22 OXIDATION–REDUCTION REACTIONS
PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
22.1 The Meaning of Oxidation and Reduction **Objectives** ▸ Define oxidation and reduction in terms of the loss or gain of oxygen or hydrogen and the loss or gain of electrons ▸ State the characteristics of a redox reaction, and identify the oxidizing agent and reducing agent	**Discover It!** *Rushing*, p. 644 **Link to Photography** *Redox in Photography*, p. 650 **Sample Problem** 22-1	**Review Module** (Chapters 21–24) ▸ Section Review 22.1 ▸ Practice Problems ▸ Quizzes **Laboratory Manual,** Experiment 44: *Oxidation-Reduction Reactions* **Laboratory Practical** 22-1 **Small-Scale Chemistry Lab Manual,** Experiment 31: *Determination of an Activity Series*
22.2 Oxidation Numbers **Objectives** ▸ Determine the oxidation number of an atom of any element in a pure substance ▸ Define oxidation and reduction in terms of a change in oxidation number, and identify atoms being oxidized or reduced in redox reactions	**Sample Problems** 22-2 through 22-4	**Review Module** ▸ Section Review 22.2 ▸ Practice Problems ▸ Quizzes
22.3 Balancing Redox Equations **Objectives** ▸ Use the oxidation-number-change method to balance redox equations ▸ Break a redox equation into oxidation and reduction half-reactions, and then use the half-reaction method to balance the equation	**Link to Biology** *Bioluminescence*, p. 667 **Mini Lab** *Bleach It! Oxidize the Color Away*, p. 669 **Small-Scale Lab** *Half-Reactions*, p. 670 **Sample Problems** 22-5 through 22-7 **Chemistry Serving . . . Society** *Could Fuel Cells Be the Power of the Future?*, p. 671 **Chemistry in Careers** *Mechanical Engineer*, p. 671	**Review Module** ▸ Section Review 22.3 ▸ Practice Problems ▸ Interpreting Graphics ▸ Vocabulary Review 22 ▸ Chapter 22 Tests and Quizzes **Laboratory Recordsheets** 22-1 and 22-2 **Small-Scale Chemistry Lab Manual,** Experiment 32: *Oxidation-Reduction Reactions* **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 22

ResourcePro CD-ROM
- Chapter 22

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Elephant Toothpaste
- Watermelon Surprise
- Thermite Reactions
- Oxidation States of Vanadium
- Oxidizing with Potassium Chloride

Small-Scale Lab Video and Videodisc
- #4: Redox Reactions

Overhead Transparencies
- #70: Oxidation-Reduction Reactions

ASSESSMENT

Student Edition
- Section Reviews 22.1–22.3
- Chapter 21 Review, pp. 672–674
- Alternative Assessment, p. 675

Technology
Chem ASAP! CD-ROM
- Assessment 22.1–22.3

Assessment Resources CD-ROM
- Chapter 22 Tests

Teacher's Resource Package
Review Module (Chap. 21–24)
- Vocabulary Review
- Chapter 22 Test A and Test B
- Chapter 22 Quizzes

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 644
- iron finishing nails
- pliers
- scissors
- copper wire
- zinc strips
- fine sandpaper
- plastic wrap
- saucers
- water
- table salt
- petroleum jelly
- paper towels

Mini Lab p. 669
- spot plates
- medicine droppers
- water
- various oxidizing agents
- various samples: stains or colors

Small-Scale Lab, p. 670
- pencils
- paper
- rulers
- reaction surfaces
- chemicals

TEACHER'S EDITION

Teacher Demo, p. 646
- 3 g copper (II) oxide (CuO)
- 3 g charcoal (C)
- crucible
- Bunsen burner
- tongs
- glass plate

Teacher Demo, p. 655
- 100 mL of 0.1*M* lead(II) acetate [$Pb(CH_3COO)_2$]
- 150-mL beaker
- 1-cm × 3-cm zinc strip
- threefold molar excess of sodium sulfide
- 3*M* NaCH
- threefold excess of 1*M* iron(III) chloride
- plastic container

Activity, p. 657
- for each pair of students: 3 small, glass test tubes containing a small portion of zinc, copper, and magnesium
- for each pair: 10 drops of 0.1*M* HCl

Teacher Demo, p. 662
- 6 crystals of potassium permanganate ($KMnO_4$)
- 500 mL of water
- large beaker
- 1 g sodium hydrogen sulfite ($NaHSO_8$)
- 20 mL of water
- two 50-mL beakers
- 1 g barium chloride dihydrate ($BaCl_2 \cdot 2H_2O$)
- 20 mL of water
- 3*M* H_2SO_4
- plastic container

Teacher Demo, p. 665
- two 600-mL beakers
- 8 mL of 6*M* H_2SO_4
- 125 mL distilled water
- 43 g of sodium pyrophosphate decahydrate ($NaP_2O_7 \cdot 10H_2O$)
- 72 mL 6*M* H_2SO_4
- 80 mL of 0.1*M* $MnSO_4$
- 40 mL of 0.25*M* potassium bromate ($KBrO_3$)
- stir bar
- magnetic stirrer

Activity, p. 667
- potatoes and apples
- beakers
- tap waters
- boiled water
- lemon juice
- carbonated beverage
- sugar, salt, vinegar solutions
- paper towels

Name _____ Class _____ Date _____

22.1 THE MEANING OF OXIDATION AND REDUCTION
SECTION REVIEW

Objectives

- Define oxidation and reduction in terms of the loss or gain of oxygen or hydrogen and the loss or gain of electrons
- State the characteristics of a redox reaction and identify the oxidizing agent and reducing agent

Key Terms

- oxidation
- reduction
- redox reactions
- oxidation-reduction reactions
- reducing agent
- oxidizing agent

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.

Oxidation–reduction, or ___1___, reactions are an important category of chemical reactions. Oxidation is considered to be any shift of electrons ___2___ from an atom. Reduction includes any shift of electrons ___3___ an atom. An oxidation reaction is always accompanied by a ___4___ reaction. The substance that does the oxidizing (the ___5___ agent) is ___6___. The substance that does the reducing (the ___7___ agent) is ___8___.

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

Part B True-False

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

_____ **9.** Reduction is the complete or partial gain of electrons by a substance.

_____ **10.** In the reaction $2Na + Cl_2 \rightarrow 2NaCl$, sodium is the reducing agent.

_____ **11.** In the reaction $2Na + Cl_2 \rightarrow 2NaCl$, sodium is being reduced.

_____ **12.** To protect an iron ship hull, you should attach a metal that is easily reduced.

Name _____ Class _____ Date _____

Part C Matching

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

Column A	Column B
_____ **13.** combustion	**a.** a metal that loses electrons easily
_____ **14.** oxidation	**b.** complete or partial loss of electrons or gain of oxygen
_____ **15.** oxidizing agent	**c.** oxidation of metals to metallic ions by oxygen and water in the environment
_____ **16.** corrosion	**d.** a metal that resists corrosion
_____ **17.** zinc	**e.** a chemical change in which oxygen reacts with another substance, often producing energy in the form of heat and light
_____ **18.** gold	**f.** a substance that accepts electrons in a redox reaction

Part D Questions and Problems

Answer the following in the space provided.

19. Define oxidation and reduction in terms of the loss or gain of electrons.

20. In the equation given, identify the substance oxidized, the substance reduced, the oxidizing agent, and the reducing agent.

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

21. Explain how putting a block of zinc or aluminum on the iron hull of a large ship will protect the ship from corrosion.

Name _____ Class _____ Date _____

22.2 OXIDATION NUMBERS
SECTION REVIEW

Objectives

- Determine the oxidation number of an atom of any element in a pure substance
- Define oxidation and reduction in terms of a change in oxidation number, and identify atoms being oxidized or reduced in redox reactions

Key Term

- oxidation number

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.

The oxidation number of an element in an uncombined state is __1__. The oxidation number of a monatomic ion is the same in magnitude and __2__ as its ionic __3__. The sum of the oxidation numbers of the elements in a neutral compound is __4__. In a polyatomic ion, however, the sum is equal to the __5__. Oxidation numbers help you keep track of __6__ – transfer in redox reactions. An oxidation number increase is __7__, while a __8__ is reduction.

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

Part B True-False

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

_____ **9.** Oxygen is more electronegative than chlorine.

_____ **10.** The oxidation number of each oxygen atom in most compounds is −2.

_____ **11.** The oxidation number of Cl in $KClO_3$ is −1.

_____ **12.** The oxidation number of each hydrogen atom in most compounds is −1.

_____ **13.** The oxidation number for copper in a copper penny is +2.

_____ **14.** In the reaction, $C + H_2O \rightarrow CO + H_2$, the oxidation number of the hydrogen doesn't change.

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_____ **15.** In the reaction, $C + H_2O \rightarrow CO + H_2$, the oxidation number of the carbon increases.

_____ **16.** An increase in the oxidation number of an atom indicates oxidation.

Part C Matching

Match the oxidation number of nitrogen in each formula in Column B to the correct oxidation number in Column A.

Column A	Column B
_____ **17.** −3	**a.** N_2
_____ **18.** −2	**b.** HNO_3
_____ **19.** −1	**c.** NO
_____ **20.** 0	**d.** NH_2OH
_____ **21.** +1	**e.** NH_3
_____ **22.** +2	**f.** N_2O_3
_____ **23.** +3	**g.** N_2O
_____ **24.** +4	**h.** N_2H_4
_____ **25.** +5	**i.** NO_2

Part D Questions and Problems

Answer the following in the space provided.

26. Define oxidation and reduction in terms of a change in oxidation number.

_____

_____

27. Use the change in oxidation number to determine which elements are oxidized and which are reduced in these reactions. (Note: It is not necessary to use balanced equations.)

a. $HNO_3 + HBr \rightarrow NO + Br_2 + H_2O$ _____

b. $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$ _____

c. $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$ _____

d. $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$ _____

Name _____ Class _____ Date _____

22.3 BALANCING REDOX EQUATIONS

SECTION REVIEW

Objectives

- Use the oxidation-number-change method to balance redox equations
- Break a redox equation into oxidation and reduction half-reactions, and then use the half-reaction method to balance the equation

Key Terms

- oxidation-number-change method
- half-reactions
- half-reaction method

Part A Completion

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

One method for balancing redox equations involves determining the change in __1__ of the substances that are oxidized and reduced. Coefficients are then used to make the increase in oxidation number equal to the decrease.

The __2__ method is another way to write a __3__ equation for a redox reaction. In this method, the net __4__ equation is divided into __5__ half-reactions. Each half-reaction is balanced independently. Finally, the half-reactions are __6__. The half-reaction method is particularly useful in balancing equations for __7__ reactions.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Part B True-False

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

_____ **8.** The reduction half-reaction in the reaction $MnO_4^- + Cl^- \rightarrow Mn^{2+} + Cl_2$ involves: $MnO_4^- \rightarrow Mn^{2+}$

_____ **9.** In an oxidation half-reaction, electrons occur on the right side of the equation

Name _____ Class _____ Date _____

_____ **10.** Electrons never appear in a balanced redox reaction.

_____ **11.** $2e^- + 2Cl^- \rightarrow Cl_2$ is a balanced half-reaction.

_____ **12.** To balance the oxygen in a half reaction involving $MnO_4^- \rightarrow Mn^{2+}$, $2H_2O$ will be added to the product side of the equation.

_____ **13.** In the equation $2FeBr_2 + Br_2 \rightarrow 2FeBr_3$, the oxidation number of the iron doesn't change.

Part C Matching

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

Column A	Column B
_____ **14.** half-reaction method	**a.** ions that are present but do not participate in or change during the reaction
_____ **15.** spectator ions	**b.** $Fe^{2+} \rightarrow Fe^{3+} + e^-$
_____ **16.** anions	**c.** balancing a redox equation by first balancing the oxidation and reduction half-reactions
_____ **17.** oxidation half-reaction	**d.** balancing a redox equation by comparing the increase and decrease in oxidation numbers
_____ **18.** half-reaction	**e.** equation showing either the reduction or the oxidation of a species in an oxidation-reduction reaction
_____ **19.** oxidation-number-change method	**f.** ions that can serve as reducing agents
_____ **20.** reduction half-reaction	**g.** $2e^- + Br_2 \rightarrow 2Br^-$

Part D Questions and Problems

Answer the following in the space provided.

21. Balance these redox equations using the oxidation-number-change method.

a. $HNO_3(aq) + HI(g) \rightarrow NO(g) + I_2(s) + H_2O$

b. $HNO_3(aq) + I_2(s) \rightarrow HIO_3(aq) + NO_2(g) + H_2O(l)$

22. Balance these redox equations using the half-reaction method.

a. $H_2S(aq) + HNO_3(aq) \rightarrow S(s) + NO(g) + H_2O(l)$

b. $Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS
PRACTICE PROBLEMS

In your notebook, solve the following problems.

SECTION 22.1 THE MEANING OF OXIDATION AND REDUCTION

Determine what is oxidized and what is reduced in each reaction. Identify the oxidizing agent and the reducing agent.

1. $2Sr + O_2 \rightarrow 2SrO$
2. $2Li + S \rightarrow 2Li_2S$
3. $2Cs + Br_2 \rightarrow 2CsBr$
4. $3Mg + N_2 \rightarrow Mg_3N_2$
5. $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
6. $Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$
7. $Si + 2F_2 \rightarrow SiF_4$
8. $2Ca + O_2 \rightarrow 2CaO$
9. $Mg + 2HCl \rightarrow MgCl_2 + H_2$
10. $2Na + 2H_2O \rightarrow 2NaOH + H_2$

SECTION 22.2 OXIDATION NUMBERS

1. Give the oxidation number of each kind of atom or ion.

   a. Sn **c.** S^{2-} **e.** Se **g.** Sn^{4+}

   b. K^+ **d.** Fe^{3+} **f.** Mg^{2+} **h.** Br^-

2. Calculate the oxidation number of chromium in each of the following formulas.

   a. Cr_2O_3 **b.** $H_2Cr_2O_7$ **c.** $CrSO_4$ **d.** CrO_4^{2-}

3. Use the changes in oxidation number to determine which elements are oxidized and which are reduced in these reactions. (Note: It is not necessary to use balanced reactions.)

   a. $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$

   b. $HNO_3 + HI \rightarrow NO + I_2 + H_2O$

   c. $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$

   d. $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$

4. For each reaction in problem 3 above, identify the oxidizing agent and reducing agent.

Name _____ Class _____ Date _____

SECTION 22.3 BALANCING REDOX EQUATIONS

1. Balance these equations using the oxidation-number-change method.
   a. $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$
   b. $H_2S + HNO_3 \rightarrow S + NO + H_2O$
   c. $HNO_3 + HI \rightarrow NO + I_2 + H_2O$
   d. $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$
   e. $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$
   f. $KIO_4 + KI + HCl \rightarrow KCl + I_2 + H_2O$
   g. $Zn + Cr_2O_7^{2-} + H^+ \rightarrow Zn^{2+} + Cr^{3+} + H_2O$
2. Write half-reactions for the oxidation and reduction processes for each of the following reactions.
   a. $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$ (acidic solution)
   b. $Sn^{2+} + IO_3^- \rightarrow Sn^{4+} + I^-$ (acidic solution)
   c. $S^{2-} + NO_3^- \rightarrow S + NO$ (acidic solution)
   d. $Mn^{2+} + H_2O_2 \rightarrow MnO_2 + H_2O$ (basic solution)
3. Balance these reactions using the half-reaction method.
   a. $Zn + HgO \rightarrow ZnO_2^{2-} + Hg$ (basic solution)
   b. $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$ (acidic solution)
   c. $Sn^{2+} + IO_3^- \rightarrow Sn^{4-} + I^-$ (acidic solution)
   d. $S^{2-} + NO_3^- \rightarrow S + NO$ (acidic solution)
   e. $Mn^{2+} + H_2O_2 \rightarrow MnO_2 + H_2O$ (basic solution)
   f. $CrO_2 + ClO^- \rightarrow CrO_4^{2-} + Cl^-$ (basic solution)

Name _____ Class _____ Date _____

22 INTERPRETING GRAPHICS

USE WITH SECTION 22.3

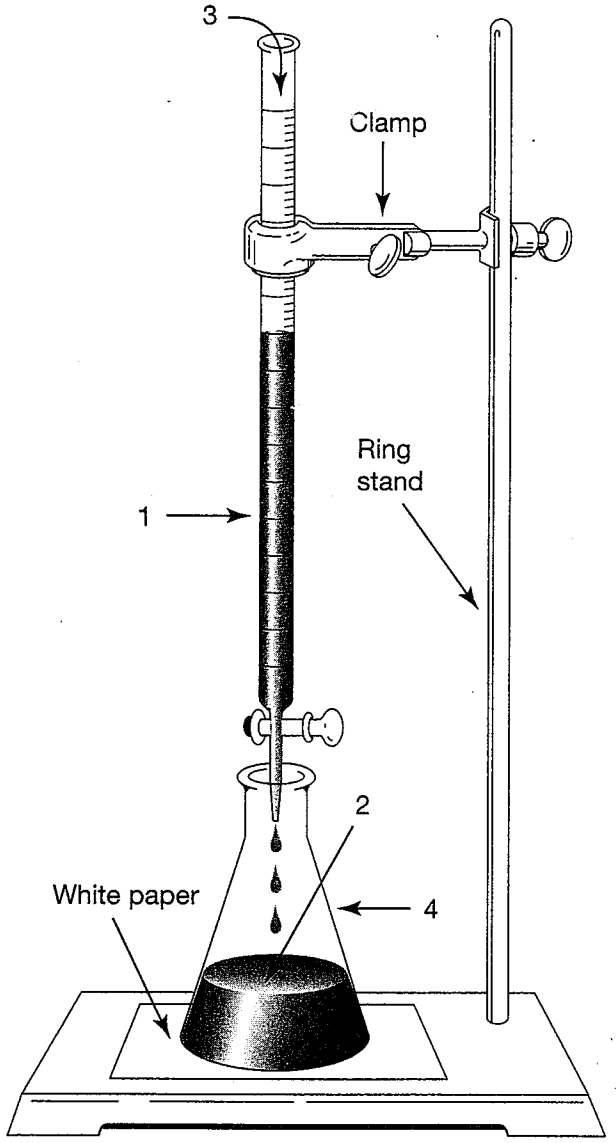

Figure 1 Titration of iron(II) ion (Fe^{2+}) with a standard solution of 0.0200*M* potassium permanganate ($KMnO_4$).

To determine the relative amount of iron in a sample of iron ore, a chemist dissolved 2.938 g of the ore in 50.0 mL of dilute sulfuric acid (H_2SO_4) in a reaction flask. The colorless solution was then titrated to the end point with potassium permanganate. The half-reactions for the oxidation and reduction processes that occur during this titration are:

$$Fe^{2+} \rightarrow Fe^{3+}$$
$$MnO_4^- \rightarrow Mn^{2+}$$

Use the data in Table 1 and what you have learned about oxidation–reduction reactions to answer the following questions.

Name _____ Class _____ Date _____

Table 1 Analysis of an Unknown Iron-Containing Ore

Initial Volume of $KMnO_4$	48.65 mL
Final Volume of $KMnO_4$	23.35 mL
Volume of MnO_4^-	
Moles MnO_4^-	
Moles Iron(II), Fe^{2+}	
Mass of Iron	
% of Iron in Ore	

1. Match each component from the following list with the correct number shown in Figure 1. The same number may be used more than once.

   _____ **a.** oxidizing agent

   _____ **b.** reducing agent

   _____ **c.** standard solution of 0.0200*M* $KMnO_4$

   _____ **d.** acidic solution of iron(II) ion, Fe^{2+}

   _____ **e.** reaction flask

   _____ **f.** buret

2. Use the half-reaction method to balance the equation for the redox reaction between permanganate ion and iron(II) ion. Write the net ionic equation only.

3. Explain what the *end point* of this particular titration means in terms of the reacting species in solution. How does the chemist recognize the end point when it occurs?

   _____

   _____

   _____

4. Use the stoichiometry of the balanced equation given in your answer to question 2 and the fact that the molar mass of Fe is 55.85 g to complete Table 1 above. Use the space below to show your work.

Name _____ Class _____ Date _____

22 VOCABULARY REVIEW

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

half-reaction	oxidation–reduction reaction
half-reaction method	oxidizing agent
oxidation	redox reaction
oxidation number	reducing agent
oxidation-number-change method	reduction

1. the substance in a redox reaction that accepts electrons

_____

2. a method of balancing a redox equation by comparing the increases and decreases in oxidation numbers

_____

3. a process that involves a complete or partial gain of electrons or the loss of oxygen; it results in a decrease in the oxidation number of an atom

_____

4. a method for balancing a redox equation by balancing the oxidation and reduction half-reactions

_____

5. a positive or negative number assigned to a combined atom according to a set of arbitrary rules

_____

6. a substance in a redox reaction that donates electrons

_____

7. an equation showing either the reduction or the oxidation of a species in an oxidation-reduction reaction

_____

8. a reaction that involves the transfer of electrons between reactants during a chemical change

_____

9. a process that involves complete or partial loss of electrons or a gain of oxygen; it results in an increase in the oxidation number of an atom

_____

10. another name for an oxidation–reduction reaction

_____

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS

Quiz for CHAPTER 22

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

_____ **1.** The oxidation number of sulfur in each of the following is +6 *except* for: *22.2*

a. SO_3.
b. $S_2O_3^{2-}$.
c. SO_4^{2-}.
d. Na_2SO_4.

_____ **2.** Reduction is: *22.1*

a. a gain of electrons.
b. a loss of electrons.
c. a gain of oxygen.
d. both a and c

_____ **3.** Identify the oxidizing agent in the following reaction. *22.1*

$$2Na + S \rightarrow Na_2S$$

a. Na
b. S
c. Na_2S
d. Na^+

_____ **4.** From the unbalanced equations below identify the one that does *not* represent a redox reaction. *22.1*

a. $HNO_3(aq) + H_3PO_3(aq) \rightarrow NO(g) + H_3PO_4(aq) + H_2O(l)$
b. $H_2SO_4(aq) + NaOH(aq) \rightarrow H_2O(l) + Na_2SO_4(aq)$
c. $C(s) + O_2(g) \rightarrow CO_2(g)$
d. $H_2O_2(aq) + PbS(s) \rightarrow PbSO_4(s) + H_2O(l)$

_____ **5.** Identify the oxidation half-reaction among the following. *22.3*

a. $Fe^{2+} \rightarrow Fe^{3+} + e^-$
b. $Cl_2 + 2e^- \rightarrow 2Cl^-$
c. $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
d. $Fe^{3+} + e^- \rightarrow Fe^{2+}$

_____ **6.** What will the coefficient of HNO_3 be when the following equation is completely balanced using the smallest whole-number coefficients? *22.3*

$$HNO_3 + MnCl_2 + HCl \rightarrow NO + MnCl_4 + H_2O$$

a. 2
b. 3
c. 6
d. 5

_____ **7.** When the half-reactions $I_2 + 2e^- \rightarrow 2I^-$ and $Na \rightarrow Na^+ + e^-$ are correctly combined, the balanced redox equation is: *22.3*

a. $Na + I + e^- \rightarrow Na^+ + 2I^-$
b. $Na + I_2 \rightarrow Na^+ + 2I^-$
c. $2Na + I_2 \rightarrow 2Na^+ + 2I^-$
d. $Na + I_2 + 2e^- \rightarrow Na^+ + 2I^- + e^-$

_____ **8.** What is the reduction half-reaction for the following unbalanced redox equation? *22.3*

$$Cr_2O_7^{2-} + NH_4^+ \rightarrow Cr_2O_3 + N_2$$

a. $NH_4^+ \rightarrow N_2$
b. $N_2 \rightarrow NH_4^+$
c. $Cr_2O_3 \rightarrow Cr_2O_7^{2-}$
d. $Cr_2O_7^{2-} \rightarrow Cr_2O_3$

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS
CHAPTER TEST A

A. Matching

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

	Column A	Column B
_____	**1.** a positive or negative number assigned to an atom according to a set of arbitrary rules	**a.** half-reaction
_____	**2.** the substance in a redox reaction that accepts electrons	**b.** oxidation-number-change method
_____	**3.** chemical change that occurs when electrons are transferred between reactants	**c.** oxidation
_____	**4.** an equation showing either the reduction or the oxidation of a species in a redox reaction	**d.** oxidation number
_____	**5.** complete or partial gain of electrons or loss of oxygen	**e.** half-reaction method
_____	**6.** ion that does not change oxidation number or composition during a reaction	**f.** oxidation–reduction reaction
_____	**7.** balances redox reactions by balancing oxidation and reduction half-reactions	**g.** spectator ion
_____	**8.** balances a redox reaction by comparing the increases and decreases in oxidation numbers	**h.** reducing agent
_____	**9.** complete or partial loss of electrons or gain of oxygen	**i.** reduction
_____	**10.** the substance in a redox reaction that donates electrons	**j.** oxidizing agent

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Identify the oxidizing agent in the following reaction:

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

a. Na
b. H_2O
c. NaOH
d. H_2

_____ **12.** Identify the reducing agent in the following reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

a. H_2O
b. CO_2
b. O_2
d. CH_4

Name _____ Class _____ Date _____

_____ **13.** Nitrogen has the same oxidation number in all of the following *except*:
a. NO_3^-.
b. N_2O_5.
c. NH_4Cl.
d. $Ca(NO_3)_2$.

_____ **14.** Determine what happens in this reaction:

$$S + Cl_2 \rightarrow SCl_2$$

(*Hint:* Chlorine is the more electronegative element.)
a. Sulfur is reduced.
b. Chlorine is reduced.
c. Chlorine is oxidized.
d. Sulfur is the oxidizing agent.

_____ **15.** $Zn \rightarrow Zn^{2+}$ represents:
a. oxidation
b. reduction
c. both of these
d. neither of these

_____ **16.** $Sn^{4+} \rightarrow Sn^{2+}$ represents:
a. oxidation
b. reduction
c. hydrolysis
d. none of these

_____ **17.** What happens to chlorine (in ClO_3^-) in the following redox reaction?

$$ClO_3^- + I^- \rightarrow Cl^- + I_2$$

a. It is oxidized.
b. Its oxidation number changes from +6 to −1.
c. Its oxidation-number change is −6.
d. Its oxidation-number change is +6.

_____ **18.** Identify the atom that increases in oxidation number in the following redox reaction:

$$2MnO_2 + 2K_2CO_3 + O_2 \rightarrow 2KMnO_4 + 2CO_2$$

a. C
b. K
c. Mn
d. O

_____ **19.** Identify the reducing agent in this reaction:

$$I^- + MnO_4^- \rightarrow I_2 + MnO_2$$

a. I^-
b. MnO_4^-
c. I_2
d. MnO_2

_____ **20.** What is the increase in oxidation number for the atom that is oxidized in the following balanced redox equation?

$$Cr_2O_7^{2-} + 8H^+ + 3SO_3^{2-} \rightarrow Cr^{3+} + 3SO_4^{2-} + 8H_2O$$

a. +2
b. +6
c. −3
d. −6

_____ **21.** To balance the oxygen and hydrogen for a redox reaction that takes place in basic solution, it is necessary to use:
a. H_2O and H^+.
b. H_2O only.
c. H_2O and OH^-.
d. OH^- only.

_____ **22.** Which of the following is an oxidation half-reaction?
a. $Zn^{2+} + 2e^- \rightarrow Zn$
b. $NO + 2H_2O \rightarrow NO_3^- + 4H^+ + 3e^-$
c. $Na^+ + e^- \rightarrow Na$
d. $2H^+ + 2e^- \rightarrow H_2$

Name _____ Class _____ Date _____

_____ **23.** What is the reduction half-reaction for the following unbalanced redox equation?

$$Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$$

a. $Cr^{3+} \rightarrow Cr_2O_7^{2-}$
b. $Fe^{2+} \rightarrow Fe^{3+}$
c. $Fe^{3+} \rightarrow Fe^{2+}$
d. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$

_____ **24.** Which atom is reduced in the following unbalanced redox equations?

$$K_2Cr_2O_7 + H_2O + S \rightarrow KOH + Cr_2O_3 + SO_2$$

a. S
b. O
c. Cr
d. K

_____ **25.** Identify a true statement about how to protect an iron object from corrosion.

a. Increase the amount of salt and/or acid in the water.
b. Place a gold or silver bar in contact with the iron.
c. Place a better reducing agent in contact with the iron.
d. Place a metal more easily reduced in contact with the iron.

_____ **26.** Identify from the unbalanced equations below the one that does *not* represent a redox reaction.

a. $H_2O_2(aq) + MnO_4^-(aq) \rightarrow O_2(g) + Mn^{2+}(aq)$
b. $H_2(g) + N_2(g) \rightarrow NH_3(g)$
c. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$
d. $Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$

C. Questions

Answer the following questions in the space provided.

27. Determine which substance is oxidized and which substance is reduced in each reaction. Identify the oxidizing agent and reducing agent in each case.

a. $2Na + Br_2 \rightarrow 2NaBr$

b. $2K + S \rightarrow K_2S$

28. Combine these two half-reactions to form a balanced redox equation.

$$Br_2 + 2e^- \rightarrow 2Br^- \text{ and } Cr \rightarrow Cr^{3+} + 3e^-$$

Name _____ Class _____ Date _____

29. Determine the oxidation number of each element in these substances.

a. Li_3AlF_6

b. Na_2O

c. S_8

30. Balance the following redox equation, using either the oxidation-number-change method or the half-reaction method. Show all your work. (In using the half-reaction method, assume that the reaction occurs in aqueous acid solution.)

$$Fe_2O_3 + CO \rightarrow Fe + CO_2 \text{ (acid solution)}$$

D. Essay

31. How are oxidation numbers determined and used?

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS

CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A. Write the letter of the correct term in the blank provided.

Column A	Column B
_____ **1.** the substance in a redox reaction that accepts electrons	**a.** oxidation-number-change method
_____ **2.** the complete or partial gain of electrons or the loss of oxygen	**b.** reducing agent
_____ **3.** those ions that do not change oxidation number or composition during a reaction	**c.** oxidation–reduction reactions
_____ **4.** a positive or negative number assigned to an atom according to a set of arbitrary rules	**d.** spectator ions
_____ **5.** the complete or partial loss of electrons or the gain of oxygen	**e.** oxidizing agent
_____ **6.** the balancing of a redox reaction by comparing the increases and decreases in oxidation numbers	**f.** reduction
_____ **7.** the chemical changes that occur when electrons are transferred between reactants	**g.** oxidation number
_____ **8.** a method of balancing redox reactions by balancing the oxidation and reduction half-reactions	**h.** half-reaction method
_____ **9.** the substance in a redox reaction that donates electrons	**i.** oxidation
_____ **10.** another name for an oxidation–reduction reaction	**j.** redox reaction

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Which of the following is true about oxidation reactions?

a. Oxidation reactions are the principal source of energy on earth.
b. All oxidation reactions are accompanied by reduction reactions.
c. The burning of wood in a fireplace and the metabolization of food by your body are oxidation reactions.
d. all of these

Name _____ Class _____ Date _____

_____ **12.** The oxidized substance in the following reaction is:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

a. Fe. **c.** $FeCl_2$.
b. HCl. **d.** H_2.

_____ **13.** The reducing agent in the reaction described in question 12 is:

a. Fe. **c.** $FeCl_2$.
b. HCl. **d.** H_2.

_____ **14.** What is occurring in the following reaction?

$$H_2 + Cl_2 \rightarrow 2HCl$$

a. H_2 is being reduced
b. Cl_2 is being oxidized
c. H_2 is gaining two electrons.
d. Cl_2 is acting as an oxidizing agent

_____ **15.** What is the oxidation number of sulfur in H_2SO_3?

a. +1 **c.** +3
b. +2 **d.** +4

_____ **16.** What is the usual oxidation number of oxygen in a compound?

a. −1 **c.** +1
b. −2 **d.** +2

_____ **17.** In the unbalanced equation below, the element being reduced is:

$$MnO_2 + HCl \rightarrow H_2O + MnCl_2 + Cl_2$$

a. Mn. **c.** H.
b. O. **d.** Cl.

_____ **18.** Which of the following is an oxidation reaction?

a. $Co^{3+} \rightarrow Co^{2+}$ **c.** $AuCl_4^- \rightarrow AuCl_2^-$
b. $Cl_2 \rightarrow ClO_3^-$ **d.** $Mn^{7+} \rightarrow Mn^{2+}$

_____ **19.** Among the following, which is an oxidation-reduction reaction?

a. $Na_2S + CaCO_3 \rightarrow CaS + Na_2CO_3$
b. $2HNO_3 + Mg(OH)_2 \rightarrow Mg(NO_3)_2 + 2H_2O$
c. $H_2 + F_2 \rightarrow 2HF$
d. $3Ba(OH)_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$

_____ **20.** Which of the following is true concerning the reaction below?

$$H_2S + HNO_3 \rightarrow S + NO + H_2O$$

a. S is reduced. **c.** N is reduced.
b. H is oxidized. **d.** O is oxidized.

_____ **21.** When the equation in question 20 is balanced, what is the coefficient for H_2O?

a. 2 **c.** 3
b. 4 **d.** 6

Name _____ Class _____ Date _____

_____ **22.** In the equation $PbO_2 + 4HCl \rightarrow 2H_2O + PbCl_2 + Cl_2$, how many electrons are transferred?

a. 1 **c.** 3
b. 2 **d.** 4

_____ **23.** The element oxidized in the reaction described in question 22 is:

a. Pb. **c.** H.
b. O. **d.** Cl.

_____ **24.** In the unbalanced equation given below, the element that is gaining electrons is:

$$HCl + MnO_2 \rightarrow MnCl_2 + H_2O + Cl_2$$

a. H. **c.** Mn.
b. Cl. **d.** O.

_____ **25.** When the equation in question 24 is balanced, what is the coefficient for HCl?

a. 1 **c.** 3
b. 2 **d.** 4

_____ **26.** Which of the following is true concerning redox reactions?

a. Double-replacement reactions are always redox reactions.
b. Single-replacement reactions may be redox reactions.
c. Acid–base reactions are always redox reactions.
d. all of these

_____ **27.** Identify a *false* statement about how to protect iron from corrosion.

a. Coat the surface with oil, paint, or plastic.
b. Attach a metal that is more easily reduced.
c. Exclude air and water.
d. Attach a metal that is a better reducing agent.

_____ **28.** From the unbalanced equations below, identify the one that does *not* represent a redox reaction.

a. $H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)$
b. $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$
c. $S_2O_3^{2-}(aq) + I_2(s) \rightarrow S_4O_6^{2-}(aq) + I^-(aq)$
d. $FeBr_2(aq) + Br_2(l) \rightarrow FeBr_3(aq)$

Name _____ Class _____ Date _____

C. Questions

Answer the following questions in the space provided.

29. For each of the following reactions, identify the element oxidized, the element reduced, the oxidizing agent, and the reducing agent.

	Oxidized	Reduced	Oxidizing Agent	Reducing Agent
a. $K + I_2 \rightarrow 2KI$				
b. $2Na + 2H_2O \rightarrow 2NaOH + H_2$				
c. $H_2 + CuO \rightarrow Cu + H_2O$				
d. $Cu(NO_3)_2 + Mg \rightarrow Mg(NO_3)_2 + Cu$				

30. Determine the oxidation number of each element in the following:

a. K_2SO_4

b. $Cu(NO_3)_2$

c. $HAsO_3$

d. MnO_4^-

31. Use the oxidation-number-change method to balance the equations given below. Show all your work.

a. $HNO_3 + Ag \rightarrow AgNO_3 + NO + H_2O$

b. $Br_2 + SO_2 + H_2O \rightarrow H_2SO_4 + HBr$

Name _____ Class _____ Date _____

32. Use the half-reaction method to balance the equations given below. Show all your work.

a. $HNO_2 + HI \rightarrow I_2 + NO + H_2O$

b. $K_2Cr_2O_7 + FeCl_2 + HCl \rightarrow CrCl_3 + KCl + FeCl_3 + H_2O$

D. Essay

33. Explain why oxidation cannot occur without reduction, and vice versa.

22 OXIDATION-REDUCTION REACTIONS

PLANNING GUIDE

SECTION	STUDENT ACTIVITIES/FEATURES	TEACHER'S RESOURCE PACKAGE
22.1 The Meaning of Oxidation and Reduction **Objectives** ▸ Define oxidation and reduction in terms of the loss or gain of oxygen or hydrogen and the loss or gain of electrons ▸ State the characteristics of a redox reaction, and identify the oxidizing agent and reducing agent	**Discover It!** *Rushing*, p. 644 **Link to Photography** *Redox in Photography*, p. 650 **Sample Problem** 22-1	**Review Module** (Chapters 21–24) ▸ Section Review 22.1 ▸ Practice Problems ▸ Quizzes **Laboratory Manual,** Experiment 44: *Oxidation-Reduction Reactions* **Laboratory Practical** 22-1 **Small-Scale Chemistry Lab Manual,** Experiment 31: *Determination of an Activity Series*
22.2 Oxidation Numbers **Objectives** ▸ Determine the oxidation number of an atom of any element in a pure substance ▸ Define oxidation and reduction in terms of a change in oxidation number, and identify atoms being oxidized or reduced in redox reactions	**Sample Problems** 22-2 through 22-4	**Review Module** ▸ Section Review 22.2 ▸ Practice Problems ▸ Quizzes
22.3 Balancing Redox Equations **Objectives** ▸ Use the oxidation-number-change method to balance redox equations ▸ Break a redox equation into oxidation and reduction half-reactions, and then use the half-reaction method to balance the equation	**Link to Biology** *Bioluminescence*, p. 667 **Mini Lab** *Bleach It! Oxidize the Color Away*, p. 669 **Small-Scale Lab** *Half-Reactions*, p. 670 **Sample Problems** 22-5 through 22-7 **Chemistry Serving . . . Society** *Could Fuel Cells Be the Power of the Future?*, p. 671 **Chemistry in Careers** *Mechanical Engineer*, p. 671	**Review Module** ▸ Section Review 22.3 ▸ Practice Problems ▸ Interpreting Graphics ▸ Vocabulary Review 22 ▸ Chapter 22 Tests and Quizzes **Laboratory Recordsheets** 22-1 and 22-2 **Small-Scale Chemistry Lab Manual,** Experiment 32: *Oxidation-Reduction Reactions* **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 22

ResourcePro CD-ROM
- Chapter 22

Assessment Resources CD-ROM

Videodiscs and Videotapes

Chemistry Alive! Videodisc
- Elephant Toothpaste
- Watermelon Surprise
- Thermite Reactions
- Oxidation States of Vanadium
- Oxidizing with Potassium Chloride

Small-Scale Lab Video and Videodisc
- #4: Redox Reactions

Overhead Transparencies
- #70: Oxidation-Reduction Reactions

ASSESSMENT

Student Edition
- Section Reviews 22.1–22.3
- Chapter 21 Review, pp. 672–674
- Alternative Assessment, p. 675

Teacher's Resource Package
Review Module (Chap. 21–24)
- Vocabulary Review
- Chapter 22 Test A and Test B
- Chapter 22 Quizzes

Technology
Chem ASAP! CD-ROM
- Assessment 22.1–22.3

Assessment Resources CD-ROM
- Chapter 22 Tests

PLANNING FOR ACTIVITIES

STUDENT EDITION

Discover It! p. 644
- iron finishing nails
- pliers
- scissors
- copper wire
- zinc strips
- fine sandpaper
- plastic wrap
- saucers
- water
- table salt
- petroleum jelly
- paper towels

Mini Lab p. 669
- spot plates
- medicine droppers
- water
- various oxidizing agents
- various samples: stains or colors

Small-Scale Lab, p. 670
- pencils
- paper
- rulers
- reaction surfaces
- chemicals

TEACHER'S EDITION

Teacher Demo, p. 646
- 3 g copper (II) oxide (CuO)
- 3 g charcoal (C)
- crucible
- Bunsen burner
- tongs
- glass plate

Teacher Demo, p. 655
- 100 mL of 0.1*M* lead(II) acetate [$Pb(CH_3COO)_2$]
- 150-mL beaker
- 1-cm × 3-cm zinc strip
- threefold molar excess of sodium sulfide
- 3*M* NaCH
- threefold excess of 1*M* iron(III) chloride
- plastic container

Activity, p. 657
- for each pair of students: 3 small, glass test tubes containing a small portion of zinc, copper, and magnesium
- for each pair: 10 drops of 0.1*M* HCl

Teacher Demo, p. 662
- 6 crystals of potassium permanganate ($KMnO_4$)
- 500 mL of water
- large beaker
- 1 g sodium hydrogen sulfite ($NaHSO_8$)
- 20 mL of water
- two 50-mL beakers
- 1 g barium chloride dihydrate ($BaCl_2 \cdot 2H_2O$)
- 20 mL of water
- 3*M* H_2SO_4
- plastic container

Teacher Demo, p. 665
- two 600-mL beakers
- 8 mL of 6*M* H_2SO_4
- 125 mL distilled water
- 43 g of sodium pyrophosphate decahydrate ($NaP_2O_7 \cdot 10H_2O$)
- 72 mL 6*M* H_2SO_4
- 80 mL of 0.1*M* $MnSO_4$
- 40 mL of 0.25*M* potassium bromate ($KBrO_3$)
- stir bar
- magnetic stirrer

Activity, p. 667
- potatoes and apples
- beakers
- tap waters
- boiled water
- lemon juice
- carbonated beverage
- sugar, salt, vinegar solutions
- paper towels

Name _____ Class _____ Date _____

22.1 THE MEANING OF OXIDATION AND REDUCTION
SECTION REVIEW

Objectives

- Define oxidation and reduction in terms of the loss or gain of oxygen or hydrogen and the loss or gain of electrons
- State the characteristics of a redox reaction and identify the oxidizing agent and reducing agent

Key Terms

- oxidation
- reduction
- redox reactions
- oxidation-reduction reactions
- reducing agent
- oxidizing agent

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.

Oxidation–reduction, or ___1___, reactions are an important category of chemical reactions. Oxidation is considered to be any shift of electrons ___2___ from an atom. Reduction includes any shift of electrons ___3___ an atom. An oxidation reaction is always accompanied by a ___4___ reaction. The substance that does the oxidizing (the ___5___ agent) is ___6___. The substance that does the reducing (the ___7___ agent) is ___8___.

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

Part B True-False

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

_____ **9.** Reduction is the complete or partial gain of electrons by a substance.

_____ **10.** In the reaction $2Na + Cl_2 \rightarrow 2NaCl$, sodium is the reducing agent.

_____ **11.** In the reaction $2Na + Cl_2 \rightarrow 2NaCl$, sodium is being reduced.

_____ **12.** To protect an iron ship hull, you should attach a metal that is easily reduced.

Name _____ Class _____ Date _____

Part C Matching

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

Column A	Column B
_____ **13.** combustion	**a.** a metal that loses electrons easily
_____ **14.** oxidation	**b.** complete or partial loss of electrons or gain of oxygen
_____ **15.** oxidizing agent	**c.** oxidation of metals to metallic ions by oxygen and water in the environment
_____ **16.** corrosion	**d.** a metal that resists corrosion
_____ **17.** zinc	**e.** a chemical change in which oxygen reacts with another substance, often producing energy in the form of heat and light
_____ **18.** gold	**f.** a substance that accepts electrons in a redox reaction

Part D Questions and Problems

Answer the following in the space provided.

19. Define oxidation and reduction in terms of the loss or gain of electrons.

20. In the equation given, identify the substance oxidized, the substance reduced, the oxidizing agent, and the reducing agent.

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

21. Explain how putting a block of zinc or aluminum on the iron hull of a large ship will protect the ship from corrosion.

Name _____ Class _____ Date _____

22.2 OXIDATION NUMBERS
SECTION REVIEW

Objectives

- Determine the oxidation number of an atom of any element in a pure substance
- Define oxidation and reduction in terms of a change in oxidation number, and identify atoms being oxidized or reduced in redox reactions

Key Term

- oxidation number

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.

The oxidation number of an element in an uncombined state is __1__. The oxidation number of a monatomic ion is the same in magnitude and __2__ as its ionic __3__. The sum of the oxidation numbers of the elements in a neutral compound is __4__. In a polyatomic ion, however, the sum is equal to the __5__. Oxidation numbers help you keep track of __6__ – transfer in redox reactions. An oxidation number increase is __7__, while a __8__ is reduction.

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

Part B True-False

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

_____ **9.** Oxygen is more electronegative than chlorine.

_____ **10.** The oxidation number of each oxygen atom in most compounds is −2.

_____ **11.** The oxidation number of Cl in $KClO_3$ is −1.

_____ **12.** The oxidation number of each hydrogen atom in most compounds is −1.

_____ **13.** The oxidation number for copper in a copper penny is +2.

_____ **14.** In the reaction, $C + H_2O \rightarrow CO + H_2$, the oxidation number of the hydrogen doesn't change.

Name _____ Class _____ Date _____

_____ **15.** In the reaction, $C + H_2O \rightarrow CO + H_2$, the oxidation number of the carbon increases.

_____ **16.** An increase in the oxidation number of an atom indicates oxidation.

Part C Matching

Match the oxidation number of nitrogen in each formula in Column B to the correct oxidation number in Column A.

Column A	Column B
_____ **17.** −3	**a.** N_2
_____ **18.** −2	**b.** HNO_3
_____ **19.** −1	**c.** NO
_____ **20.** 0	**d.** NH_2OH
_____ **21.** +1	**e.** NH_3
_____ **22.** +2	**f.** N_2O_3
_____ **23.** +3	**g.** N_2O
_____ **24.** +4	**h.** N_2H_4
_____ **25.** +5	**i.** NO_2

Part D Questions and Problems

Answer the following in the space provided.

26. Define oxidation and reduction in terms of a change in oxidation number.

_____

_____

27. Use the change in oxidation number to determine which elements are oxidized and which are reduced in these reactions. (Note: It is not necessary to use balanced equations.)

a. $HNO_3 + HBr \rightarrow NO + Br_2 + H_2O$ _____

b. $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$ _____

c. $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$ _____

d. $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$ _____

Name _____ Class _____ Date _____

22.3 BALANCING REDOX EQUATIONS
SECTION REVIEW

Objectives

- Use the oxidation-number-change method to balance redox equations
- Break a redox equation into oxidation and reduction half-reactions, and then use the half-reaction method to balance the equation

Key Terms

- oxidation-number-change method
- half-reactions
- half-reaction method

Part A Completion

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

One method for balancing redox equations involves determining the change in __1__ of the substances that are oxidized and reduced. Coefficients are then used to make the increase in oxidation number equal to the decrease.

The __2__ method is another way to write a __3__ equation for a redox reaction. In this method, the net __4__ equation is divided into __5__ half-reactions. Each half-reaction is balanced independently. Finally, the half-reactions are __6__. The half-reaction method is particularly useful in balancing equations for __7__ reactions.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Part B True-False

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

_____ **8.** The reduction half-reaction in the reaction $MnO_4^- + Cl^- \rightarrow Mn^{2+} + Cl_2$ involves: $MnO_4^- \rightarrow Mn^{2+}$

_____ **9.** In an oxidation half-reaction, electrons occur on the right side of the equation

Name _____ Class _____ Date _____

_____ **10.** Electrons never appear in a balanced redox reaction.

_____ **11.** $2e^- + 2Cl^- \rightarrow Cl_2$ is a balanced half-reaction.

_____ **12.** To balance the oxygen in a half reaction involving $MnO_4^- \rightarrow Mn^{2+}$, $2H_2O$ will be added to the product side of the equation.

_____ **13.** In the equation $2FeBr_2 + Br_2 \rightarrow 2FeBr_3$, the oxidation number of the iron doesn't change.

Part C Matching

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

Column A	Column B
_____ **14.** half-reaction method	**a.** ions that are present but do not participate in or change during the reaction
_____ **15.** spectator ions	**b.** $Fe^{2+} \rightarrow Fe^{3+} + e^-$
_____ **16.** anions	**c.** balancing a redox equation by first balancing the oxidation and reduction half-reactions
_____ **17.** oxidation half-reaction	**d.** balancing a redox equation by comparing the increase and decrease in oxidation numbers
_____ **18.** half-reaction	**e.** equation showing either the reduction or the oxidation of a species in an oxidation-reduction reaction
_____ **19.** oxidation-number-change method	**f.** ions that can serve as reducing agents
_____ **20.** reduction half-reaction	**g.** $2e^- + Br_2 \rightarrow 2Br^-$

Part D Questions and Problems

Answer the following in the space provided.

21. Balance these redox equations using the oxidation-number-change method.

a. $HNO_3(aq) + HI(g) \rightarrow NO(g) + I_2(s) + H_2O$

b. $HNO_3(aq) + I_2(s) \rightarrow HIO_3(aq) + NO_2(g) + H_2O(l)$

22. Balance these redox equations using the half-reaction method.

a. $H_2S(aq) + HNO_3(aq) \rightarrow S(s) + NO(g) + H_2O(l)$

b. $Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$

Name _____ Class _____ Date _____

22 OXIDATION-REDUCTION REACTIONS
PRACTICE PROBLEMS

In your notebook, solve the following problems.

SECTION 22.1 THE MEANING OF OXIDATION AND REDUCTION

Determine what is oxidized and what is reduced in each reaction. Identify the oxidizing agent and the reducing agent.

1. $2Sr + O_2 \rightarrow 2SrO$
2. $2Li + S \rightarrow 2Li_2S$
3. $2Cs + Br_2 \rightarrow 2CsBr$
4. $3Mg + N_2 \rightarrow Mg_3N_2$
5. $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
6. $Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$
7. $Si + 2F_2 \rightarrow SiF_4$
8. $2Ca + O_2 \rightarrow 2CaO$
9. $Mg + 2HCl \rightarrow MgCl_2 + H_2$
10. $2Na + 2H_2O \rightarrow 2NaOH + H_2$

SECTION 22.2 OXIDATION NUMBERS

1. Give the oxidation number of each kind of atom or ion.

   a. Sn **c.** S^{2-} **e.** Se **g.** Sn^{4+}

   b. K^+ **d.** Fe^{3+} **f.** Mg^{2+} **h.** Br^-

2. Calculate the oxidation number of chromium in each of the following formulas.

   a. Cr_2O_3 **b.** $H_2Cr_2O_7$ **c.** $CrSO_4$ **d.** CrO_4^{2-}

3. Use the changes in oxidation number to determine which elements are oxidized and which are reduced in these reactions. (Note: It is not necessary to use balanced reactions.)

   a. $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$

   b. $HNO_3 + HI \rightarrow NO + I_2 + H_2O$

   c. $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$

   d. $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$

4. For each reaction in problem 3 above, identify the oxidizing agent and reducing agent.

Name _____ Class _____ Date _____

SECTION 22.3 BALANCING REDOX EQUATIONS

1. Balance these equations using the oxidation-number-change method.
   - **a.** $C + H_2SO_4 \rightarrow CO_2 + SO_2 + H_2O$
   - **b.** $H_2S + HNO_3 \rightarrow S + NO + H_2O$
   - **c.** $HNO_3 + HI \rightarrow NO + I_2 + H_2O$
   - **d.** $Sb + HNO_3 \rightarrow Sb_2O_5 + NO + H_2O$
   - **e.** $KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$
   - **f.** $KIO_4 + KI + HCl \rightarrow KCl + I_2 + H_2O$
   - **g.** $Zn + Cr_2O_7^{2-} + H^+ \rightarrow Zn^{2+} + Cr^{3+} + H_2O$
2. Write half-reactions for the oxidation and reduction processes for each of the following reactions.
   - **a.** $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$ (acidic solution)
   - **b.** $Sn^{2+} + IO_3^- \rightarrow Sn^{4+} + I^-$ (acidic solution)
   - **c.** $S^{2-} + NO_3^- \rightarrow S + NO$ (acidic solution)
   - **d.** $Mn^{2+} + H_2O_2 \rightarrow MnO_2 + H_2O$ (basic solution)
3. Balance these reactions using the half-reaction method.
   - **a.** $Zn + HgO \rightarrow ZnO_2^{2-} + Hg$ (basic solution)
   - **b.** $Fe^{2+} + MnO_4^- \rightarrow Fe^{3+} + Mn^{2+}$ (acidic solution)
   - **c.** $Sn^{2+} + IO_3^- \rightarrow Sn^{4-} + I^-$ (acidic solution)
   - **d.** $S^{2-} + NO_3^- \rightarrow S + NO$ (acidic solution)
   - **e.** $Mn^{2+} + H_2O_2 \rightarrow MnO_2 + H_2O$ (basic solution)
   - **f.** $CrO_2 + ClO^- \rightarrow CrO_4^{2-} + Cl^-$ (basic solution)

Name _____ Class _____ Date _____

22 INTERPRETING GRAPHICS

USE WITH SECTION 22.3

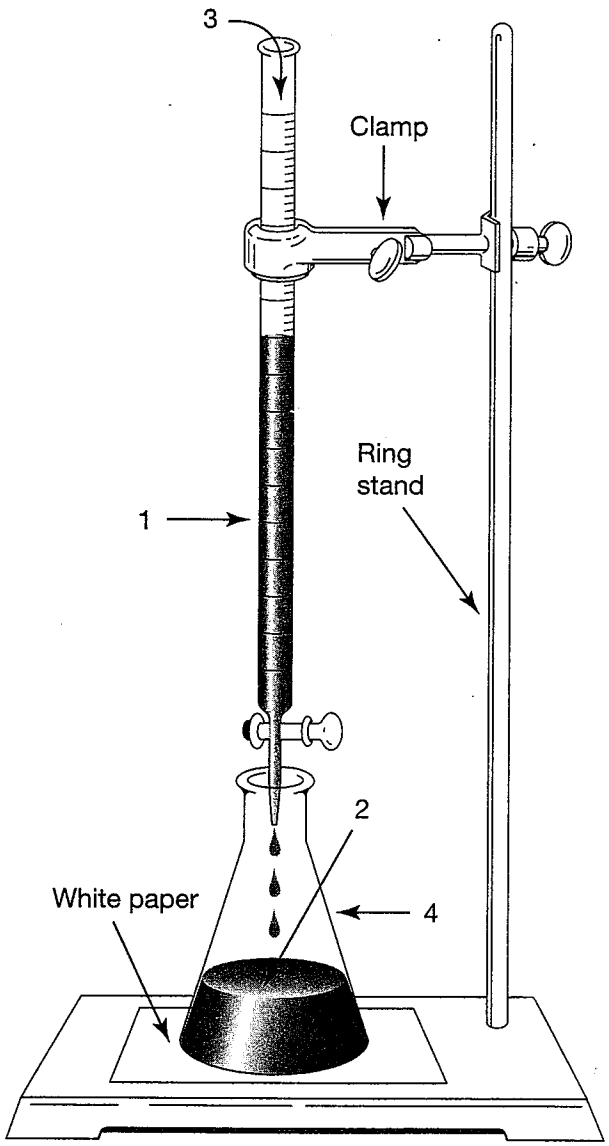

Figure 1 Titration of iron(II) ion (Fe^{2+}) with a standard solution of 0.0200*M* potassium permanganate ($KMnO_4$).

To determine the relative amount of iron in a sample of iron ore, a chemist dissolved 2.938 g of the ore in 50.0 mL of dilute sulfuric acid (H_2SO_4) in a reaction flask. The colorless solution was then titrated to the end point with potassium permanganate. The half-reactions for the oxidation and reduction processes that occur during this titration are:

$$Fe^{2+} \rightarrow Fe^{3+}$$
$$MnO_4^- \rightarrow Mn^{2+}$$

Use the data in Table 1 and what you have learned about oxidation–reduction reactions to answer the following questions.

Name _____ Class _____ Date _____

Table 1 Analysis of an Unknown Iron-Containing Ore

Initial Volume of $KMnO_4$	48.65 mL
Final Volume of $KMnO_4$	23.35 mL
Volume of MnO_4^-	
Moles MnO_4^-	
Moles Iron(II), Fe^{2+}	
Mass of Iron	
% of Iron in Ore	

1. Match each component from the following list with the correct number shown in Figure 1. The same number may be used more than once.

   _____ **a.** oxidizing agent

   _____ **b.** reducing agent

   _____ **c.** standard solution of 0.0200*M* $KMnO_4$

   _____ **d.** acidic solution of iron(II) ion, Fe^{2+}

   _____ **e.** reaction flask

   _____ **f.** buret

2. Use the half-reaction method to balance the equation for the redox reaction between permanganate ion and iron(II) ion. Write the net ionic equation only.

3. Explain what the *end point* of this particular titration means in terms of the reacting species in solution. How does the chemist recognize the end point when it occurs?

   _____

   _____

   _____

4. Use the stoichiometry of the balanced equation given in your answer to question 2 and the fact that the molar mass of Fe is 55.85 g to complete Table 1 above. Use the space below to show your work.

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22 VOCABULARY REVIEW

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

half-reaction	oxidation–reduction reaction
half-reaction method	oxidizing agent
oxidation	redox reaction
oxidation number	reducing agent
oxidation-number-change method	reduction

1. the substance in a redox reaction that accepts electrons

_____

2. a method of balancing a redox equation by comparing the increases and decreases in oxidation numbers

_____

3. a process that involves a complete or partial gain of electrons or the loss of oxygen; it results in a decrease in the oxidation number of an atom

_____

4. a method for balancing a redox equation by balancing the oxidation and reduction half-reactions

_____

5. a positive or negative number assigned to a combined atom according to a set of arbitrary rules

_____

6. a substance in a redox reaction that donates electrons

_____

7. an equation showing either the reduction or the oxidation of a species in an oxidation-reduction reaction

_____

8. a reaction that involves the transfer of electrons between reactants during a chemical change

_____

9. a process that involves complete or partial loss of electrons or a gain of oxygen; it results in an increase in the oxidation number of an atom

_____

10. another name for an oxidation–reduction reaction

_____

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS

Quiz for CHAPTER 22

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

_____ **1.** The oxidation number of sulfur in each of the following is +6 *except* for: *22.2*

a. SO_3.
b. $S_2O_3^{2-}$.
c. SO_4^{2-}.
d. Na_2SO_4.

_____ **2.** Reduction is: *22.1*

a. a gain of electrons.
b. a loss of electrons.
c. a gain of oxygen.
d. both a and c

_____ **3.** Identify the oxidizing agent in the following reaction. *22.1*

$$2Na + S \rightarrow Na_2S$$

a. Na
b. S
c. Na_2S
d. Na^+

_____ **4.** From the unbalanced equations below identify the one that does *not* represent a redox reaction. *22.1*

a. $HNO_3(aq) + H_3PO_3(aq) \rightarrow NO(g) + H_3PO_4(aq) + H_2O(l)$
b. $H_2SO_4(aq) + NaOH(aq) \rightarrow H_2O(l) + Na_2SO_4(aq)$
c. $C(s) + O_2(g) \rightarrow CO_2(g)$
d. $H_2O_2(aq) + PbS(s) \rightarrow PbSO_4(s) + H_2O(l)$

_____ **5.** Identify the oxidation half-reaction among the following. *22.3*

a. $Fe^{2+} \rightarrow Fe^{3+} + e^-$
b. $Cl_2 + 2e^- \rightarrow 2Cl^-$
c. $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
d. $Fe^{3+} + e^- \rightarrow Fe^{2+}$

_____ **6.** What will the coefficient of HNO_3 be when the following equation is completely balanced using the smallest whole-number coefficients? *22.3*

$$HNO_3 + MnCl_2 + HCl \rightarrow NO + MnCl_4 + H_2O$$

a. 2
b. 3
c. 6
d. 5

_____ **7.** When the half-reactions $I_2 + 2e^- \rightarrow 2I^-$ and $Na \rightarrow Na^+ + e^-$ are correctly combined, the balanced redox equation is: *22.3*

a. $Na + I + e^- \rightarrow Na^+ + 2I^-$
b. $Na + I_2 \rightarrow Na^+ + 2I^-$
c. $2Na + I_2 \rightarrow 2Na^+ + 2I^-$
d. $Na + I_2 + 2e^- \rightarrow Na^+ + 2I^- + e^-$

_____ **8.** What is the reduction half-reaction for the following unbalanced redox equation? *22.3*

$$Cr_2O_7^{2-} + NH_4^+ \rightarrow Cr_2O_3 + N_2$$

a. $NH_4^+ \rightarrow N_2$
b. $N_2 \rightarrow NH_4^+$
c. $Cr_2O_3 \rightarrow Cr_2O_7^{2-}$
d. $Cr_2O_7^{2-} \rightarrow Cr_2O_3$

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS

CHAPTER TEST A

A. Matching

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

Column A	Column B
_____ **1.** a positive or negative number assigned to an atom according to a set of arbitrary rules	**a.** half-reaction
_____ **2.** the substance in a redox reaction that accepts electrons	**b.** oxidation-number-change method
_____ **3.** chemical change that occurs when electrons are transferred between reactants	**c.** oxidation
_____ **4.** an equation showing either the reduction or the oxidation of a species in a redox reaction	**d.** oxidation number
_____ **5.** complete or partial gain of electrons or loss of oxygen	**e.** half-reaction method
_____ **6.** ion that does not change oxidation number or composition during a reaction	**f.** oxidation–reduction reaction
_____ **7.** balances redox reactions by balancing oxidation and reduction half-reactions	**g.** spectator ion
_____ **8.** balances a redox reaction by comparing the increases and decreases in oxidation numbers	**h.** reducing agent
_____ **9.** complete or partial loss of electrons or gain of oxygen	**i.** reduction
_____ **10.** the substance in a redox reaction that donates electrons	**j.** oxidizing agent

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Identify the oxidizing agent in the following reaction:

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

a. Na **c.** NaOH
b. H_2O **d.** H_2

_____ **12.** Identify the reducing agent in the following reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

a. H_2O **b.** O_2
b. CO_2 **d.** CH_4

Name _____ Class _____ Date _____

_____ **13.** Nitrogen has the same oxidation number in all of the following *except*:
a. NO_3^-.
b. N_2O_5.
c. NH_4Cl.
d. $Ca(NO_3)_2$.

_____ **14.** Determine what happens in this reaction:

$$S + Cl_2 \rightarrow SCl_2$$

(*Hint:* Chlorine is the more electronegative element.)
a. Sulfur is reduced.
b. Chlorine is reduced.
c. Chlorine is oxidized.
d. Sulfur is the oxidizing agent.

_____ **15.** $Zn \rightarrow Zn^{2+}$ represents:
a. oxidation
b. reduction
c. both of these
d. neither of these

_____ **16.** $Sn^{4+} \rightarrow Sn^{2+}$ represents:
a. oxidation
b. reduction
c. hydrolysis
d. none of these

_____ **17.** What happens to chlorine (in ClO_3^-) in the following redox reaction?

$$ClO_3^- + I^- \rightarrow Cl^- + I_2$$

a. It is oxidized.
b. Its oxidation number changes from +6 to −1.
c. Its oxidation-number change is −6.
d. Its oxidation-number change is +6.

_____ **18.** Identify the atom that increases in oxidation number in the following redox reaction:

$$2MnO_2 + 2K_2CO_3 + O_2 \rightarrow 2KMnO_4 + 2CO_2$$

a. C
b. K
c. Mn
d. O

_____ **19.** Identify the reducing agent in this reaction:

$$I^- + MnO_4^- \rightarrow I_2 + MnO_2$$

a. I^-
b. MnO_4^-
c. I_2
d. MnO_2

_____ **20.** What is the increase in oxidation number for the atom that is oxidized in the following balanced redox equation?

$$Cr_2O_7^{2-} + 8H^+ + 3SO_3^{2-} \rightarrow Cr^{3+} + 3SO_4^{2-} + 8H_2O$$

a. +2
b. +6
c. −3
d. −6

_____ **21.** To balance the oxygen and hydrogen for a redox reaction that takes place in basic solution, it is necessary to use:
a. H_2O and H^+.
b. H_2O only.
c. H_2O and OH^-.
d. OH^- only.

_____ **22.** Which of the following is an oxidation half-reaction?
a. $Zn^{2+} + 2e^- \rightarrow Zn$
b. $NO + 2H_2O \rightarrow NO_3^- + 4H^+ + 3e^-$
c. $Na^+ + e^- \rightarrow Na$
d. $2H^+ + 2e^- \rightarrow H_2$

Name _____ Class _____ Date _____

_____ **23.** What is the reduction half-reaction for the following unbalanced redox equation?

$$Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$$

a. $Cr^{3+} \rightarrow Cr_2O_7^{2-}$
b. $Fe^{2+} \rightarrow Fe^{3+}$
c. $Fe^{3+} \rightarrow Fe^{2+}$
d. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$

_____ **24.** Which atom is reduced in the following unbalanced redox equations?

$$K_2Cr_2O_7 + H_2O + S \rightarrow KOH + Cr_2O_3 + SO_2$$

a. S
b. O
c. Cr
d. K

_____ **25.** Identify a true statement about how to protect an iron object from corrosion.

a. Increase the amount of salt and/or acid in the water.
b. Place a gold or silver bar in contact with the iron.
c. Place a better reducing agent in contact with the iron.
d. Place a metal more easily reduced in contact with the iron.

_____ **26.** Identify from the unbalanced equations below the one that does *not* represent a redox reaction.

a. $H_2O_2(aq) + MnO_4^-(aq) \rightarrow O_2(g) + Mn^{2+}(aq)$
b. $H_2(g) + N_2(g) \rightarrow NH_3(g)$
c. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$
d. $Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$

C. Questions

Answer the following questions in the space provided.

27. Determine which substance is oxidized and which substance is reduced in each reaction. Identify the oxidizing agent and reducing agent in each case.

a. $2Na + Br_2 \rightarrow 2NaBr$

b. $2K + S \rightarrow K_2S$

28. Combine these two half-reactions to form a balanced redox equation.

$$Br_2 + 2e^- \rightarrow 2Br^- \text{ and } Cr \rightarrow Cr^{3+} + 3e^-$$

Name _____ Class _____ Date _____

29. Determine the oxidation number of each element in these substances.

a. Li_3AlF_6

b. Na_2O

c. S_8

30. Balance the following redox equation, using either the oxidation-number-change method or the half-reaction method. Show all your work. (In using the half-reaction method, assume that the reaction occurs in aqueous acid solution.)

$$Fe_2O_3 + CO \rightarrow Fe + CO_2 \text{ (acid solution)}$$

D. Essay

31. How are oxidation numbers determined and used?

Name _____ Class _____ Date _____

22 OXIDATION–REDUCTION REACTIONS

CHAPTER TEST B

A. Matching

Match each term in Column B with the correct description in Column A. Write the letter of the correct term in the blank provided.

Column A	Column B
_____ **1.** the substance in a redox reaction that accepts electrons	**a.** oxidation-number-change method
_____ **2.** the complete or partial gain of electrons or the loss of oxygen	**b.** reducing agent
_____ **3.** those ions that do not change oxidation number or composition during a reaction	**c.** oxidation–reduction reactions
_____ **4.** a positive or negative number assigned to an atom according to a set of arbitrary rules	**d.** spectator ions
_____ **5.** the complete or partial loss of electrons or the gain of oxygen	**e.** oxidizing agent
_____ **6.** the balancing of a redox reaction by comparing the increases and decreases in oxidation numbers	**f.** reduction
_____ **7.** the chemical changes that occur when electrons are transferred between reactants	**g.** oxidation number
_____ **8.** a method of balancing redox reactions by balancing the oxidation and reduction half-reactions	**h.** half-reaction method
_____ **9.** the substance in a redox reaction that donates electrons	**i.** oxidation
_____ **10.** another name for an oxidation–reduction reaction	**j.** redox reaction

B. Multiple Choice

Write the letter of the best answer in the blank.

_____ **11.** Which of the following is true about oxidation reactions?

a. Oxidation reactions are the principal source of energy on earth.
b. All oxidation reactions are accompanied by reduction reactions.
c. The burning of wood in a fireplace and the metabolization of food by your body are oxidation reactions.
d. all of these

Name _____ Class _____ Date _____

_____ **12.** The oxidized substance in the following reaction is:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

a. Fe.
b. HCl.
c. $FeCl_2$.
d. H_2.

_____ **13.** The reducing agent in the reaction described in question 12 is:

a. Fe.
b. HCl.
c. $FeCl_2$.
d. H_2.

_____ **14.** What is occurring in the following reaction?

$$H_2 + Cl_2 \rightarrow 2HCl$$

a. H_2 is being reduced
b. Cl_2 is being oxidized
c. H_2 is gaining two electrons.
d. Cl_2 is acting as an oxidizing agent

_____ **15.** What is the oxidation number of sulfur in H_2SO_3?

a. +1
b. +2
c. +3
d. +4

_____ **16.** What is the usual oxidation number of oxygen in a compound?

a. −1
b. −2
c. +1
d. +2

_____ **17.** In the unbalanced equation below, the element being reduced is:

$$MnO_2 + HCl \rightarrow H_2O + MnCl_2 + Cl_2$$

a. Mn.
b. O.
c. H.
d. Cl.

_____ **18.** Which of the following is an oxidation reaction?

a. $Co^{3+} \rightarrow Co^{2+}$
b. $Cl_2 \rightarrow ClO_3^-$
c. $AuCl_4^- \rightarrow AuCl_2^-$
d. $Mn^{7+} \rightarrow Mn^{2+}$

_____ **19.** Among the following, which is an oxidation-reduction reaction?

a. $Na_2S + CaCO_3 \rightarrow CaS + Na_2CO_3$
b. $2HNO_3 + Mg(OH)_2 \rightarrow Mg(NO_3)_2 + 2H_2O$
c. $H_2 + F_2 \rightarrow 2HF$
d. $3Ba(OH)_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$

_____ **20.** Which of the following is true concerning the reaction below?

$$H_2S + HNO_3 \rightarrow S + NO + H_2O$$

a. S is reduced.
b. H is oxidized.
c. N is reduced.
d. O is oxidized.

_____ **21.** When the equation in question 20 is balanced, what is the coefficient for H_2O?

a. 2
b. 4
c. 3
d. 6

Name _____ Class _____ Date _____

_____ **22.** In the equation $PbO_2 + 4HCl \rightarrow 2H_2O + PbCl_2 + Cl_2$, how many electrons are transferred?

a. 1 **c.** 3
b. 2 **d.** 4

_____ **23.** The element oxidized in the reaction described in question 22 is:

a. Pb. **c.** H.
b. O. **d.** Cl.

_____ **24.** In the unbalanced equation given below, the element that is gaining electrons is:

$$HCl + MnO_2 \rightarrow MnCl_2 + H_2O + Cl_2$$

a. H. **c.** Mn.
b. Cl. **d.** O.

_____ **25.** When the equation in question 24 is balanced, what is the coefficient for HCl?

a. 1 **c.** 3
b. 2 **d.** 4

_____ **26.** Which of the following is true concerning redox reactions?

a. Double-replacement reactions are always redox reactions.
b. Single-replacement reactions may be redox reactions.
c. Acid–base reactions are always redox reactions.
d. all of these

_____ **27.** Identify a *false* statement about how to protect iron from corrosion.

a. Coat the surface with oil, paint, or plastic.
b. Attach a metal that is more easily reduced.
c. Exclude air and water.
d. Attach a metal that is a better reducing agent.

_____ **28.** From the unbalanced equations below, identify the one that does *not* represent a redox reaction.

a. $H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)$
b. $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$
c. $S_2O_3^{2-}(aq) + I_2(s) \rightarrow S_4O_6^{2-}(aq) + I^-(aq)$
d. $FeBr_2(aq) + Br_2(l) \rightarrow FeBr_3(aq)$

Name _____ Class _____ Date _____

C. Questions

Answer the following questions in the space provided.

29. For each of the following reactions, identify the element oxidized, the element reduced, the oxidizing agent, and the reducing agent.

	Oxidized	Reduced	Oxidizing Agent	Reducing Agent
a. $K + I_2 \rightarrow 2KI$				
b. $2Na + 2H_2O \rightarrow 2NaOH + H_2$				
c. $H_2 + CuO \rightarrow Cu + H_2O$				
d. $Cu(NO_3)_2 + Mg \rightarrow Mg(NO_3)_2 + Cu$				

30. Determine the oxidation number of each element in the following:

a. K_2SO_4

b. $Cu(NO_3)_2$

c. $HAsO_3$

d. MnO_4^-

31. Use the oxidation-number-change method to balance the equations given below. Show all your work.

a. $HNO_3 + Ag \rightarrow AgNO_3 + NO + H_2O$

b. $Br_2 + SO_2 + H_2O \rightarrow H_2SO_4 + HBr$

Name _____ Class _____ Date _____

32. Use the half-reaction method to balance the equations given below. Show all your work.

a. $HNO_2 + HI \rightarrow I_2 + NO + H_2O$

b. $K_2Cr_2O_7 + FeCl_2 + HCl \rightarrow CrCl_3 + KCl + FeCl_3 + H_2O$

D. Essay

33. Explain why oxidation cannot occur without reduction, and vice versa.