21 NEUTRALIZATION
PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
21.1 Neutralization Reactions **Objectives** ▸ Explain how acid-base titration is used to calculate the concentration of an acid or a base ▸ Explain the concept of equivalence in neutralization reactions	**Discover It!** *Reaction of an Acid with an Egg*, p. 612 **Mini Lab** *The Neutralizing Power of Antacids*, p. 615 **Sample Problems** 21-2 through 21-8 **Link to Cosmetology** *Neutral Curls from Permanent Waves*, p. 619 **Small-Scale Lab** *Small-Scale Titrations*, p. 625	**Review Module** (Chapters 21–24) ▸ Section Review 21.1 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheets** 21-1 and 21-2 **Laboratory Manual** ▸ Experiment 39: *Neutralization Reactions* ▸ Experiment 40: *Acid-Base Titrations* **Laboratory Practical** 21-1 **Small-Scale Chemistry Lab Manual,** Experiment 29: *Titration Curves*
21.2 Salts in Solution **Objectives** ▸ Demonstrate with equations how buffers resist changes in pH ▸ Calculate the solubility product constant of a slightly soluble salt	**Link to Biology** *Blood Buffers*, p. 629 **CHEMath** *Algebra and K_{sp}*, p. 633 **Sample Problems** 21-9 through 21-13 **Chemistry Serving . . . Industry** *Extreme Organisms*, p. 638 **Chemistry in Careers** *Microbiologist*, p. 638	**Review Module** ▸ Section Review 21.2 ▸ Practice Problems ▸ Interpreting Graphics ▸ Vocabulary Review 21 ▸ Chapter 21 Tests and Quizzes **Laboratory Manual** ▸ Experiment 41: *Salt Hydrolysis* ▸ Experiment 42: *Buffers* ▸ Experiment 43: *A Solubility Product Constant* **Small-Scale Chemistry Lab Manual,** Experiment 30: *Buffers* **Solutions Manual for Chapter Reviews**

TECHNOLOGY RESOURCES

Internet Connections
Within this chapter, you will see the chemSURF logo. If you and your students have access to the Internet, the following URL address will provide various Internet connections that are related to topics and features presented in this chapter.

http://www.chemsurf.com

You can also find relevant chapter material at
The Chemistry Place address:
http://www.chemplace.com

CD-ROMs

Chem ASAP! CD-ROM
- Chapter 21

ResourcePro CD-ROM
- Chapter 21

ActivChemistry CD-ROM
- Acid-Base Titrations

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Milk of Magnesia
- Titration

Small-Scale Lab Video and Videodisc
- #8: Titrations
- #11: Small-Scale pH-Meter

ASSESSMENT

Student Edition
- Section Reviews 21.1–21.2
- Chapter 21 Review, pp. 639–642
- Alternative Assessment, p. 643

Teacher's Resource Package
Review Module (Chap. 21–24)
- Vocabulary Review
- Chapter 21 Test A and Test B
- Chapter 21 Quizzes

Technology
Chem ASAP! CD-ROM
- Assessment 21.1–21.2

Assessment Resources CD-ROM
- Chapter 21 Tests

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 612
- eggs
- small containers
- white vinegar
- paper
- pens or pencils
- clocks

Mini Lab p. 615
- antacids (several brands)
- mortar and pestle
- paper towels
- measuring teaspoons
- clear plastic cups
- droppers
- universal indicator
- white vinegar
- sodium hydrogen carbonate

Small-Scale Lab, p. 625
- plastic cups
- well strips
- pipettes
- NaOH
- HNO_3
- HCl
- H_2SO_4
- CH_3COOH
- phenolphthalein

TEACHER'S EDITION

Teacher Demo, p. 614
- equimolar solutions of HCl and NaOH
- phenolphthalein indicator
- protective goggles
- laboratory apron
- electric stirrer with a magnetic stir bar
- beaker
- table salt

Teacher Demo, p. 617
- beaker
- acid
- buret
- pH meter

Teacher Demo, p. 622
- 1.0*M* HCl
- pH meter

Teacher Demo, p. 627
- 1*M* solutions of the following salts:
  NH_4NO_3
  KCl
  $NaHCO_3$
  Na_2SO_3
- pH meter *or* universal pH paper

Teacher Demo, p. 634
- saturated solutions of: silver chloride and silver nitrate
- 2 test tubes

Name _____ Class _____ Date _____

21.1 NEUTRALIZATION REACTIONS
SECTION REVIEW

Objectives

- Explain how acid–base titration is used to calculate the concentration of an acid or a base
- Explain the concept of equivalence in neutralization reactions

Key Terms

- neutralization reactions
- standard solution
- titration
- end point
- equivalent (equiv)
- gram equivalent mass
- normality (N)
- equivalence point

Key Equations

- Acid + Base → Salt + Water
- Gram equivalent mass = $\frac{\text{molar mass}}{\text{number of ionizable hydrogens}}$
- Normality (N) = equiv/L
- $N_1 \times V_1 = N_2 \times V_2$
- $N_A \times V_A = N_B \times V_B$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

In the reaction of a(n) __1__ with a base, hydrogen ions and __2__ ions react to produce __3__. This reaction, called __4__, is usually carried out by __5__. The __6__ in a titration is the point at which the solution is neutral. At the __7__ point of a titration the number of equivalents of acid equals the number of equivalents of base.

An equivalent of acid is the __8__ of the acid that provides __9__ of hydrogen ions in solution. A solution that contains one equivalent of an acid or a base in one liter of solution is a one normal (1N) solution. Thus, a 2N solution of H_2SO_4 contains __10__ of H^+ per liter of solution.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** A solution of known concentration is called a standard solution.

_____ **12.** The end point of a titration of a strong base with a strong acid occurs when $[H^+] = [OH^-]$.

_____ **13.** The gram molecular mass of a substance is the same as its gram equivalent mass.

_____ **14.** A 1*M* solution of H_2SO_4 is 2*N*.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** titration	**a.** number of equivalents of solute in one liter of solution
_____ **16.** neutralization reactions	**b.** a solution of known concentration
_____ **17.** normality (*N*)	**c.** a process for determining the concentration of a solution by adding a known amount of a standard solution
_____ **18.** standard solution	**d.** point of neutralization
_____ **19.** end point	**e.** reactions between acids and bases to produce a salt and water

Part D Questions and Problems

Answer the following in the space provided.

20. Complete and balance the equations for the following acid–base reactions.

a. $H_3PO_4 + Al(OH)_3$

_____

b. $HI + Ca(OH)_2$

_____

Name _____ Class _____ Date _____

21.2 SALTS IN SOLUTION
SECTION REVIEW

Objectives

- Demonstrate with equations how buffers resist changes in pH
- Calculate the solubility product constant of a slightly soluble salt

Key Terms

- salt hydrolysis
- buffers
- buffer capacity
- solubility product constant (K_{sp})
- common ion
- common ion effect

Key Equation

- For a slightly soluble salt (MX), $K_{sp} = [M^+] \times [X^-]$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

A __1__ forms when an acid is neutralized by a base. Salts can be neutral, __2__, or __3__ in solutions. Salts of strong acid–strong base reactions produce __4__ solutions with water. Salts formed from the neutralization of weak acids or weak bases __5__ water. They produce solutions that are acidic or basic.

For example, the pH of a solution at the equivalence point is greater than 7 for a __6__ base-__7__ acid titration. Solutions that resist changes in pH are called __8__ solutions. The buffer __9__ is the amount of acid or base that can be added to a buffer without changing the pH greatly. The __10__ is the equilibrium constant for the equilibrium between an ionic solid and its ions in solution.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** An aqueous solution of NH_4Cl is basic.

_____ **12.** HCl–NaCl would be a good buffer system.

_____ **13.** The term *common ion effect* refers to the lowering of the solubility of a substance by the addition of a common ion.

_____ **14.** If the ion-product concentration of two ions in solution is less than the K_{sp} of the compound formed from the ions, no precipitate will form.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** solubility product constant (K_{sp})	**a.** an equilibrium constant that can be applied to the solubility of electrolytes
_____ **16.** buffer	**b.** a decrease in the solubility of a substance caused by the addition of a common ion
_____ **17.** common ion effect	**c.** the salt produced by the titration of ammonia with hydrochloric acid.
_____ **18.** NH_4Cl	**d.** a solution in which the pH remains relatively constant when small amounts of acid or base are added

Part D Questions and Problems

Answer the following in the space provided.

19. Will a precipitate form when 0.00070 mol Na_2CO_3 is mixed with 0.0015 mol $Ba(OH)_2$ in one liter of solution? Assume that these two salts both dissolve completely. Refer to Table 21.4 in your textbook.

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21 NEUTRALIZATION
PRACTICE PROBLEMS

In your notebook, solve the following problems.

SECTION 21.1 NEUTRALIZATION REACTIONS

1. What is the molarity of a sodium hydroxide solution if 38 mL of the solution is titrated to the end point with 14 mL of 0.75*M* sulfuric acid?
2. If 24.6 mL of a $Ca(OH)_2$ solution are needed to neutralize 14.2 mL of 0.0140*M* $HC_2H_3O_2$, what is the concentration of the calcium hydroxide solution?
3. A 12.4 mL solution of H_2SO_4 is completely neutralized by 19.8 mL of 0.0100*M* $Ca(OH)_2$. What is the concentration of the H_2SO_4 solution?
4. What volume of 0.12*M* $Ba(OH)_3$ is needed to neutralize 12.2 mL of 0.25*M* HCl?
5. A 55.0 mg sample of $Al(OH)_3$ is reacted with 0.200*M* HCl. How many milliliters of the acid are needed to neutralize the $Al(OH)_3$?
6. Calculate the equivalents of KOH in 4.20 L of 1.20*N* KOH.
7. What is the normality of 0.40*M* H_3PO_4?
8. What is the normality of 1.50 L of solution that contains 24.6 g HCl?
9. How many milliliters of 0.250*N* H_2SO_4 are required to titrate 68.0 mL of 0.110*N* NaOH to the end point?

SECTION 21.2 SALTS IN SOLUTION

1. A buffer solution is prepared by mixing together equal quantities of formic acid, $HCHO_2$, and sodium formate, $NaCHO_2$. Write equations that show what happens when first acid, and then base, is added to this buffer solution.
2. Write the solubility product expression for **a.** $Ca(OH)_2$ and **b.** Ag_2CO_3.
3. What is the concentration of silver ions in a saturated solution of silver carbonate? The K_{sp} of Ag_2CO_3 is 8.1×10^{-12}.
4. The equilibrium concentration of hydroxide ions in a saturated solution of iron(II) hydroxide is $1.2 \times 10^{-5}M$ at a certain temperature. Calculate the K_{sp} of $Fe(OH)_2$ at this temperature.
5. Strontium carbonate has a $K_{sp} = 9.3 \times 10^{-10}$ at 25 °C. What is the concentration of strontium ions in a saturated solution of $SrCO_3$?
6. What is the equilibrium concentration of silver ions at 25 °C in a 1.0-L saturated solution of silver carbonate to which 0.20 mol of Na_2CO_3 has been added. The K_{sp} of Ag_2CO_3 is 8.1×10^{-12} at 25 °C.
7. Will a precipitate of $PbSO_4$ form when 400.0 mL of 0.0050*M* $MgSO_4$ is mixed with 600.0 mL of 0.0020*M* $Pb(NO_3)_2$? The K_{sp} of $PbSO_4 = 6.3 \times 10^{-7}$.
8. Will precipitation of $CaCO_3$ occur when 500.0 mL of $4.2 \times 10^{-3}M$ $CaCl_2$ is mixed with 500.0 mL of $2.6 \times 10^{-3}M$ Na_2CO_3? The K_{sp} of $CaCO_3$ is 4.5×10^{-9}.
9. Which of these compounds would not decrease the solubility of $Mg(OH)_2$ when added to a saturated solution of the compound?

NaOH, $MgCl_2$, NaCl, KOH

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21 INTERPRETING GRAPHICS

USE WITH SECTION 21.2

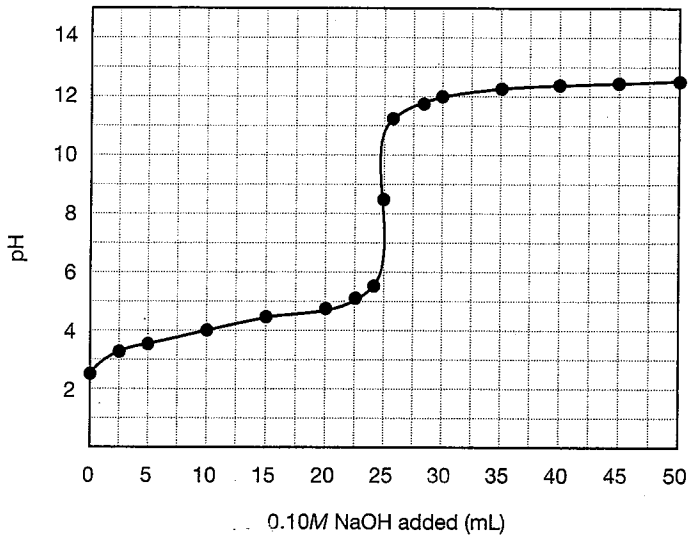

Figure 1 The pH curve for the titration of a benzoic acid (C_6H_5COOH) solution with a standard solution of 0.10*M* sodium hydroxide (NaOH).

The plot shown in Figure 1 shows how the pH of a benzoic acid solution of unknown concentration changes as a function of the volume of 0.10M NaOH added. The starting volume of benzoic acid solution was 25 mL. Use this titration curve to answer the following questions.

1. Write the chemical equation for the reaction of benzoic acid ($C_6H_5COO\mathbf{H}$) with NaOH. Note that the acidic hydrogen atom in benzoic acid is shown in bold. How many moles of benzoic acid are neutralized per mole of NaOH added?

_____

_____

2. Estimate the pH of the solution at the equivalence point of the titration. Is the solution acidic, neutral, or basic at the equivalence point?

_____

_____

3. Based on your estimate of the pH at the equivalence point, characterize benzoic acid as a weak acid or a strong acid? Explain your answer.

_____

_____

4. How many moles of NaOH were needed to reach the equivalence point?

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5. Define the equivalence point in this reaction. What are [NaOH], [C_6H_5COOH], and [C_6H_5COONa] at the equivalence point?

_____

_____

6. What is the concentration of benzoic acid in the original "unknown" solution?

7. Refer to Figure 20.8 in your textbook. Which of the acid–base indicators shown would be most appropriate for this particular titration? Label the titration curve in Figure 1 to indicate the range of pH values for which your chosen indicator is most effective.

_____

_____

_____

8. At the equivalence point, the pH of the solution is determined be the hydrolysis of the sodium benzoate salt, C_6H_5COONa. Write the chemical equation showing the hydrolysis of water by the benzoate ion ($C_6H_5COO^-$). How does this equation support your answer to question 2?

_____

_____

9. Use your answer to question 8 to write the base dissociation constant (K_b) expression for the reaction of benzoate ion with water.

10. Based on your estimate of the pH at the equivalence point and using the expression for K_b, determine the numerical value of K_b for the benzoate ion ($C_6H_5COO^-$).

Name _____ Class _____ Date _____

21 VOCABULARY REVIEW

Select the term from the following list that best matches each description.

equivalence point	neutral salts
normality (N)	one equivalent
hydrolyzing salts	buffer
neutral	solubility product constant (K_{sp})

1. compounds derived from the reaction of a strong base with a weak acid or from the reaction of a strong acid with a weak base

_____

2. a measure of the equilibrium concentrations of ions in a saturated solution of a sparingly soluble salt

_____

3. a term used to describe the pH of a solution that results when one equivalent of a strong acid is mixed with one equivalent of a strong base

_____

4. the point in a titration at which the number of equivalents of acid and base are equal

_____

5. a unit of concentration used to express the number of equivalents of a solute, such as an acid or base, in one liter of solution

_____

6. compounds that are derived from the neutralization of a strong acid with a strong base

_____

7. a solution that consists of a weak acid and the salt of a weak acid, or that consists of a weak base and the salt of a weak base

_____

8. the amount of an acid or base that can give one mole of hydrogen or hydroxide ions

_____

Name _____ Class _____ Date _____

21 NEUTRALIZATION

Quiz for CHAPTER 21

Choose the best answer and write its letter in the blank.

_____ **1.** How many milliters of 0.20*N* NaOH are required to neutralize 40 mL of 0.50*N* HCl? *21.1*

a. 12 mL **c.** 75 mL
b. 50 mL **d.** 100 mL

_____ **2.** A 100-mL sample of hydrobromic acid, HBr, is titrated to an end point with 24.0 mL of 1.5*N* NaOH. What is the concentration of HBr? *21.1*

a. 0.36*N* **c.** 2.8*N*
b. 0.72*N* **d.** 1.4*N*

_____ **3.** The reaction that takes place when an acid is added to an ethanoic acid-ethanoate (CH_3COOH/CH_3COO^-) buffer is: *21.2*

a. $CH_3COO^- + H^+ \rightleftharpoons CH_4 + CO_2$
b. $CH_3COOH + H^+ \rightleftharpoons CH_3COO^- + H^+$
c. $CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$
d. $CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$

_____ **4.** Which of the following would *not* make a good buffering system? *21.2*

a. sulfate ion and sulfuric acid
b. hydrogen carbonate ion and carbonic acid
c. ammonia and ammonium ion
d. ethanoate ion and ethanoic acid

_____ **5.** Which substance, when dissolved in water, will produce a solution with a pH greater than 7? *21.2*

a. CH_3COOH **c.** $KC_2H_3O_2$
b. KCl **d.** NaCl

_____ **6.** Which salt hydrolyzes water to form a solution that is acidic? *21.2*

a. LiBr **c.** NaBr
b. NH_4Br **d.** KBr

_____ **7.** Given the reaction at equilibrium: *21.2*

$$Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2OH^-(aq)$$

what is the expression for the solubility product constant, K_{sp} for this reaction?

a. $K_{sp} = [Zn^{2+}] \times [2OH^-]$ **c.** $K_{sp} = \dfrac{[Zn^{2+}] \times [OH^-]}{[Zn(OH)_2]}$

b. $K_{sp} = [Zn^{2+}] \times [OH^-]^2$ **d.** $K_{sp} = \dfrac{[Zn(OH)_2]}{[Zn^{2+}] \times [OH^-]}$

_____ **8.** When 0.1*M* HCl is added to the following system at equilibrium: *21.2*

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$$

the point of equilibrium will shift to the:

a. right and the concentration of $Ag^+(aq)$ will decrease.
b. right and the concentration of $Ag^+(aq)$ will increase.
c. left and the concentration of $Ag^+(aq)$ will decrease.
d. left and the concentration of $Ag^+(aq)$ will increase.

Name _____ Class _____ Date _____

21 NEUTRALIZATION
CHAPTER TEST A

A. Matching

Match each term in Column B with the correct description in Column A.

Column A	Column B
_____ **1.** the amount of an acid (or base) that will give one mole of hydrogen (or hydroxide) ions	**a.** buffer
_____ **2.** the point at which neutralization is achieved	**b.** titration
_____ **3.** the addition of a known amount of a standard solution to determine the concentration of another solution	**c.** end point
_____ **4.** the concentration of a solution expressed as the number of equivalents of solute in one liter of solution	**d.** equivalent
_____ **5.** a solution in which pH remains relatively constant when small amounts of acid or base are added	**e.** neutralization reaction
_____ **6.** production of a salt and water by an acid and a base in aqueous solution	**f.** normality
_____ **7.** a solution of known concentration	**g.** salt hydrolysis
_____ **8.** process in which ions of a dissociated salt accept hydrogen ions from water or donate hydrogen ions to water	**h.** standard solution

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **9.** The products of the reaction of one mole of $Ca(OH)_2$ and one mole of H_2SO_4 are:
a. $CaSO_4 + H_3O^+ + H_2O$
b. $CaSO_4 + H_3O^+ + OH^-$
c. $CaH_2 + H_3SO_4$
d. $CaSO_4 + 2H_2O$

_____ **10.** A solution that contains one mole of the diprotic acid oxalic acid ($H_2C_2O_4$) per liter is:
a. 1*N*.
b. 0.5*N*.
c. 2*N*.
d. none of these

_____ **11.** How many grams of sodium hydroxide are in 500 mL of a 0.2*N* NaOH solution?
a. 2 g
b. 4 g
c. 20 g
d. 40 g

Name _____ Class _____ Date _____

_____ **12.** What is the gram equivalent mass of KOH?
a. 56.1 g **c.** 28.1 g
b. 1.0 g **d.** 112 g

_____ **13.** A solution labeled 1*N* H_2SO_4 contains how many moles of H_2SO_4 per liter?
a. 0.5 mol/L **c.** 0.2 mol/L
b. 1 mol/L **d.** 2 mol/L

_____ **14.** The hydrolysis of water by the salt of a weak base and a strong acid should give a solution that is:
a. weakly basic. **c.** strongly basic.
b. neutral. **d.** acidic.

_____ **15.** A basic solution would result from the hydrolysis of one of the ions in the compound:
a. KNO_3. **c.** CH_3COOK.
b. NH_4Cl. **d.** $MgCl_2$.

_____ **16.** A solution of one of the following compounds is acidic because one of its ions undergoes hydrolysis. The compound is:
a. KCl. **c.** CH_3COOK.
b. NH_4Cl. **d.** NH_3.

C. True–False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **17.** At the equivalence point of titration, the volume of acid equals the volume of base.

_____ **18.** A solution containing only water and sodium acetate, $NaC_2H_3O_2$, has a pH of less than 7.

_____ **19.** A hydrolysis reaction involves the splitting of a covalent bond in water.

_____ **20.** The number of ionizable hydrogens in an acid must be known to calculate the gram equivalent mass of the acid.

_____ **21.** In a titration, the amount of acid added to a base is used to calculate the concentration of the base.

D. Problems

Solve the following problems in the space provided. Show your work.

22. How many equivalents are in 20.5 g of sulfurous acid, H_2SO_3?

Name _____ Class _____ Date _____

23. Write complete and balanced equations for each of the following acid–base reactions.

a. $H_3PO_4 + Ca(OH)_2 \rightarrow$

b. $HBr + Mg(OH)_2 \rightarrow$

c. $H_2SO_4 + Al(OH)_3 \rightarrow$

d. $HCl + NH_4OH \rightarrow$

24. A 50.0-mL sample of hydrobromic acid, HBr, is titrated to an end point with 20.0 mL of 1.50*N* NaOH. What is the concentration of HBr?

25. How many milliliters of 0.600*N* H_2SO_4 are required to neutralize 90.0 mL of 0.40*N* NaOH?

26. How much of a 5.0*N* H_2SO_4 stock solution would you need to make 400.0 mL of 0.20*N* H_2SO_4?

27. Predict whether an aqueous solution of each salt will be acidic, basic, or neutral.

a. Na_2CO_3

b. KNO_3

c. $(NH_4)_2SO_4$

d. $Mg(C_2H_3O_2)_2$

E. Essay

Write a short essay for the following.

28. Explain how the process of titration can be used to determine the concentration of a base.

F. Additional Questions and Problems

Answer the following questions and solve the problems in the space provided. Show your work.

29. What range of pH values is associated with an aqueous solution of each of the following salts? For each answer write: greater than 7, 7, or less than 7.

a. K_3PO_4

b. NH_4Cl

c. $Mg(NO_3)_2$

d. K_2SO_4

e. CH_3COOLi

30. Write equations for the addition of an acid and a base to an ammonium ion-ammonia buffer.

a. When acid is added:

b. When base is added:

31. Will a precipitate of $CaCO_3$ form when 0.96 g of $(NH_4)_2CO_3$ is mixed with 0.20 g of $CaBr_2$ in 20.0 L of solution?

$$K_{sp} \text{ of } CaCO_3 = 4.5 \times 10^{-9}$$

32. The solubility of $CaSO_4$ in water is 0.67 g/L of solution. Calculate K_{sp}.

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21 NEUTRALIZATION
CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A.

Column A	Column B
_____ **1.** the product of the ion concentration terms in a dissociation equation, each raised to the power of the coefficient of the ion	**a.** normality
_____ **2.** the concentration of a solution expressed as the number of equivalents of solute in one liter of solution	**b.** common ion effect
_____ **3.** the addition of a known amount of a standard solution to determine the concentration of another solution	**c.** neutralization reactions
_____ **4.** a solution in which the pH remains constant when small amounts of acid or base are added	**d.** equivalence point
_____ **5.** the amount of an acid (or base) that will give one mole of hydrogen (or hydroxide) ions	**e.** gram equivalent mass
_____ **6.** the process whereby ions of a dissociated salt either accept hydrogen ions from water or donate hydrogen ions to water	**f.** buffer
_____ **7.** reactions in which an acid and a base produce a salt and water	**g.** titration
_____ **8.** the lowering of the solubility of a substance by the addition of a common ion	**h.** solubility product constant
_____ **9.** the mass of one equivalent of a substance	**i.** one equivalent
_____ **10.** the point of neutralization in a titration	**j.** salt hydrolysis

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Which of the following is true about neutralization reactions?
- **a.** They involve strong acids and strong bases.
- **b.** They result in the production of a salt and water.
- **c.** They are all double-replacement reactions.
- **d.** all of these

Name _____ Class _____ Date _____

_____ **12.** The products of the neutralization reaction between $HNO_3(aq)$ and $Ca(OH)_2(aq)$ are:
a. $CaNO_3 + H_2O$
b. $Ca(NO_3)_2 + H_2O$
c. $CaNO_3 + 2H_2O$
d. $Ca(NO_3)_2 + 2H_2O$

_____ **13.** In what ratio would $HCl(aq)$ and $Mg(OH)_2(aq)$ react through neutralization?
a. 1:1
b. 2:1
c. 1:2
d. 2:2

_____ **14.** How many moles of $Mg(OH)_2(aq)$ would be required to neutralize 3.0 mol $HCl(aq)$?
a. 1.5 mol
b. 3.0 mol
c. 6.0 mol
d. 2.0 mol

_____ **15.** Which of the following is true about the substance phenolphthalein?
a. It is used as an indicator for neutralization reactions.
b. Basic solutions containing phenolphthalein are colorless.
c. Acidic solutions containing phenolphthalein are pink.
d. all of these

_____ **16.** If 30.0 mL of 0.250*M* HCl is neutralized by 35.0 mL of a KOH solution, what is the concentration of the KOH solution?
a. 7.50*M*
b. 0.0300*M*
c. 0.214*M*
d. 0.00750*M*

_____ **17.** How many equivalents are contained in one mole of $Mg(OH)_2$?
a. 1
b. 2
c. 58.3
d. 29.2

_____ **18.** The mass of one equivalent of $Ba(OH)_2$ is:
a. 85.6 g.
b. 154.3 g.
c. 171.3 g.
d. 77.2 g.

_____ **19.** The normality of a 2.50*M* H_2SO_4 solution is:
a. 2.50*N*
b. 5.00*N*
c. 1.25*N*
d. 0.625*N*

_____ **20.** What is the normality of a solution containing 14.8 g of $Ca(OH)_2$ in 250.0 mL?
a. 0.0592*N*
b. 37.0*N*
c. 0.400*N*
d. 1.60*N*

_____ **21.** What volume of 0.300*N* HCl would be required to neutralize 30.0 mL of 0.400*N* $Ba(OH)_2$?
a. 22.5 mL
b. 12.0 mL
c. 40.0 mL
d. 4.00 mL

_____ **22.** Hydrolyzing salts are usually derived from:
a. a strong acid and a strong base
b. a weak acid and a weak base
c. a strong acid and a weak base or a weak acid and a strong base.
d. none of these

Name _____ Class _____ Date _____

_____ **23.** Which of the following is true about a buffer?

a. Its pH value remains relatively constant when small amounts of acid or base are added.

b. It may consist of a weak acid and one of its salts.

c. It has a limited capacity beyond which significant pH changes occur.

d. all of these

_____ **24.** The K_{sp} expression for $CaCl_2$ at equilibrium is:

a. $K_{sp} = \dfrac{[Ca^{2+}][2Cl^-]}{[CaCl_2]}$

b. $K_{sp} = \dfrac{[Ca^{2+}][2Cl^-]^2}{[CaCl_2]}$

c. $K_{sp} = [Ca^{2+}][2Cl^-]^2$

d. $K_{sp} = [Ca^{2+}][Cl^-]^2$

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **25.** When an acid reacts with a base, a neutral solution results.

_____ **26.** In titration, the end point is where the indicator changes color.

_____ **27.** In neutralization reactions, one mole of an acid will neutralize one mole of a base.

_____ **28.** At the equivalence point in a titration, the number of equivalents of acid and base is equal.

_____ **29.** If the K_{sp} for a given solution exceeds the ion product for that solution, a precipitate will form.

D. Problems

Solve the following problems in the space provided. Show your work.

30. Write complete and balanced equations for each of the following neutralization reactions:

a. $HF(aq) + KOH(aq) \rightarrow$

b. $HNO_3(aq) + Ba(OH)_2(aq) \rightarrow$

c. $H_2SO_4(aq) + LiOH(aq) \rightarrow$

d. $H_3PO_4(aq) + Ca(OH)_2(aq) \rightarrow$

31. How many moles of sulfuric acid would be required to neutralize 0.35 mol of KOH?

32. What is the molarity of a solution of HCl if 27.4 mL of 0.0154*M* $Ba(OH)_2$ is required to neutralize 20.0 mL of the HCl solution?

33. What volume of 0.750*N* $Al(OH)_3$ would be required to neutralize 50.0 mL of 0.350*N* H_2SO_4?

34. If the K_{sp} for a CuCl solution is 3.2×10^{-7}, what is the concentration of Cu and of Cl ions at equilibrium?

E. Essay

Write a short essay for the following.

35. Explain the relationship between the normality and the molarity of a 0.25*M* H_3PO_4 solution.

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F. Additional Questions and Problems

Answer the following questions and solve the problems in the space provided. Show your work.

36. How many equivalents are contained in 15.0 g of H_3PO_4?

37. What is the normality of a solution of H_3PO_4 if 250.0 mL are neutralized by 150.0 mL of 4.0*N* $Mg(OH)_2$?

38. The K_{sp} for $CaSO_4$ is 6.10×10^{-5}. What is the sulfate ion concentration of a 1.00-L solution of $CaSO_4$ to which 0.450 mol of $Ca(NO_3)_2$ is added?

39. If 0.50 L of $1.0 \times 10^{-7}M$ $AgNO_3$ is mixed with 0.50 L of $2.0 \times 10^{-9}M$ NaCl, will AgCl precipitate out? K_{sp} for AgCl = 1.8×10^{-10}

40. If 500.0 mL of 0.400*M* $Pb(NO_3)_2$ is added to 500.0 mL of 0.200*M* Na_2SO_4, will a precipitate of $PbSO_4$ be produced? K_{sp} for $PbSO_4$ = 1.8×10^{-8}

21 NEUTRALIZATION
PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
21.1 Neutralization Reactions **Objectives** ▸ Explain how acid-base titration is used to calculate the concentration of an acid or a base ▸ Explain the concept of equivalence in neutralization reactions	**Discover It!** *Reaction of an Acid with an Egg,* p. 612 **Mini Lab** *The Neutralizing Power of Antacids,* p. 615 **Sample Problems** 21-2 through 21-8 **Link to Cosmetology** *Neutral Curls from Permanent Waves,* p. 619 **Small-Scale Lab** *Small-Scale Titrations,* p. 625	**Review Module** (Chapters 21–24) ▸ Section Review 21.1 ▸ Practice Problems ▸ Quizzes **Laboratory Recordsheets** 21-1 and 21-2 **Laboratory Manual** ▸ Experiment 39: *Neutralization Reactions* ▸ Experiment 40: *Acid-Base Titrations* **Laboratory Practical** 21-1 **Small-Scale Chemistry Lab Manual,** Experiment 29: *Titration Curves*
21.2 Salts in Solution **Objectives** ▸ Demonstrate with equations how buffers resist changes in pH ▸ Calculate the solubility product constant of a slightly soluble salt	**Link to Biology** *Blood Buffers,* p. 629 **CHEMath** *Algebra and K_{sp},* p. 633 **Sample Problems** 21-9 through 21-13 **Chemistry Serving . . . Industry** *Extreme Organisms,* p. 638 **Chemistry in Careers** *Microbiologist,* p. 638	**Review Module** ▸ Section Review 21.2 ▸ Practice Problems ▸ Interpreting Graphics ▸ Vocabulary Review 21 ▸ Chapter 21 Tests and Quizzes **Laboratory Manual** ▸ Experiment 41: *Salt Hydrolysis* ▸ Experiment 42: *Buffers* ▸ Experiment 43: *A Solubility Product Constant* **Small-Scale Chemistry Lab Manual,** Experiment 30: *Buffers* **Solutions Manual for Chapter Reviews**

TECHNOLOGY RESOURCES

Internet Connections
Within this chapter, you will see the chemSURF logo. If you and your students have access to the Internet, the following URL address will provide various Internet connections that are related to topics and features presented in this chapter.

http://www.chemsurf.com

You can also find relevant chapter material at
The Chemistry Place address:
http://www.chemplace.com

CD-ROMs

Chem ASAP! CD-ROM
- Chapter 21

ResourcePro CD-ROM
- Chapter 21

ActivChemistry CD-ROM
- Acid-Base Titrations

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Milk of Magnesia
- Titration

Small-Scale Lab Video and Videodisc
- #8: Titrations
- #11: Small-Scale pH-Meter

ASSESSMENT

Student Edition
- Section Reviews 21.1–21.2
- Chapter 21 Review, pp. 639–642
- Alternative Assessment, p. 643

Teacher's Resource Package
Review Module (Chap. 21–24)
- Vocabulary Review
- Chapter 21 Test A and Test B
- Chapter 21 Quizzes

Technology
Chem ASAP! CD-ROM
- Assessment 21.1–21.2

Assessment Resources CD-ROM
- Chapter 21 Tests

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 612
- eggs
- small containers
- white vinegar
- paper
- pens or pencils
- clocks

Mini Lab p. 615
- antacids (several brands)
- mortar and pestle
- paper towels
- measuring teaspoons
- clear plastic cups
- droppers
- universal indicator
- white vinegar
- sodium hydrogen carbonate

Small-Scale Lab, p. 625
- plastic cups
- well strips
- pipettes
- NaOH
- HNO_3
- HCl
- H_2SO_4
- CH_3COOH
- phenolphthalein

TEACHER'S EDITION

Teacher Demo, p. 614
- equimolar solutions of HCl and NaOH
- phenolphthalein indicator
- protective goggles
- laboratory apron
- electric stirrer with a magnetic stir bar
- beaker
- table salt

Teacher Demo, p. 617
- beaker
- acid
- buret
- pH meter

Teacher Demo, p. 622
- 1.0*M* HCl
- pH meter

Teacher Demo, p. 627
- 1*M* solutions of the following salts:
  NH_4NO_3
  KCl
  $NaHCO_3$
  Na_2SO_3
- pH meter *or* universal pH paper

Teacher Demo, p. 634
- saturated solutions of: silver chloride and silver nitrate
- 2 test tubes

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21.1 NEUTRALIZATION REACTIONS
SECTION REVIEW

Objectives

- Explain how acid–base titration is used to calculate the concentration of an acid or a base
- Explain the concept of equivalence in neutralization reactions

Key Terms

- neutralization reactions
- standard solution
- titration
- end point
- equivalent (equiv)
- gram equivalent mass
- normality (N)
- equivalence point

Key Equations

- Acid + Base → Salt + Water
- Gram equivalent mass = $\frac{\text{molar mass}}{\text{number of ionizable hydrogens}}$
- Normality (N) = equiv/L
- $N_1 \times V_1 = N_2 \times V_2$
- $N_A \times V_A = N_B \times V_B$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

In the reaction of a(n) __1__ with a base, hydrogen ions and __2__ ions react to produce __3__. This reaction, called __4__, is usually carried out by __5__. The __6__ in a titration is the point at which the solution is neutral. At the __7__ point of a titration the number of equivalents of acid equals the number of equivalents of base.

An equivalent of acid is the __8__ of the acid that provides __9__ of hydrogen ions in solution. A solution that contains one equivalent of an acid or a base in one liter of solution is a one normal (1N) solution. Thus, a 2N solution of H_2SO_4 contains __10__ of H^+ per liter of solution.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** A solution of known concentration is called a standard solution.

_____ **12.** The end point of a titration of a strong base with a strong acid occurs when $[H^+] = [OH^-]$.

_____ **13.** The gram molecular mass of a substance is the same as its gram equivalent mass.

_____ **14.** A 1*M* solution of H_2SO_4 is 2*N*.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** titration	**a.** number of equivalents of solute in one liter of solution
_____ **16.** neutralization reactions	**b.** a solution of known concentration
_____ **17.** normality (*N*)	**c.** a process for determining the concentration of a solution by adding a known amount of a standard solution
_____ **18.** standard solution	**d.** point of neutralization
_____ **19.** end point	**e.** reactions between acids and bases to produce a salt and water

Part D Questions and Problems

Answer the following in the space provided.

20. Complete and balance the equations for the following acid–base reactions.

a. $H_3PO_4 + Al(OH)_3$

_____

b. $HI + Ca(OH)_2$

_____

Name _____ Class _____ Date _____

21.2 SALTS IN SOLUTION
SECTION REVIEW

Objectives

- Demonstrate with equations how buffers resist changes in pH
- Calculate the solubility product constant of a slightly soluble salt

Key Terms

- salt hydrolysis
- buffers
- buffer capacity
- solubility product constant (K_{sp})
- common ion
- common ion effect

Key Equation

- For a slightly soluble salt (MX), $K_{sp} = [M^+] \times [X^-]$

Part A Completion

Use this completion exercise to check your understanding of the concepts and terms that are introduced in this section. Each blank can be completed with a term, short phrase, or number.

A __1__ forms when an acid is neutralized by a base. Salts can be neutral, __2__, or __3__ in solutions. Salts of strong acid–strong base reactions produce __4__ solutions with water. Salts formed from the neutralization of weak acids or weak bases __5__ water. They produce solutions that are acidic or basic.

For example, the pH of a solution at the equivalence point is greater than 7 for a __6__ base-__7__ acid titration. Solutions that resist changes in pH are called __8__ solutions. The buffer __9__ is the amount of acid or base that can be added to a buffer without changing the pH greatly. The __10__ is the equilibrium constant for the equilibrium between an ionic solid and its ions in solution.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Name _____ Class _____ Date _____

Part B True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **11.** An aqueous solution of NH_4Cl is basic.

_____ **12.** HCl–NaCl would be a good buffer system.

_____ **13.** The term *common ion effect* refers to the lowering of the solubility of a substance by the addition of a common ion.

_____ **14.** If the ion-product concentration of two ions in solution is less than the K_{sp} of the compound formed from the ions, no precipitate will form.

Part C Matching

Match each description in Column B to the correct term in Column A.

Column A	Column B
_____ **15.** solubility product constant (K_{sp})	**a.** an equilibrium constant that can be applied to the solubility of electrolytes
_____ **16.** buffer	**b.** a decrease in the solubility of a substance caused by the addition of a common ion
_____ **17.** common ion effect	**c.** the salt produced by the titration of ammonia with hydrochloric acid.
_____ **18.** NH_4Cl	**d.** a solution in which the pH remains relatively constant when small amounts of acid or base are added

Part D Questions and Problems

Answer the following in the space provided.

19. Will a precipitate form when 0.00070 mol Na_2CO_3 is mixed with 0.0015 mol $Ba(OH)_2$ in one liter of solution? Assume that these two salts both dissolve completely. Refer to Table 21.4 in your textbook.

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21 NEUTRALIZATION
PRACTICE PROBLEMS

In your notebook, solve the following problems.

SECTION 21.1 NEUTRALIZATION REACTIONS

1. What is the molarity of a sodium hydroxide solution if 38 mL of the solution is titrated to the end point with 14 mL of 0.75*M* sulfuric acid?
2. If 24.6 mL of a $Ca(OH)_2$ solution are needed to neutralize 14.2 mL of 0.0140*M* $HC_2H_3O_2$, what is the concentration of the calcium hydroxide solution?
3. A 12.4 mL solution of H_2SO_4 is completely neutralized by 19.8 mL of 0.0100*M* $Ca(OH)_2$. What is the concentration of the H_2SO_4 solution?
4. What volume of 0.12*M* $Ba(OH)_3$ is needed to neutralize 12.2 mL of 0.25*M* HCl?
5. A 55.0 mg sample of $Al(OH)_3$ is reacted with 0.200*M* HCl. How many milliliters of the acid are needed to neutralize the $Al(OH)_3$?
6. Calculate the equivalents of KOH in 4.20 L of 1.20*N* KOH.
7. What is the normality of 0.40*M* H_3PO_4?
8. What is the normality of 1.50 L of solution that contains 24.6 g HCl?
9. How many milliliters of 0.250*N* H_2SO_4 are required to titrate 68.0 mL of 0.110*N* NaOH to the end point?

SECTION 21.2 SALTS IN SOLUTION

1. A buffer solution is prepared by mixing together equal quantities of formic acid, $HCHO_2$, and sodium formate, $NaCHO_2$. Write equations that show what happens when first acid, and then base, is added to this buffer solution.
2. Write the solubility product expression for **a.** $Ca(OH)_2$ and **b.** Ag_2CO_3.
3. What is the concentration of silver ions in a saturated solution of silver carbonate? The K_{sp} of Ag_2CO_3 is 8.1×10^{-12}.
4. The equilibrium concentration of hydroxide ions in a saturated solution of iron(II) hydroxide is $1.2 \times 10^{-5}M$ at a certain temperature. Calculate the K_{sp} of $Fe(OH)_2$ at this temperature.
5. Strontium carbonate has a $K_{sp} = 9.3 \times 10^{-10}$ at 25 °C. What is the concentration of strontium ions in a saturated solution of $SrCO_3$?
6. What is the equilibrium concentration of silver ions at 25 °C in a 1.0-L saturated solution of silver carbonate to which 0.20 mol of Na_2CO_3 has been added. The K_{sp} of Ag_2CO_3 is 8.1×10^{-12} at 25 °C.
7. Will a precipitate of $PbSO_4$ form when 400.0 mL of 0.0050*M* $MgSO_4$ is mixed with 600.0 mL of 0.0020*M* $Pb(NO_3)_2$? The K_{sp} of $PbSO_4 = 6.3 \times 10^{-7}$.
8. Will precipitation of $CaCO_3$ occur when 500.0 mL of $4.2 \times 10^{-3}M$ $CaCl_2$ is mixed with 500.0 mL of $2.6 \times 10^{-3}M$ Na_2CO_3? The K_{sp} of $CaCO_3$ is 4.5×10^{-9}.
9. Which of these compounds would not decrease the solubility of $Mg(OH)_2$ when added to a saturated solution of the compound?

NaOH, $MgCl_2$, NaCl, KOH

Name _____ Class _____ Date _____

21 INTERPRETING GRAPHICS

USE WITH SECTION 21.2

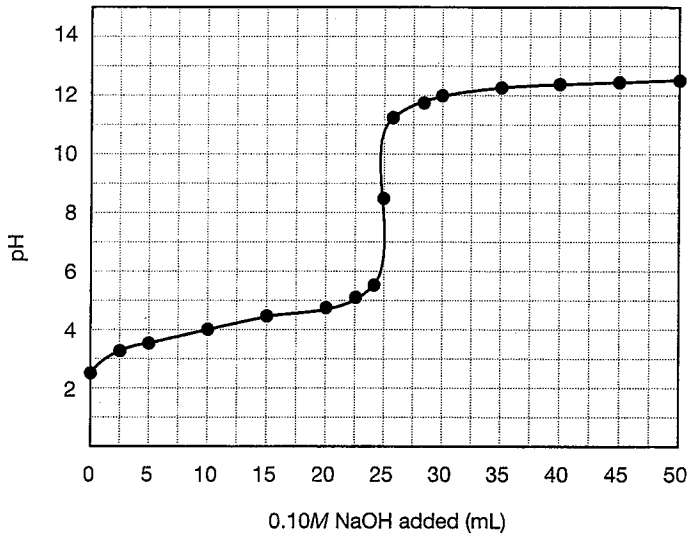

Figure 1 The pH curve for the titration of a benzoic acid (C_6H_5COOH) solution with a standard solution of 0.10*M* sodium hydroxide (NaOH).

The plot shown in Figure 1 shows how the pH of a benzoic acid solution of unknown concentration changes as a function of the volume of 0.10M NaOH added. The starting volume of benzoic acid solution was 25 mL. Use this titration curve to answer the following questions.

1. Write the chemical equation for the reaction of benzoic acid ($C_6H_5COO\mathbf{H}$) with NaOH. Note that the acidic hydrogen atom in benzoic acid is shown in bold. How many moles of benzoic acid are neutralized per mole of NaOH added?

_____

_____

2. Estimate the pH of the solution at the equivalence point of the titration. Is the solution acidic, neutral, or basic at the equivalence point?

_____

_____

3. Based on your estimate of the pH at the equivalence point, characterize benzoic acid as a weak acid or a strong acid? Explain your answer.

_____

_____

4. How many moles of NaOH were needed to reach the equivalence point?

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5. Define the equivalence point in this reaction. What are [NaOH], [C_6H_5COOH], and [C_6H_5COONa] at the equivalence point?

6. What is the concentration of benzoic acid in the original "unknown" solution?

7. Refer to Figure 20.8 in your textbook. Which of the acid–base indicators shown would be most appropriate for this particular titration? Label the titration curve in Figure 1 to indicate the range of pH values for which your chosen indicator is most effective.

8. At the equivalence point, the pH of the solution is determined be the hydrolysis of the sodium benzoate salt, C_6H_5COONa. Write the chemical equation showing the hydrolysis of water by the benzoate ion ($C_6H_5COO^-$). How does this equation support your answer to question 2?

9. Use your answer to question 8 to write the base dissociation constant (K_b) expression for the reaction of benzoate ion with water.

10. Based on your estimate of the pH at the equivalence point and using the expression for K_b, determine the numerical value of K_b for the benzoate ion ($C_6H_5COO^-$).

Name _____ Class _____ Date _____

21 VOCABULARY REVIEW

Select the term from the following list that best matches each description.

equivalence point	neutral salts
normality (N)	one equivalent
hydrolyzing salts	buffer
neutral	solubility product constant (K_{sp})

1. compounds derived from the reaction of a strong base with a weak acid or from the reaction of a strong acid with a weak base

_____

2. a measure of the equilibrium concentrations of ions in a saturated solution of a sparingly soluble salt

_____

3. a term used to describe the pH of a solution that results when one equivalent of a strong acid is mixed with one equivalent of a strong base

_____

4. the point in a titration at which the number of equivalents of acid and base are equal

_____

5. a unit of concentration used to express the number of equivalents of a solute, such as an acid or base, in one liter of solution

_____

6. compounds that are derived from the neutralization of a strong acid with a strong base

_____

7. a solution that consists of a weak acid and the salt of a weak acid, or that consists of a weak base and the salt of a weak base

_____

8. the amount of an acid or base that can give one mole of hydrogen or hydroxide ions

_____

Name _____ Class _____ Date _____

21 NEUTRALIZATION

Quiz for CHAPTER 21

Choose the best answer and write its letter in the blank.

_____ **1.** How many milliters of 0.20*N* NaOH are required to neutralize 40 mL of 0.50*N* HCl? *21.1*

a. 12 mL **c.** 75 mL
b. 50 mL **d.** 100 mL

_____ **2.** A 100-mL sample of hydrobromic acid, HBr, is titrated to an end point with 24.0 mL of 1.5*N* NaOH. What is the concentration of HBr? *21.1*

a. 0.36*N* **c.** 2.8*N*
b. 0.72*N* **d.** 1.4*N*

_____ **3.** The reaction that takes place when an acid is added to an ethanoic acid-ethanoate (CH_3COOH/CH_3COO^-) buffer is: *21.2*

a. $CH_3COO^- + H^+ \rightleftharpoons CH_4 + CO_2$
b. $CH_3COOH + H^+ \rightleftharpoons CH_3COO^- + H^+$
c. $CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$
d. $CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$

_____ **4.** Which of the following would *not* make a good buffering system? *21.2*

a. sulfate ion and sulfuric acid
b. hydrogen carbonate ion and carbonic acid
c. ammonia and ammonium ion
d. ethanoate ion and ethanoic acid

_____ **5.** Which substance, when dissolved in water, will produce a solution with a pH greater than 7? *21.2*

a. CH_3COOH **c.** $KC_2H_3O_2$
b. KCl **d.** NaCl

_____ **6.** Which salt hydrolyzes water to form a solution that is acidic? *21.2*

a. LiBr **c.** NaBr
b. NH_4Br **d.** KBr

_____ **7.** Given the reaction at equilibrium: *21.2*

$$Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2OH^-(aq)$$

what is the expression for the solubility product constant, K_{sp} for this reaction?

a. $K_{sp} = [Zn^{2+}] \times [2OH^-]$ **c.** $K_{sp} = \dfrac{[Zn^{2+}] \times [OH^-]}{[Zn(OH)_2]}$

b. $K_{sp} = [Zn^{2+}] \times [OH^-]^2$ **d.** $K_{sp} = \dfrac{[Zn(OH)_2]}{[Zn^{2+}] \times [OH^-]}$

_____ **8.** When 0.1*M* HCl is added to the following system at equilibrium: *21.2*

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$$

the point of equilibrium will shift to the:

a. right and the concentration of $Ag^+(aq)$ will decrease.
b. right and the concentration of $Ag^+(aq)$ will increase.
c. left and the concentration of $Ag^+(aq)$ will decrease.
d. left and the concentration of $Ag^+(aq)$ will increase.

Name _____ Class _____ Date _____

21 NEUTRALIZATION
CHAPTER TEST A

A. Matching

Match each term in Column B with the correct description in Column A.

Column A	Column B
_____ **1.** the amount of an acid (or base) that will give one mole of hydrogen (or hydroxide) ions	**a.** buffer
_____ **2.** the point at which neutralization is achieved	**b.** titration
_____ **3.** the addition of a known amount of a standard solution to determine the concentration of another solution	**c.** end point
_____ **4.** the concentration of a solution expressed as the number of equivalents of solute in one liter of solution	**d.** equivalent
_____ **5.** a solution in which pH remains relatively constant when small amounts of acid or base are added	**e.** neutralization reaction
_____ **6.** production of a salt and water by an acid and a base in aqueous solution	**f.** normality
_____ **7.** a solution of known concentration	**g.** salt hydrolysis
_____ **8.** process in which ions of a dissociated salt accept hydrogen ions from water or donate hydrogen ions to water	**h.** standard solution

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **9.** The products of the reaction of one mole of $Ca(OH)_2$ and one mole of H_2SO_4 are:

a. $CaSO_4 + H_3O^+ + H_2O$
b. $CaSO_4 + H_3O^+ + OH^-$
c. $CaH_2 + H_3SO_4$
d. $CaSO_4 + 2H_2O$

_____ **10.** A solution that contains one mole of the diprotic acid oxalic acid ($H_2C_2O_4$) per liter is:

a. 1*N*.
b. 0.5*N*.
c. 2*N*.
d. none of these

_____ **11.** How many grams of sodium hydroxide are in 500 mL of a 0.2*N* NaOH solution?

a. 2 g
b. 4 g
c. 20 g
d. 40 g

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_____ **12.** What is the gram equivalent mass of KOH?
a. 56.1 g **c.** 28.1 g
b. 1.0 g **d.** 112 g

_____ **13.** A solution labeled 1*N* H_2SO_4 contains how many moles of H_2SO_4 per liter?
a. 0.5 mol/L **c.** 0.2 mol/L
b. 1 mol/L **d.** 2 mol/L

_____ **14.** The hydrolysis of water by the salt of a weak base and a strong acid should give a solution that is:
a. weakly basic. **c.** strongly basic.
b. neutral. **d.** acidic.

_____ **15.** A basic solution would result from the hydrolysis of one of the ions in the compound:
a. KNO_3. **c.** CH_3COOK.
b. NH_4Cl. **d.** $MgCl_2$.

_____ **16.** A solution of one of the following compounds is acidic because one of its ions undergoes hydrolysis. The compound is:
a. KCl. **c.** CH_3COOK.
b. NH_4Cl. **d.** NH_3.

C. True–False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **17.** At the equivalence point of titration, the volume of acid equals the volume of base.

_____ **18.** A solution containing only water and sodium acetate, $NaC_2H_3O_2$, has a pH of less than 7.

_____ **19.** A hydrolysis reaction involves the splitting of a covalent bond in water.

_____ **20.** The number of ionizable hydrogens in an acid must be known to calculate the gram equivalent mass of the acid.

_____ **21.** In a titration, the amount of acid added to a base is used to calculate the concentration of the base.

D. Problems

Solve the following problems in the space provided. Show your work.

22. How many equivalents are in 20.5 g of sulfurous acid, H_2SO_3?

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23. Write complete and balanced equations for each of the following acid–base reactions.

a. $H_3PO_4 + Ca(OH)_2 \rightarrow$

b. $HBr + Mg(OH)_2 \rightarrow$

c. $H_2SO_4 + Al(OH)_3 \rightarrow$

d. $HCl + NH_4OH \rightarrow$

24. A 50.0-mL sample of hydrobromic acid, HBr, is titrated to an end point with 20.0 mL of 1.50*N* NaOH. What is the concentration of HBr?

25. How many milliliters of 0.600*N* H_2SO_4 are required to neutralize 90.0 mL of 0.40*N* NaOH?

26. How much of a 5.0*N* H_2SO_4 stock solution would you need to make 400.0 mL of 0.20*N* H_2SO_4?

27. Predict whether an aqueous solution of each salt will be acidic, basic, or neutral.

a. Na_2CO_3

b. KNO_3

c. $(NH_4)_2SO_4$

d. $Mg(C_2H_3O_2)_2$

E. Essay

Write a short essay for the following.

28. Explain how the process of titration can be used to determine the concentration of a base.

F. Additional Questions and Problems

Answer the following questions and solve the problems in the space provided. Show your work.

29. What range of pH values is associated with an aqueous solution of each of the following salts? For each answer write: greater than 7, 7, or less than 7.

a. K_3PO_4

b. NH_4Cl

c. $Mg(NO_3)_2$

d. K_2SO_4

e. CH_3COOLi

30. Write equations for the addition of an acid and a base to an ammonium ion-ammonia buffer.

a. When acid is added:

b. When base is added:

31. Will a precipitate of $CaCO_3$ form when 0.96 g of $(NH_4)_2CO_3$ is mixed with 0.20 g of $CaBr_2$ in 20.0 L of solution?

$$K_{sp} \text{ of } CaCO_3 = 4.5 \times 10^{-9}$$

32. The solubility of $CaSO_4$ in water is 0.67 g/L of solution. Calculate K_{sp}.

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21 NEUTRALIZATION
CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A.

Column A	Column B
_____ 1. the product of the ion concentration terms in a dissociation equation, each raised to the power of the coefficient of the ion	**a.** normality
_____ 2. the concentration of a solution expressed as the number of equivalents of solute in one liter of solution	**b.** common ion effect
_____ 3. the addition of a known amount of a standard solution to determine the concentration of another solution	**c.** neutralization reactions
_____ 4. a solution in which the pH remains constant when small amounts of acid or base are added	**d.** equivalence point
_____ 5. the amount of an acid (or base) that will give one mole of hydrogen (or hydroxide) ions	**e.** gram equivalent mass
_____ 6. the process whereby ions of a dissociated salt either accept hydrogen ions from water or donate hydrogen ions to water	**f.** buffer
_____ 7. reactions in which an acid and a base produce a salt and water	**g.** titration
_____ 8. the lowering of the solubility of a substance by the addition of a common ion	**h.** solubility product constant
_____ 9. the mass of one equivalent of a substance	**i.** one equivalent
_____ 10. the point of neutralization in a titration	**j.** salt hydrolysis

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ 11. Which of the following is true about neutralization reactions?
- **a.** They involve strong acids and strong bases.
- **b.** They result in the production of a salt and water.
- **c.** They are all double-replacement reactions.
- **d.** all of these

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_____ **12.** The products of the neutralization reaction between $HNO_3(aq)$ and $Ca(OH)_2(aq)$ are:
a. $CaNO_3 + H_2O$
b. $Ca(NO_3)_2 + H_2O$
c. $CaNO_3 + 2H_2O$
d. $Ca(NO_3)_2 + 2H_2O$

_____ **13.** In what ratio would $HCl(aq)$ and $Mg(OH)_2(aq)$ react through neutralization?
a. 1:1
b. 2:1
c. 1:2
d. 2:2

_____ **14.** How many moles of $Mg(OH)_2(aq)$ would be required to neutralize 3.0 mol $HCl(aq)$?
a. 1.5 mol
b. 3.0 mol
c. 6.0 mol
d. 2.0 mol

_____ **15.** Which of the following is true about the substance phenolphthalein?
a. It is used as an indicator for neutralization reactions.
b. Basic solutions containing phenolphthalein are colorless.
c. Acidic solutions containing phenolphthalein are pink.
d. all of these

_____ **16.** If 30.0 mL of 0.250*M* HCl is neutralized by 35.0 mL of a KOH solution, what is the concentration of the KOH solution?
a. 7.50*M*
b. 0.0300*M*
c. 0.214*M*
d. 0.00750*M*

_____ **17.** How many equivalents are contained in one mole of $Mg(OH)_2$?
a. 1
b. 2
c. 58.3
d. 29.2

_____ **18.** The mass of one equivalent of $Ba(OH)_2$ is:
a. 85.6 g.
b. 154.3 g.
c. 171.3 g.
d. 77.2 g.

_____ **19.** The normality of a 2.50*M* H_2SO_4 solution is:
a. 2.50*N*
b. 5.00*N*
c. 1.25*N*
d. 0.625*N*

_____ **20.** What is the normality of a solution containing 14.8 g of $Ca(OH)_2$ in 250.0 mL?
a. 0.0592*N*
b. 37.0*N*
c. 0.400*N*
d. 1.60*N*

_____ **21.** What volume of 0.300*N* HCl would be required to neutralize 30.0 mL of 0.400*N* $Ba(OH)_2$?
a. 22.5 mL
b. 12.0 mL
c. 40.0 mL
d. 4.00 mL

_____ **22.** Hydrolyzing salts are usually derived from:
a. a strong acid and a strong base
b. a weak acid and a weak base
c. a strong acid and a weak base or a weak acid and a strong base.
d. none of these

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_____ **23.** Which of the following is true about a buffer?

a. Its pH value remains relatively constant when small amounts of acid or base are added.

b. It may consist of a weak acid and one of its salts.

c. It has a limited capacity beyond which significant pH changes occur.

d. all of these

_____ **24.** The K_{sp} expression for $CaCl_2$ at equilibrium is:

a. $K_{sp} = \dfrac{[Ca^{2+}][2Cl^-]}{[CaCl_2]}$

b. $K_{sp} = \dfrac{[Ca^{2+}][2Cl^-]^2}{[CaCl_2]}$

c. $K_{sp} = [Ca^{2+}][2Cl^-]^2$

d. $K_{sp} = [Ca^{2+}][Cl^-]^2$

C. True-False

Classify each of these statements as always true, AT; sometimes true, ST; or never true, NT.

_____ **25.** When an acid reacts with a base, a neutral solution results.

_____ **26.** In titration, the end point is where the indicator changes color.

_____ **27.** In neutralization reactions, one mole of an acid will neutralize one mole of a base.

_____ **28.** At the equivalence point in a titration, the number of equivalents of acid and base is equal.

_____ **29.** If the K_{sp} for a given solution exceeds the ion product for that solution, a precipitate will form.

D. Problems

Solve the following problems in the space provided. Show your work.

30. Write complete and balanced equations for each of the following neutralization reactions:

a. $HF(aq) + KOH(aq) \rightarrow$

b. $HNO_3(aq) + Ba(OH)_2(aq) \rightarrow$

c. $H_2SO_4(aq) + LiOH(aq) \rightarrow$

d. $H_3PO_4(aq) + Ca(OH)_2(aq) \rightarrow$

31. How many moles of sulfuric acid would be required to neutralize 0.35 mol of KOH?

32. What is the molarity of a solution of HCl if 27.4 mL of 0.0154*M* $Ba(OH)_2$ is required to neutralize 20.0 mL of the HCl solution?

33. What volume of 0.750*N* $Al(OH)_3$ would be required to neutralize 50.0 mL of 0.350*N* H_2SO_4?

34. If the K_{sp} for a CuCl solution is 3.2×10^{-7}, what is the concentration of Cu and of Cl ions at equilibrium?

E. Essay

Write a short essay for the following.

35. Explain the relationship between the normality and the molarity of a 0.25*M* H_3PO_4 solution.

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F. Additional Questions and Problems

Answer the following questions and solve the problems in the space provided. Show your work.

36. How many equivalents are contained in 15.0 g of H_3PO_4?

37. What is the normality of a solution of H_3PO_4 if 250.0 mL are neutralized by 150.0 mL of 4.0*N* $Mg(OH)_2$?

38. The K_{sp} for $CaSO_4$ is 6.10×10^{-5}. What is the sulfate ion concentration of a 1.00-L solution of $CaSO_4$ to which 0.450 mol of $Ca(NO_3)_2$ is added?

39. If 0.50 L of $1.0 \times 10^{-7}M$ $AgNO_3$ is mixed with 0.50 L of $2.0 \times 10^{-9}M$ NaCl, will AgCl precipitate out? K_{sp} for AgCl = 1.8×10^{-10}

40. If 500.0 mL of 0.400*M* $Pb(NO_3)_2$ is added to 500.0 mL of 0.200*M* Na_2SO_4, will a precipitate of $PbSO_4$ be produced? K_{sp} for $PbSO_4 = 1.8 \times 10^{-8}$