KEY REACTIONS AND EQUATIONS

1. Weak-acid equilibrium and acid ionization constant (K_a) expression (Section 10.5)

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

2. Weak-base equilibrium and base ionization constant (K_b) expression (Section 10.5)

$$B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)$$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

3. Ion product constant for water (Section 10.8)

$$[H_3O^+][OH^-] = 1.0 \times 10^{-14}$$

4. Relationship between $[H_3O^+]$ and pH (Section 10.9)

$$pH = -\log [H_3O^+]$$

5. Henderson–Hasselbalch equation (Section 10.13)

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

6. Equivalent concentration unit (Section 10.15)

1 equivalent = molar amount of an ion that carries 1 mole of electrical charge

EXERCISES *and* PROBLEMS

The members of each pair of problems in this section test similar material.

Arrhenius Acid-Base Theory (Section 10.1)

10.1 In Arrhenius acid–base theory, what ion is responsible for the properties of
a. acidic solutions b. basic solutions

10.2 What term is used to describe the formation of ions, in aqueous solution, from
a. a molecular compound b. an ionic compound

10.3 Classify each of the following as a property of an Arrhenius acid or the property of an Arrhenius base.
a. Has a sour taste b. Has a bitter taste

10.4 Classify each of the following as a property of an Arrhenius acid or the property of an Arrhenius base.
a. Changes the color of blue litmus paper to red
b. Changes the color of red litmus paper to blue

10.5 Write equations depicting the behavior of the following Arrhenius acids and bases in water.
a. HI (hydroiodic acid) b. HClO (hypochlorous acid)
c. LiOH (lithium hydroxide) d. CsOH (cesium hydroxide)

10.6 Write equations depicting the behavior of the following Arrhenius acids and bases in water.
a. HBr (hydrobromic acid)
b. HCN (hydrocyanic acid)
c. RbOH (rubidium hydroxide)
d. KOH (potassium hydroxide)

Brønsted-Lowry Acid-Base Theory (Section 10.2)

10.7 In each of the following reactions, decide whether the underlined species is functioning as a Brønsted–Lowry acid or base.
a. $\underline{HF} + H_2O \rightarrow H_3O^+ + F^-$
b. $\underline{H_2O} + \underline{S^{2-}} \rightarrow HS^- + OH^-$
c. $H_2O + \underline{H_2CO_3} \rightarrow H_3O^+ + HCO_3^-$
d. $\underline{HCO_3^-} + H_2O \rightarrow H_3O^+ + CO_3^{2-}$

10.8 In each of the following reactions, decide whether the underlined species is functioning as a Brønsted–Lowry acid or base.
a. $\underline{HClO_2} + H_2O \rightarrow H_3O^+ + ClO_2^-$
b. $\underline{OCl^-} + H_2O \rightarrow HOCl + OH^-$
c. $\underline{NH_3} + \underline{HNO_2} \rightarrow NH_4^+ + NO_2^-$
d. $HCl + \underline{H_2PO_4^-} \rightarrow H_3PO_4 + Cl^-$

10.9 Write equations to illustrate the acid–base reactions that can take place between the following Brønsted–Lowry acids and bases.
a. Acid: HClO; base: H_2O
b. Acid: $HClO_4$; base: NH_3
c. Acid: H_3O^+; base: OH^-
d. Acid: H_3O^+; base: NH_2^-

10.10 Write equations to illustrate the acid–base reactions that can take place between the following Brønsted–Lowry acids and bases.
a. Acid: $H_2PO_4^-$; base: NH_3
b. Acid: H_2O; base: ClO_4^-
c. Acid: HCl; base: OH^-
d. Acid: $HC_2H_3O_2$; base: H_2O

10.11 Write the formula of each of the following.
a. Conjugate base of H_2SO_3
b. Conjugate acid of CN^-
c. Conjugate base of $HC_2O_4^-$
d. Conjugate acid of HPO_4^{2-}

10.12 Write the formula of each of the following.
a. Conjugate base of NH_4^+
b. Conjugate acid of OH^-
c. Conjugate base of H_2S
d. Conjugate acid of NO_2^-

10.13 For each of the following amphiprotic substances, write the two equations needed to describe its behavior in aqueous solution.
a. HS^- b. HPO_4^{2-} c. NH_3 d. OH^-

10.14 For each of the following amphiprotic substances, write the two equations needed to describe its behavior in aqueous solution.
a. $H_2PO_4^-$ b. HSO_4^- c. $HC_2O_4^-$ d. PH_3

Polyprotic Acids (Section 10.3)

10.15 Classify the following acids as monoprotic, diprotic, or triprotic.
a. $HClO_4$ (perchloric acid)
b. $H_2C_2O_4$ (oxalic acid)
c. $HC_2H_3O_2$ (acetic acid)
d. H_2SO_4 (sulfuric acid)

10.16 Classify the following acids as monoprotic, diprotic, or triprotic.
a. $HC_4H_7O_2$ (butyric acid)
b. H_3PO_4 (phosphoric acid)

c. HNO_3 (nitric acid)
d. $H_2C_4H_4O_4$ (succinic acid)

10.17 Write equations showing all steps in the dissociation of citric acid ($H_3C_6H_5O_7$).

10.18 Write equations showing all steps in the dissociation of arsenic acid (H_3AsO_4).

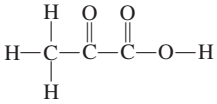
10.19 How many acidic hydrogen atoms and how many nonacidic hydrogen atoms are present in each of the following molecules?
a. HNO_3 (nitric acid)
b. $H_2C_4H_4O_4$ (succinic acid)
c. $HC_4H_7O_2$ (butyric acid)
d. CH_4 (methane)

10.20 How many acidic hydrogen atoms and how many nonacidic hydrogen atoms are present in each of the following molecules?
a. H_2CO_3 (carbonic acid)
b. $H_2C_3H_2O_4$ (malonic acid)
c. NH_3 (ammonia)
d. $HC_3H_5O_2$ (propanoic acid)

10.21 The formula for lactic acid is preferably written as $HC_3H_5O_3$ rather than as $C_3H_6O_3$. Explain why.

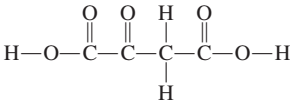
10.22 The formula for tartaric acid is preferably written as $H_2C_4H_4O_6$ rather than as $C_4H_6O_6$. Explain why.

10.23 Pyruvic acid, which is produced in metabolic reactions, has the structure



Would you predict that this acid is a mono-, di-, tri-, or tetraprotic acid? Give your reasoning.

10.24 Oxaloacetic acid, which is produced in metabolic reactions, has the structure



Would you predict that this acid is a mono-, di-, tri-, or tetraprotic acid? Give your reasoning.

Strengths of Acids and Bases (Section 10.4)

10.25 Classify each of the acids in Problem 10.15 as a strong acid or a weak acid.

10.26 Classify each of the acids in Problem 10.16 as a strong acid or a weak acid.

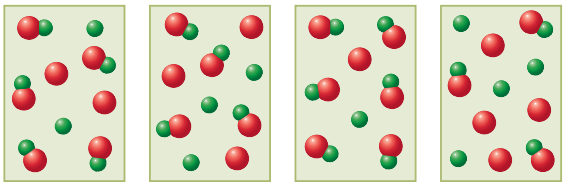
10.27 What is the difference between a strong acid and a weak acid in terms of equilibrium position?

10.28 What is the difference between a strong base and a weak base in terms of equilibrium position?

10.29 The HCl in a 0.10 M HCl solution is 100% dissociated. What are the molar concentrations of HCl, H_3O^+, and Cl^- in the solution?

10.30 The HNO_3 in a 0.50 M HNO_3 solution is 100% dissociated. What are the molar concentrations of HNO_3, H_3O^+, and NO_3^- in the solution?

10.31 The following four diagrams represent aqueous solutions of four different acids with the general formula HA. Which of the four acids is the strongest acid?



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10.32 Using the diagrams shown in Problem 10.31, which of the four acids is the weakest acid?

Ionization Constants for Acids and Bases (Section 10.5)

10.33 Write the acid ionization constant expression for the ionization of each of the following monoprotic acids.
a. HF (hydrofluoric acid) b. $HC_2H_3O_2$ (acetic acid)

10.34 Write the acid ionization constant expression for the ionization of each of the following monoprotic acids.
a. HCN (hydrocyanic acid) b. $HC_6H_7O_6$ (ascorbic acid)

10.35 Write the base ionization constant expression for the ionization of each of the following bases. In each case, the nitrogen atom accepts the proton.
a. NH_3 (ammonia) b. $C_6H_5NH_2$ (aniline)

10.36 Write the base ionization constant expression for the ionization of each of the following bases. In each case, the nitrogen atom accepts the proton.
a. CH_3NH_2 (methylamine) b. $C_2H_5NH_2$ (ethylamine)

10.37 Using the acid ionization constant information given in Table 10.3, indicate which acid is the stronger in each of the following acid pairs.
a. H_3PO_4 and HNO_2 b. HCN and HF
c. H_2CO_3 and HCO_3^- d. HNO_2 and HCN

10.38 Using the acid ionization constant information given in Table 10.3, indicate which acid is the stronger in each of the following acid pairs.
a. H_3PO_4 and $H_2PO_4^-$ b. H_3PO_4 and H_2CO_3
c. HPO_4^{2-} and $H_2PO_4^-$ d. $HC_2H_3O_2$ and HCN

10.39 A 0.00300 M solution of an acid is 12% ionized. Calculate the acid ionization constant K_a.

10. 40 A 0.0500 M solution of a base is 7.5% ionized. Calculate the base ionization constant K_b.

Salts (Section 10.6)

10.41 Classify each of the following substances as an acid, a base, or a salt.
a. HBr b. NaI c. NH_4NO_3 d. $Ba(OH)_2$

10.42 Classify each of the following substances as an acid, a base, or a salt.
a. $AlPO_4$ b. KOH c. HNO_3 d. $HC_2H_3O_2$

10.43 Classify each of the following substances as an acid, a base, or a salt.
a. NaOH b. NH_4I c. H_2SO_4 d. $Ba_3(PO_4)_2$

10.44 Classify each of the following substances as an acid, a base, or a salt.
a. $Ca(OH)_2$ b. HCN c. KBr d. HCl

10.45 Write a balanced equation for the dissociation into ions of each of the following soluble salts in aqueous solution.
a. $Ba(NO_3)_2$ b. Na_2SO_4 c. $CaBr_2$ d. K_2CO_3

10.46 Write a balanced equation for the dissociation into ions of each of the following soluble salts in aqueous solution.
a. CaS b. $BeSO_4$ c. $MgCl_2$ d. $NaC_2H_3O_2$

Acid–Base Neutralization Reactions (Section 10.7)

10.47 Indicate whether each of the following reactions is an acid–base neutralization reaction.
a. $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$
b. $HNO_3 + NaOH \longrightarrow NaNO_3 + H_2O$
c. $HBr + KOH \longrightarrow KBr + H_2O$
d. $H_2SO_4 + Pb(NO_3)_2 \longrightarrow PbSO_4 + 2HNO_3$

10.48 Indicate whether each of the following reactions is an acid–base neutralization reaction.
a. $H_2S + CuSO_4 \longrightarrow H_2SO_4 + CuS$
b. $HCN + LiOH \longrightarrow LiCN + H_2O$
c. $H_2SO_4 + Ba(OH)_2 \longrightarrow BaSO_4 + 2H_2O$
d. $Ni + 2HCl \longrightarrow NiCl_2 + H_2$

10.49 Without writing an equation, specify the molecular ratio in which each of the following acid–base pairs will react.
a. HNO_3 and NaOH b. H_2SO_4 and NaOH
c. H_2SO_4 and $Ba(OH)_2$ d. HNO_3 and $Ba(OH)_2$

10.50 Without writing an equation, specify the molecular ratio in which each of the following acid–base pairs will react.
a. HCl and KOH b. H_2CO_3 and KOH
c. HCl and $Ca(OH)_2$ d. H_2CO_3 and $Ca(OH)_2$

10.51 Write a balanced chemical equation to represent each of the following acid–base neutralization reactions.
a. HCl and NaOH b. HNO_3 and KOH
c. H_2SO_4 and LiOH d. $Ba(OH)_2$ and H_3PO_4

10.52 Write a balanced chemical equation to represent each of the following acid–base neutralization reactions.
a. HCl and LiOH b. HNO_3 and $Ba(OH)_2$
c. H_2SO_4 and NaOH d. KOH and H_3PO_4

10.53 Write a balanced molecular equation for the preparation of each of the following salts, using an acid–base neutralization reaction.
a. Li_2SO_4 (lithium sulfate)
b. NaCl (sodium chloride)
c. KNO_3 (potassium nitrate)
d. $Ba_3(PO_4)_2$ (barium phosphate)

10.54 Write a balanced molecular equation for the preparation of each of the following salts, using an acid–base neutralization reaction.
a. $LiNO_3$ (lithium nitrate)
b. $BaCl_2$ (barium chloride)
c. K_3PO_4 (potassium phosphate)
d. Na_2SO_4 (sodium sulfate)

Hydronium Ion and Hydroxide Ion Concentrations (Section 10.8)

10.55 Calculate the molar H_3O^+ ion concentration of a solution if the OH^- ion concentration is
a. 3.0×10^{-3} M b. 6.7×10^{-6} M
c. 9.1×10^{-8} M d. 1.2×10^{-11} M

10.56 Calculate the molar H_3O^+ ion concentration of a solution if the OH^- ion concentration is
a. 5.0×10^{-4} M b. 7.5×10^{-7} M
c. 2.3×10^{-12} M d. 1.1×10^{-10} M

10.57 Indicate whether each of the following solutions is acidic, basic, or neutral.
a. $[H_3O^+] = 1.0 \times 10^{-3}$ b. $[H_3O^+] = 3.0 \times 10^{-11}$
c. $[OH^-] = 4.0 \times 10^{-6}$ d. $[OH^-] = 2.3 \times 10^{-10}$

10.58 Indicate whether each of the following solutions is acidic, basic, or neutral.
a. $[H_3O^+] = 2.0 \times 10^{-4}$
b. $[H_3O^+] = 2.0 \times 10^{-8}$
c. $[OH^-] = 1.0 \times 10^{-7}$
d. $[OH^-] = 5.0 \times 10^{-9}$

10.59 Selected information about four solutions, each at 24°C, is given in the following table. Complete the table by filling in the missing information.

$[H_3O^+]$	$[OH^-]$	Acidic or Basic
2.2×10^{-2}		
	3.3×10^{-3}	
6.8×10^{-8}		
	7.2×10^{-8}	

10.60 Selected information about four solutions, each at 24°C, is given in the following table. Complete the table by filling in the missing information.

$[H_3O^+]$	$[OH^-]$	Acidic or Basic
	7.7×10^{-2}	
6.3×10^{-8}		
4.2×10^{-6}		
	3.3×10^{-10}	

pH Scale (Section 10.9)

10.61 Calculate the pH of the following solutions.
a. $[H_3O^+] = 1.0 \times 10^{-4}$
b. $[H_3O^+] = 1.0 \times 10^{-11}$
c. $[OH^-] = 1.0 \times 10^{-3}$
d. $[OH^-] = 1.0 \times 10^{-7}$

10.62 Calculate the pH of the following solutions.
a. $[H_3O^+] = 1.0 \times 10^{-6}$
b. $[H_3O^+] = 1.0 \times 10^{-2}$
c. $[OH^-] = 1.0 \times 10^{-9}$
d. $[OH^-] = 1.0 \times 10^{-5}$

10.63 Calculate the pH of the following solutions.
a. $[H_3O^+] = 2.1 \times 10^{-8}$
b. $[H_3O^+] = 4.0 \times 10^{-8}$
c. $[OH^-] = 7.2 \times 10^{-11}$
d. $[OH^-] = 7.2 \times 10^{-3}$

10.64 Calculate the pH of the following solutions.
a. $[H_3O^+] = 3.3 \times 10^{-5}$
b. $[H_3O^+] = 7.6 \times 10^{-5}$
c. $[OH^-] = 8.2 \times 10^{-10}$
d. $[OH^-] = 8.2 \times 10^{-4}$

10.65 What is the molar hydronium ion concentration in solutions with each of the following pH values?
a. 2.0 b. 6.0 c. 8.0 d. 10.0

10.66 What is the molar hydronium ion concentration in solutions with each of the following pH values?
a. 3.0 b. 5.0 c. 9.0 d. 12.0

10.67 What is the molar hydronium ion concentration in solutions with each of the following pH values?
a. 3.67 b. 5.09 c. 7.35 d. 12.45

10.68 What is the molar hydronium ion concentration in solutions with each of the following pH values?
a. 2.05 b. 4.88 c. 6.75 d. 11.33

10.69 Selected information about four solutions, each at 24°C, is given in the following table. Complete the table by filling in the missing information.

$[H_3O^+]$	$[OH^-]$	pH	Acidic or Basic
		7.21	
7.2×10^{-10}			
		5.30	
	7.2×10^{-10}		

10.70 Selected information about four solutions, each at 24°C, is given in the following table. Complete the table by filling in the missing information.

$[H_3O^+]$	$[OH^-]$	pH	Acidic or Basic
		8.73	
	7.2×10^{-5}		
6.3×10^{-3}			
		2.00	

pK_a Values (Section 10.10)

10.71 Calculate the pK_a value for each of the following acids.
a. Nitrous acid (HNO_2), $K_a = 4.5 \times 10^{-4}$
b. Carbonic acid (H_2CO_3), $K_a = 4.3 \times 10^{-7}$
c. Dihydrogen phosphate ion ($H_2PO_4^-$), $K_a = 6.2 \times 10^{-8}$
d. Sulfurous acid (H_2SO_3), $K_a = 1.5 \times 10^{-2}$

10.72 Calculate the pK_a value for each of the following acids.
a. Phosphoric acid (H_3PO_4), $K_a = 7.5 \times 10^{-3}$
b. Hydrofluoric acid (HF), $K_a = 6.8 \times 10^{-4}$
c. Hydrogen phosphate ion (HPO_4^{2-}), $K_a = 4.2 \times 10^{-13}$
d. Propanoic acid ($HC_3H_5O_2$), $K_a = 1.3 \times 10^{-5}$

10.73 Acid A has a pK_a value of 4.23, and acid B has a pK_a value of 3.97. Which of the two acids is the stronger?

10.74 Acid A has a pK_a value of 5.71, and acid B has a pK_a value of 5.30. Which of the two acids is the weaker?

Hydrolysis of Salts (Section 10.11)

10.75 Classify each of the following salts as a "strong acid–strong base salt," a "strong acid–weak base salt," a "weak acid–strong base salt," or a "weak acid–weak base salt."
a. NaCl b. $KC_2H_3O_2$
c. NH_4Br d. $Ba(NO_3)_2$

10.76 Classify each of the following salts as a "strong acid–strong base salt," a "strong acid–weak base salt," a "weak acid–strong base salt," or a "weak acid–weak base salt."
a. K_3PO_4 b. $NaNO_3$
c. KCl d. $Na_2C_2O_4$

10.77 Identify the ion (or ions) present in each of the salts in Problem 10.75 that will undergo hydrolysis in aqueous solution.

10.78 Identify the ion (or ions) present in each of the salts in Problem 10.76 that will undergo hydrolysis in aqueous solution.

10.79 Predict whether solutions of each of the salts in Problem 10.75 will be acidic, basic, or neutral.

10.80 Predict whether solutions of each of the salts in Problem 10.76 will be acidic, basic, or neutral.

Buffers (Section 10.12)

10.81 Predict whether each of the following pairs of substances could function as a buffer system in aqueous solution.
a. HNO_3 and $NaNO_3$ b. HF and NaF
c. KCl and KCN d. H_2CO_3 and $NaHCO_3$

10.82 Predict whether each of the following pairs of substances could function as a buffer system in aqueous solution.
a. HNO_3 and HCl b. HNO_2 and KNO_2
c. $NaC_2H_3O_2$ and $KC_2H_3O_2$ d. $HC_2H_3O_2$ and $NaNO_3$

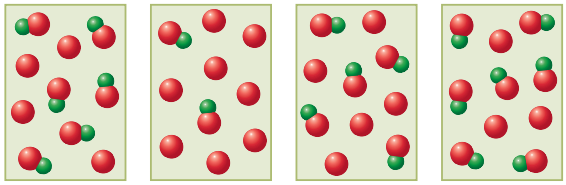
10.83 Identify the two "active species" in each of the following buffer systems.
a. HCN and KCN b. H_3PO_4 and NaH_2PO_4
c. H_2CO_3 and $KHCO_3$ d. $NaHCO_3$ and K_2CO_3

10.84 Identify the two "active species" in each of the following buffer systems.
a. HF and LiF b. Na_2HPO_4 and KH_2PO_4
c. K_2CO_3 and $KHCO_3$ d. $NaNO_2$ and HNO_2

10.85 Write an equation for each of the following buffering actions.
a. The response of a HF/F^- buffer to the addition of H_3O^+ ions
b. The response of a H_2CO_3/HCO_3^- buffer to the addition of OH^- ions
c. The response of a HCO_3^-/CO_3^{2-} buffer to the addition of H_3O^+ ions
d. The response of a $H_3PO_4/H_2PO_4^-$ buffer to the addition of OH^- ions

10.86 Write an equation for each of the following buffering actions.
a. The response of a HPO_4^{2-}/PO_4^{3-} buffer to the addition of OH^- ions
b. The response of a HF/F^- buffer to the addition of OH^- ions
c. The response of a HCN/CN^- buffer to the addition of H_3O^+ ions
d. The response of a $H_3PO_4/H_2PO_4^-$ buffer to the addition of H_3O^+ ions

10.87 The following four diagrams represent aqueous solutions containing a weak acid (HA) and/or its conjugate base (A^-). Which of the four solutions is a buffer solution? There may be more than one correct answer.



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10.88 Using the diagrams shown in Problem 10.87, which of the solutions would have the greatest buffer capacity, that is, greatest protection against pH change, when the following occurs?
a. A strong acid is added to the solution.
b. A strong base is added to the solution.

The Henderson-Hasselbalch Equation (Section 10.13)

10.89 What is the pH of a buffer that is 0.230 M in a weak acid and 0.500 M in the acid's conjugate base? The pK_a for the acid is 6.72.

10.90 What is the pH of a buffer that is 0.250 M in a weak acid and 0.260 M in the acid's conjugate base? The pK_a for the acid is 5.53.

10.91 What is the pH of a buffer that is 0.150 M in a weak acid and 0.150 M in the acid's conjugate base? The acid's ionization constant is 6.8×10^{-6}.

10.92 What is the pH of a buffer that is 0.175 M in a weak acid and 0.200 M in the acid's conjugate base? The acid's ionization constant is 5.7×10^{-4}.

Electrolytes (Section 10.14)

10.93 Classify each of the following compounds as a strong electrolyte or a weak electrolyte.
a. H_2CO_3 b. KOH c. NaCl d. H_2SO_4

10.94 Classify each of the following compounds as a strong electrolyte or a weak electrolyte.
a. H_3PO_4 b. HNO_3 c. KNO_3 d. NaOH

10.95 Indicate whether solutions of each of the following substances contain ions, molecules, or both.
a. Acetic acid, a weak acid
b. Sucrose, a nonelectrolyte
c. Sodium sulfate, a soluble salt
d. Hydrofluoric acid, a weak electrolyte

10.96 Indicate whether solutions of each of the following substances contain ions, molecules, or both.
a. Hydrochloric acid, a strong acid
b. Sodium nitrate, a soluble salt
c. Potassium chloride, a strong electrolyte
d. Ethanol, a nonelectrolyte

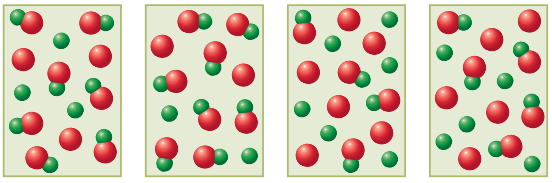
10.97 How many ions, per formula unit, are produced when each of the following soluble salts (strong electrolytes) dissolves in water?
a. NaCl b. $Mg(NO_3)_2$ c. K_2S d. NH_4CN

10.98 How many ions, per formula unit, are produced when each of the following soluble salts (strong electrolytes) dissolves in water?
a. KNO_3 b. Na_2CO_3 c. $MgCl_2$ d. K_3N

10.99 Write a balanced chemical equation for the dissociation in water of each of the salts listed in Problem 10.97.

10.100 Write a balanced chemical equation for the dissociation in water of each of the salts listed in Problem 10.98.

10.101 Four different substances of the generalized formula HA were dissolved in water with the results shown in the diagrams. Which of the diagrams represents the substance that is the strongest electrolyte?



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10.102 Which of the diagrams in Problem 10.101 represents the substance that is the weakest electrolyte?

Equivalents and Milliequivalents of Electrolytes (Section 10.15)

10.103 Indicate the number of equivalents in each of the following molar quantities of ions.
a. 1 mole Na^+ b. 1 mole NO_3^-
c. 1 mole Mg^{2+} d. 1 mole HCO_3^-

10.104 Indicate the number of equivalents in each of the following molar quantities of ions.
a. 1 mole K^+ b. 1 mole $H_2PO_4^-$
c. 1 mole HPO_4^{2-} d. 1 mole Ca^{2+}

10.105 Indicate the number of equivalents in each of the following molar quantities of ions.
a. 2 moles K^+ b. 3 moles $H_2PO_4^-$
c. 2 moles HPO_4^{2-} d. 7 moles Ca^{2+}

10.106 Indicate the number of equivalents in each of the following molar quantities of ions.
a. 4 moles Na^+ b. 2 moles NO_3^-
c. 3 moles Mg^{2+} d. 5 moles HCO_3^-

10.107 A physiological solution contains 47 mEq/L of Cl^- ion. How many moles of Cl^- ion are present in 2.00 L of the solution?

10.108 A physiological solution contains 49 mEq/L of Na^+ ion. How many moles of Na^+ ion are present in 1.50 L of the solution?

10.109 How many milligrams of Ca^{2+} ion are present in 250.0 mL of a solution whose Ca^{2+} ion concentration is 4.1 mEq/L?

10.110 How many milligrams of Mg^{2+} ion are present in 350.0 mL of a solution whose Mg^{2+} ion concentration is 3.8 mEq/L?

Titration Calculations (Section 10.16)

10.111 Determine the molarity of a NaOH solution when each of the following amounts of acid neutralizes 25.0 mL of the NaOH solution.
a. 5.00 mL of 0.250 M HNO_3
b. 20.00 mL of 0.500 M H_2SO_4
c. 23.76 mL of 1.00 M HCl
d. 10.00 mL of 0.100 M H_3PO_4

10.112 Determine the molarity of a KOH solution when each of the following amounts of acid neutralizes 25.0 mL of the KOH solution.
a. 5.00 mL of 0.500 M H_2SO_4
b. 20.00 mL of 0.250 M HNO_3
c. 13.07 mL of 0.100 M H_3PO_4
d. 10.00 mL of 1.00 M HCl

ADDITIONAL PROBLEMS

10.113 In which of the following pairs of substances do the two members of the pair constitute a conjugate acid–base pair?
a. HN_3 and N_3^- b. H_2SO_4 and SO_4^{2-}
c. H_2CO_3 and $HClO_3$ d. NH_3 and NH_2^-

10.114 For which of the following pairs of acids are both members of the pair of "like strength"—that is, both strong or both weak?
a. HNO_3 and HNO_2 b. HCl and HBr
c. H_3PO_4 and $HClO_4$ d. H_2CO_3 and $H_2C_2O_4$

10.115 Solution A has a pH of 3.20, solution B a pH of 12.50, solution C a pH of 7.00, and solution D a pH of 4.44. Arrange the four solutions in order of the following:
a. Decreasing acidity b. Increasing $[H_3O^+]$
c. Decreasing $[OH^-]$ d. Increasing basicity

10.116 What would be the pH of a solution that contains 0.1 mole of each of the solutes NaCl, NaOH, and HCl in enough water to give 2.00 L of solution?

10.117 Arrange the following 0.1 M aqueous solutions in order of increasing pH: HCl, HCN, NaOH, and KCl.

10.118 Identify the buffer system(s)—the conjugate acid–base pair(s)—present in solutions that contain equal molar amounts of the following.
a. HCN, KCN, NaBr, and NaCl
b. HF, HCl, $NaC_2H_3O_2$, and NaF

10.119 It is possible to make two completely different buffers that involve the dihydrogen phosphate ion, $H_2PO_4^-$. Characterize each of the buffers by specifying the conjugate acid–base pair that is present.

10.120 Both ions in each of the salts NH_4CN and $NH_4C_2H_3O_2$ undergo hydrolysis in aqueous solution. Upon hydrolysis, the first listed salt gives a basic solution and the second a neutral solution. Explain how this is possible.

10.121 How many grams of NaOH are needed to make 875 mL of a solution with a pH of 10.00?

Multiple-Choice Practice Test

10.122 In an Arrhenius acid–base context, the compounds HCl, HNO_3, and NaOH, when dissolved in water, are which of the following, respectively?
a. Acid, acid, and base
b. Base, base, and acid
c. Base, acid, and base
d. Acid, base, and acid

10.123 Which statement is *correct* for the Brønsted–Lowry acid–base reaction

$$HCN + HCO_3^- \rightleftharpoons CN^- + H_2CO_3$$

a. HCO_3^- is the conjugate base of HCN.
b. HCN is the conjugate acid of HCO_3^-.
c. HCO_3^- is the Brønsted–Lowry acid for the forward reaction.
d. CN^- is the Brønsted–Lowry base for the reverse reaction.

10.124 In which of the following pairs of acids are both members of the pair *weak* acids?
a. HNO_3 and HCl
b. HCN and HF
c. H_2SO_4 and H_3PO_4
d. HBr and HI

10.125 Which of the following is produced in the *second* step of the dissociation of the polyprotic acid H_3PO_4?
a. H_3PO_3
b. $H_2PO_4^-$
c. HPO_4^{2-}
d. PO_4^{3-}

10.126 Which of the following chemical equations represents an acid–base neutralization reaction?
a. $H_2SO_4 + Zn \longrightarrow ZnSO_4 + H_2$
b. $HNO_3 + KOH \longrightarrow KNO_3 + H_2O$
c. $Ba(OH)_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaOH$
d. $2H_2 + O_2 \longrightarrow 2H_2O$

10.127 Which of the following is a *correct* statement concerning an aqueous solution with a pH of 8.00?
a. The hydroxide ion concentration is greater than the hydronium ion concentration.
b. The hydronium ion concentration is 8.00 M.
c. The hydroxide ion concentration is 1.0×10^{-8} M.
d. The hydronium ion concentration is 8.0×10^{-8} M.

10.128 In which of the following salts would both the positive ion and the negative ion hydrolyze when the salt is dissolved in water?
a. NaCl
b. NaCN
c. NH_4Cl
d. NH_4CN

10.129 Which of the following combinations of substances would produce a buffer?
a. A strong acid and a salt of the strong acid
b. A weak acid and a salt of the weak acid
c. A salt of a strong acid and a salt of a weak acid
d. A strong acid and a weak acid

10.130 Which of the following statements concerning electrolytes is *correct*?
a. All strong acids are strong electrolytes.
b. All salts are weak electrolytes.
c. Some molecular substances are strong electrolytes and others are weak electrolytes.
d. All bases are weak electrolytes.

10.131 Determining the concentration of an acid using an acid–base titration always involves which of the following?
a. Reacting a strong acid with a weak base
b. Reacting an acid of known concentration with an indicator
c. Reacting a 1.0 M acid solution with a 1.0 M base solution
d. An acid–base neutralization reaction