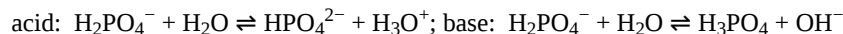


15.11: Exercises

15.4: Acids and Bases Defined

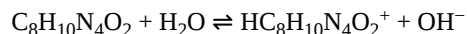
1. Write equations showing H_2PO_4^- acting as both a Brønsted-Lowry acid and as a base with water.

Answer



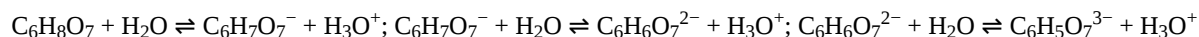
2. Write the equation for the chemical reaction that occurs when caffeine ($\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$) acts as a Brønsted-Lowry base in water.

Answer



3. Citric acid ($\text{C}_6\text{H}_8\text{O}_7$) is the acid found in citrus fruits. It can lose a maximum of three H^+ ions in the presence of a base. Write the chemical equations for citric acid acting stepwise as a Brønsted-Lowry acid in water.

Answer



4. What is the conjugate acid of each of the following?

- a. OH^-
- b. H_2O
- c. HCO_3^-
- d. NH_3
- e. HSO_4^-
- f. H_4N_2

Answer

- a. H_2O
- b. H_3O^+
- c. H_2CO_3
- d. NH_4^+
- e. H_2SO_4
- f. H_5N_2^+

5. What is the conjugate base of each of the following?

- a. H_2PO_4^-
- b. HS^-
- c. H_3O_2^+
- d. H_4N_2
- e. H_2S
- f. CH_3OH

Answer

- a. HPO_4^{2-}
- b. S^{2-}
- c. H_2O_2

- d. H_3N_2^-
- e. HS^-
- f. CH_3O^-

6. Identify and label the Brønsted-Lowry acid, its conjugate base, the Brønsted-Lowry base, and its conjugate acid in each of the following equations:

- a. $\text{HNO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NO}_3^-$
- b. $\text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^-$
- c. $\text{H}_2\text{SO}_4 + \text{Cl}^- \rightleftharpoons \text{HCl} + \text{HSO}_4^-$
- d. $\text{HSO}_4^- + \text{OH}^- \rightleftharpoons \text{SO}_4^{2-} + \text{H}_2\text{O}$

Answer

- a. BL acid = HNO_3 ; conjugate base = NO_3^- ; BL base = H_2O ; conjugate acid = H_3O^+
- b. BL acid = H_2O ; conjugate base = OH^- ; BL base = CN^- ; conjugate acid = HCN
- c. BL acid = H_2SO_4 ; conjugate base = HSO_4^- ; BL base = Cl^- ; conjugate acid = HCl
- d. BL acid = HSO_4^- ; conjugate base = SO_4^{2-} ; BL base = OH^- ; conjugate acid = H_2O

7. Identify and label the Brønsted-Lowry acid, its conjugate base, the Brønsted-Lowry base, and its conjugate acid in each of the following equations:

- a. $\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-$
- b. $\text{HBr} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Br}^-$
- c. $\text{HS}^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{S} + \text{OH}^-$
- d. $\text{H}_2\text{PO}_4^- + \text{HCl} \rightleftharpoons \text{H}_3\text{PO}_4 + \text{Cl}^-$

Answer

- a. BL acid = H_2O ; conjugate base = OH^- ; BL base = NO_2^- ; conjugate acid = HNO_2
- b. BL acid = HBr ; conjugate base = Br^- ; BL base = H_2O ; conjugate acid = H_3O^+
- c. BL acid = H_2O ; conjugate base = OH^- ; BL base = HS^- ; conjugate acid = H_2S
- d. BL acid = HCl ; conjugate base = Cl^- ; BL base = H_2PO_4^- ; conjugate acid = H_3PO_4

15.5: Strong and Weak Acids and Bases

8. Identify each of the following acids or bases as strong or weak:

- a. $\text{HC}_2\text{H}_3\text{O}_2$
- b. $\text{Ba}(\text{OH})_2$
- c. HClO_4
- d. CH_3NH_2

Answer

- a. weak acid
- b. strong base
- c. strong acid
- d. weak base

9. Identify each of the following acids or bases as strong or weak:

- a. NaOH
- b. $\text{C}_{17}\text{H}_{21}\text{NO}_4$ (cocaine)
- c. H_2SO_3

d. HBr

Answer

- a. strong base
- b. weak base
- c. weak acid
- d. strong acid

15.6: Water as an Acid and as a Base

10. Are the concentrations of hydronium ion and hydroxide ion in a solution of an acid or a base in water directly proportional or inversely proportional? Explain.

Answer

Inversely proportional. As the concentration of one increases, the concentration of the other will decrease.

11. The hydronium ion concentration in a sample of rainwater is found to be 1.7×10^{-6} M. What is the concentration of hydroxide ions in the rainwater?

Answer

$$[\text{OH}^-] = 5.9 \times 10^{-9} \text{ M}$$

12. The hydroxide ion concentration in household ammonia is 3.2×10^{-3} M. What is the concentration of hydronium in the solution?

Answer

$$[\text{H}_3\text{O}^+] = 3.1 \times 10^{-12} \text{ M}$$

13. Calculate the hydroxide ion concentration for each of the following solutions. Is the solution acidic, basic, or neutral?

- a. $[\text{H}_3\text{O}^+] = 3.5 \times 10^{-4}$ M
- b. $[\text{H}_3\text{O}^+] = 8.1 \times 10^{-8}$ M
- c. $[\text{H}_3\text{O}^+] = 7.0 \times 10^{-3}$ M

Answer

- a. $[\text{OH}^-] = 2.9 \times 10^{-11}$ M; acidic
- b. $[\text{OH}^-] = 1.2 \times 10^{-7}$ M; basic
- c. $[\text{OH}^-] = 1.4 \times 10^{-12}$ M; acidic

14. Calculate the hydronium ion concentration for each of the following solutions. Is the solution acidic, basic, or neutral?

- a. $[\text{OH}^-] = 1.0 \times 10^{-7}$ M
- b. $[\text{OH}^-] = 9.3 \times 10^{-11}$ M
- c. $[\text{OH}^-] = 2.5 \times 10^{-2}$ M

Answer

- a. $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-7}$ M; neutral
- b. $[\text{H}_3\text{O}^+] = 1.1 \times 10^{-4}$ M; acidic
- c. $[\text{H}_3\text{O}^+] = 4.0 \times 10^{-13}$ M; basic

15. Calculate the hydronium and hydroxide ion concentrations of the following solutions:

- a. 0.200 M HCl
- b. 0.0143 M NaOH
- c. 3.0 M HNO₃
- d. 0.0031 M Ca(OH)₂

Answer

- a. $[\text{H}_3\text{O}^+] = 0.200 \text{ M}$; $[\text{OH}^-] = 5.0 \times 10^{-14} \text{ M}$
- b. $[\text{H}_3\text{O}^+] = 6.99 \times 10^{-13} \text{ M}$; $[\text{OH}^-] = 0.0143 \text{ M}$
- c. $[\text{H}_3\text{O}^+] = 3.0 \text{ M}$; $[\text{OH}^-] = 3.3 \times 10^{-15} \text{ M}$
- d. $[\text{H}_3\text{O}^+] = 1.6 \times 10^{-12} \text{ M}$; $[\text{OH}^-] = 0.0062 \text{ M}$

16. Calculate the hydronium and hydroxide ion concentrations of each of the following solutions:

- a. 0.000259 M HClO₄
- b. 0.21 M NaOH
- c. 0.000071 M Ba(OH)₂
- d. 2.5 M KOH

Answer

- a. $[\text{H}_3\text{O}^+] = 0.000259 \text{ M}$; $[\text{OH}^-] = 3.86 \times 10^{-11} \text{ M}$
- b. $[\text{H}_3\text{O}^+] = 4.8 \times 10^{-14} \text{ M}$; $[\text{OH}^-] = 0.21 \text{ M}$
- c. $[\text{H}_3\text{O}^+] = 7.1 \times 10^{-11} \text{ M}$; $[\text{OH}^-] = 0.00014 \text{ M}$
- d. $[\text{H}_3\text{O}^+] = 4.0 \times 10^{-15} \text{ M}$; $[\text{OH}^-] = 2.5 \text{ M}$

15.7: An Introduction to pH

17. Identify each of the following solutions as acidic, basic, or neutral.

- a. pH = 8.2 (baking soda)
- b. pH = 2.54 (vinegar)
- c. pH = 9.4 (laundry detergent)

Answer

- a. basic
- b. acidic
- c. basic

18. Identify each of the following solutions as acidic, basic, or neutral.

- a. pH = 7.44 (human tears)
- b. pH = 3.4 (white wine)
- c. pH = 4.85 (coffee)

Answer

- a. basic
- b. acidic
- c. acidic

19. Normal clean rain has a pH of 5.0 to 5.5. Typical acid rain has a pH of 4.0. How much more acidic is acid rain than normal rain with a pH of 5.0?

Answer

One pH unit corresponds to a factor of 10. So typical acid rain is 10 times more acidic than normal rain.

20. When a sparkling water was first opened, it had a pH of 3.7. Tap water was found to have a pH of 6.7. Which water is more basic? How much more basic is it?

Answer

The tap water has a higher pH, so it is more basic. The tap water's pH is 3 pH units greater. This means that the tap water is 10^3 or 1000 times more basic.

15.8: pH and pOH Calculations

21. What is the pOH range for an acidic solution?

Answer

The pOH is greater than 7 for an acidic solution (typically up to 14).

22. What is the pOH range for a basic solution?

Answer

The pOH is less than 7 for a basic solution (typically down to 0).

23. Calculate the pH of each solution and classify it as acidic or basic.

- a. pOH = 5.18
- b. pOH = 9.26
- c. pOH = 2.84

Answer

- a. pH = 8.82; basic
- b. pH = 4.74; acidic
- c. pH = 11.16; basic

24. Calculate the pOH of each solution and classify it as acidic or basic.

- a. pH = 8.31
- b. pH = 5.20
- c. pH = 7.43

Answer

- a. pOH = 5.69; basic
- b. pOH = 8.80; acidic
- c. pOH = 6.57; basic

25. The concentration of commercial HCl is about 12 M. What is its pH and pOH?

Answer

$$\text{pH} = -1.08; \text{pOH} = 15.08$$

26. The concentration of concentrated H_2SO_4 is about 18 M. Assuming only one H^+ comes off the H_2SO_4 molecule, what is its pH and pOH?

Answer

$$\text{pH} = -1.26; \text{pOH} = 15.26$$

27. Calculate the pH and pOH of each of the following solutions:

- a. 0.200 M HCl
- b. 0.0143 M NaOH
- c. 3.0 M HNO_3
- d. 0.0031 M $\text{Ca}(\text{OH})_2$

Answer

- a. $\text{pH} = 0.699$; $\text{pOH} = 13.301$
- b. $\text{pH} = 12.155$; $\text{pOH} = 1.845$
- c. $\text{pH} = -0.48$; $\text{pOH} = 14.48$
- d. $\text{pH} = 11.79$; $\text{pOH} = 2.21$

28. Calculate the pH and pOH of each of the following solutions:

- a. 0.000259 M HClO_4
- b. 0.21 M NaOH
- c. 0.000071 M $\text{Ba}(\text{OH})_2$
- d. 2.5 M KOH

Answer

- a. $\text{pH} = 3.587$; $\text{pOH} = 10.413$
- b. $\text{pH} = 13.32$; $\text{pOH} = 0.68$
- c. $\text{pH} = 10.15$; $\text{pOH} = 3.85$
- d. $\text{pH} = 14.40$; $\text{pOH} = -0.40$

29. What are the hydronium and hydroxide ion concentrations in a solution whose pH is 6.52?

Answer

$$[\text{H}_3\text{O}^+] = 3.0 \times 10^{-7} \text{ M}; [\text{OH}^-] = 3.3 \times 10^{-8} \text{ M}$$

30. What are the hydronium and hydroxide ion concentrations in a solution whose pH is 9.20?

Answer

$$[\text{H}_3\text{O}^+] = 6.3 \times 10^{-10} \text{ M}; [\text{OH}^-] = 1.6 \times 10^{-5} \text{ M}$$

31. What are the hydronium and hydroxide ion concentrations in a solution whose pOH is 2.18?

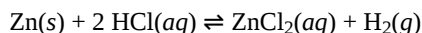
Answer

$$[\text{H}_3\text{O}^+] = 1.5 \times 10^{-12} \text{ M}; [\text{OH}^-] = 6.6 \times 10^{-3} \text{ M}$$

15.9: Reactions of Acids and Bases

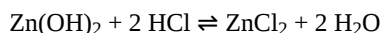
32. Write the balanced chemical equation between Zn metal and $\text{HCl}(aq)$. The other product is ZnCl_2 .

Answer



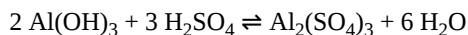
33. Write the neutralization reaction in which ZnCl_2 , also found in Exercise 32, is the salt product.

Answer



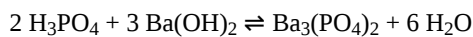
34. Write the balanced chemical equation between aluminum hydroxide and sulfuric acid.

Answer



35. Write the balanced chemical equation between phosphoric acid and barium hydroxide.

Answer



36. Complete and balance the following acid-base reactions:

- HCl solution reacts with solid $\text{Ca}(\text{OH})_2(s)$
- a solution of $\text{Sr}(\text{OH})_2$ is added to a solution of HNO_3

Answer

- $2 \text{HCl}(aq) + \text{Ca}(\text{OH})_2(s) \rightleftharpoons \text{CaCl}_2(aq) + 2 \text{H}_2\text{O}(l)$
- $\text{Sr}(\text{OH})_2(aq) + 2 \text{HNO}_3(aq) \rightleftharpoons \text{Sr}(\text{NO}_3)_2(aq) + 2 \text{H}_2\text{O}(l)$

37. Complete and balance the following acid-base reactions:

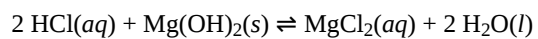
- aqueous H_2SO_4 reacts with NaOH
- $\text{Ba}(\text{OH})_2$ reacts with HF gas

Answer

- $\text{H}_2\text{SO}_4(aq) + 2 \text{NaOH}(aq) \rightleftharpoons \text{Na}_2\text{SO}_4(aq) + 2 \text{H}_2\text{O}(l)$
- $\text{Ba}(\text{OH})_2(aq) + 2 \text{HF}(g) \rightleftharpoons \text{BaF}_2(aq) + 2 \text{H}_2\text{O}(l)$

38. Gastric juice, the digestive fluid produced in the stomach, contains hydrochloric acid, HCl . Milk of Magnesia, a suspension of solid $\text{Mg}(\text{OH})_2$ in an aqueous medium, is sometimes used to neutralize excess stomach acid. Write a complete balanced equation for the neutralization reaction.

Answer



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