.
9. $C_2H_3O_2^-$ and $C_5H_5NH^+$

10.

11. H_3O^+; NH_4^+

12.

13. SO_4^{2-}; OH^-

14.

15. HSO_4^- and SO_4^{2-}; PO_4^{3-} and HPO_4^{2-}

16.

17. NH_3 and NH_2^-; $C_6H_5O^-$ and C_6H_5OH

12.2.3: Strong and Weak Acids and Bases and their Salts

? Exercise 12.*E*. 1

1. Differentiate between a strong acid and a weak acid.
2. Differentiate between a strong base and a weak base.
3. Identify each as a strong acid or a weak acid. Assume aqueous solutions.
   a. HF
   b. HCl
   c. HC_2O_4
4. Identify each as a strong base or a weak base. Assume aqueous solutions.
   a. NaOH
   b. $Al(OH)_3$
   c. $C_4H_9NH_2$
5. Write a chemical equation for the ionization of each acid and indicate whether it proceeds 100% to products or not.
   a. HNO_3
   b. HNO_2
   c. HI_3
6. Write a chemical equation for the ionization of each base and indicate whether it proceeds 100% to products or not.
   a. NH_3
   b. $(CH_3)_3N$
   c. $Mg(OH)_2$
7. Write the balanced chemical equation for the reaction of each acid and base pair.
   a. HCl + C_5H_5N
   b. $H_2C_2O_4$ + NH_3
   c. HNO_2 + C_7H_9N
8. Write the balanced chemical equation for the reaction of each acid and base pair.
   a. $H_3C_5H_5O_7$ + $Mg(OH)_2$
   b. $HC_3H_3O_3$ + $(CH_3)_3N$
   c. HBr + $Fe(OH)_3$
9. Write the hydrolysis reaction that occurs, if any, when each salt dissolves in water.
   a. K_2SO_3
   b. KI
   c. NH_4ClO_3
10. Write the hydrolysis reaction that occurs, if any, when each salt dissolves in water.
    a. $NaNO_3$
    b. CaC_2O_4
    c. C_5H_5NHCl

11. When NH_4NO_2 dissolves in H_2O, both ions hydrolyze. Write chemical equations for both reactions. Can you tell if the solution will be acidic or basic overall?
12. When pyridinium acetate ($C_5H_5NHC_2H_3O_2$) dissolves in H_2O, both ions hydrolyze. Write chemical equations for both reactions. Can you tell if the solution will be acidic or basic overall?
13. A lab technician mixes a solution of 0.015 M $Mg(OH)_2$. Is the resulting OH^- concentration greater than, equal to, or less than 0.015 M? Explain your answer.
14. A lab technician mixes a solution of 0.55 M HNO_3. Is the resulting H^+ concentration greater than, equal to, or less than 0.55 M? Explain your answer.

Answers

1. A strong acid is 100% ionized in aqueous solution, whereas a weak acid is not 100% ionized.
2.
3. a. weak acid
   b. strong acid
   c. weak acid
4.
5. a. $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$; proceeds 100%
   b. $HNO_2(aq) \rightarrow H^+(aq) + NO_2^-(aq)$; does not proceed 100%
   c. $HI_3(aq) \rightarrow H^+(aq) + I_3^-(aq)$; does not proceed 100%
6.
7. a. $HCl + C_5H_5N \rightarrow Cl^- + C_5H_5NH^+$
   b. $H_2C_2O_4 + 2NH_3 \rightarrow C_2O_4^{2-} + 2NH_4^+$
   c. $HNO_2 + C_7H_9N \rightarrow NO_2^- + C_7H_9NH^+$
8.
9. a. $SO_3^{2-} + H_2O \rightarrow HSO_3^- + OH^-$
   b. no reaction
   c. $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$
10.
11. $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$; $NO_2^- + H_2O \rightarrow HNO_2 + OH^-$; it is not possible to determine whether the solution will be acidic or basic.
12.
13. greater than 0.015 M because there are two OH^- ions per formula unit of $Mg(OH)_2$

12.3.1: Autoionization of Water

? Exercise 12.E.4

1. Does $[H^+]$ remain constant in all aqueous solutions? Why or why not?
2. Does $[OH^-]$ remain constant in all aqueous solutions? Why or why not?
3. What is the relationship between $[H^+]$ and K_w? Write a mathematical expression that relates them.
4. What is the relationship between $[OH^-]$ and K_w? Write a mathematical expression that relates them.
5. Write the chemical equation for the autoionization of water and label the conjugate acid-base pairs.
6. Write the reverse of the reaction for the autoionization of water. It is still an acid-base reaction? If so, label the acid and base.
7. For a given aqueous solution, if $[H^+] = 1.0 \times 10^{-3}$ M, what is $[OH^-]$?
8. For a given aqueous solution, if $[H^+] = 1.0 \times 10^{-9}$ M, what is $[OH^-]$?
9. For a given aqueous solution, if $[H^+] = 7.92 \times 10^{-5}$ M, what is $[OH^-]$?
10. For a given aqueous solution, if $[H^+] = 2.07 \times 10^{-11}$ M, what is $[H^+]$?
11. For a given aqueous solution, if $[OH^-] = 1.0 \times 10^{-5}$ M, what is $[H^+]$?
12. For a given aqueous solution, if $[OH^-] = 1.0 \times 10^{-12}$ M, what is $[H^+]$?
13. For a given aqueous solution, if $[OH^-] = 3.77 \times 10^{-4}$ M, what is $[H^+]$?
14. For a given aqueous solution, if $[OH^-] = 7.11 \times 10^{-10}$ M, what is $[H^+]$?

15. What are $[H^+]$ and $[OH^-]$ in a 0.344 M solution of HNO_3?
16. What are $[H^+]$ and $[OH^-]$ in a 2.86 M solution of HBr?
17. What are $[H^+]$ and $[OH^-]$ in a 0.00338 M solution of KOH?
18. What are $[H^+]$ and $[OH^-]$ in a 6.02×10^{-4} M solution of $Ca(OH)_2$?
19. If HNO_2 is dissociated only to an extent of 0.445%, what are $[H^+]$ and $[OH^-]$ in a 0.307 M solution of HNO_2?
20. If $(C_2H_5)_2NH$ is dissociated only to an extent of 0.077%, what are $[H^+]$ and $[OH^-]$ in a 0.0955 M solution of $(C_2H_5)_2NH$?

Answers

1. $[H^+]$ varies with the amount of acid or base in a solution.
2.
3. $$[H^+] = \frac{K_W}{[OH^-]} \tag{12.E.1}$$
4.
5. $H_2O + H_2O \rightarrow H_3O^+ + OH^-$; H_2O/H_3O^+ and H_2O/OH^-
6.
7. 1.0×10^{-11} M
8.
9. 1.26×10^{-10} M
10.
11. 1.0×10^{-9} M
12.
13. 2.65×10^{-11} M
14.
15. $[H^+] = 0.344$ M; $[OH^-] = 2.91 \times 10^{-14}$ M
16.
17. $[OH^-] = 0.00338$ M; $[H^+] = 2.96 \times 10^{-12}$ M
18.
19. $[H^+] = 0.00137$ M; $[OH^-] = 7.32 \times 10^{-12}$ M

12.3.2: The pH Scale

? Exercise 12.*E*.1

1. Define *pH*. How is it related to pOH?
2. Define *pOH*. How is it related to pH?
3. What is the pH range for an acidic solution?
4. What is the pH range for a basic solution?
5. What is $[H^+]$ for a neutral solution?
6. What is $[OH^-]$ for a neutral solution? Compare your answer to Exercise 6. Does this make sense?

7. Which substances in Table 12.7.1 are acidic?
8. Which substances in Table 12.7.1 are basic?
9. What is the pH of a solution when $[H^+]$ is 3.44×10^{-4} M?
10. What is the pH of a solution when $[H^+]$ is 9.04×10^{-13} M?

11. What is the pH of a solution when $[OH^-]$ is 6.22×10^{-7} M?
12. What is the pH of a solution when $[OH^-]$ is 0.0222 M?
13. What is the pOH of a solution when $[H^+]$ is 3.44×10^{-4} M?
14. What is the pOH of a solution when $[H^+]$ is 9.04×10^{-13} M?
15. What is the pOH of a solution when $[OH^-]$ is 6.22×10^{-7} M?
16. What is the pOH of a solution when $[OH^-]$ is 0.0222 M?
17. If a solution has a pH of 0.77, what is its pOH, $[H^+]$, and $[OH^-]$?
18. If a solution has a pOH of 13.09, what is its pH, $[H^+]$, and $[OH^-]$?

Answers

1. pH is the negative logarithm of $[H^+]$ and is equal to 14 − pOH.
2.
3. pH < 7
4.
5. 1.0×10^{-7} M
6.
7. Every entry above pure water is acidic.
8.
9. 3.46
10.
11. 7.79
12.
13. 10.54
14.
15. 6.21
16.
17. pOH = 13.23; $[H^+] = 1.70 \times 10^{-1}$ M; $[OH^-] = 5.89 \times 10^{-14}$ M

12.4: Buffers

? Exercise 12.E.1

1. Define *buffer*. What two related chemical components are required to make a buffer?
2. Can a buffer be made by combining a strong acid with a strong base? Why or why not?
3. Which combinations of compounds can make a buffer? Assume aqueous solutions.
   a. HCl and NaCl
   b. HNO_2 and $NaNO_2$
   c. NH_4NO_3 and HNO_3
   d. NH_4NO_3 and NH_3
4. Which combinations of compounds can make a buffer? Assume aqueous solutions.
   a. H_3PO_4 and Na_3PO_4
   b. $NaHCO_3$ and Na_2CO_3
   c. $NaNO_3$ and $Ca(NO_3)_2$
   d. HN_3 and NH_3
5. For each combination in Exercise 3 that is a buffer, write the chemical equations for the reactions of the buffer components when a strong acid and a strong base is added.

6. For each combination in Exercise 4 that is a buffer, write the chemical equations for the reactions of the buffer components when a strong acid and a strong base is added.
7. The complete phosphate buffer system is based on four substances: H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}. What different buffer solutions can be made from these substances?
8. Explain why NaBr cannot be a component in either an acidic or a basic buffer.
9. Two solutions are made containing the same concentrations of solutes. One solution is composed of H_3PO_4 and Na_3PO_4, while the other is composed of HCN and NaCN. Which solution should have the larger capacity as a buffer?
10. Two solutions are made containing the same concentrations of solutes. One solution is composed of NH_3 and NH_4NO_3, while the other is composed of H_2SO_4 and Na_2SO_4. Which solution should have the larger capacity as a buffer?

Answers

1. A buffer is the combination of a weak acid or base and a salt of that weak acid or base.
2.
3. a. no
   b. yes
   c. no
   d. yes
4.
5. 3b: strong acid: $NO_2^- + H^+ \rightarrow HNO_2$; strong base: $HNO_2 + OH^- \rightarrow NO_2^- + H_2O$; 3d: strong base: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$; strong acid: $NH_3 + H^+ \rightarrow NH_4^+$
6.
7. Buffers can be made from three combinations: (1) H_3PO_4 and $H_2PO_4^-$, (2) $H_2PO_4^-$ and HPO_4^{2-}, and (3) HPO_4^{2-} and PO_4^{3-}. (Technically, a buffer can be made from any two components.)
8.
9. The phosphate buffer should have the larger capacity.