Chapter 8

Preview

Lesson Starter

- The photograph in the textbook provides evidence that an exothermic chemical reaction is occurring.
- How would you convey to other scientists what is occurring in the photograph?
- A chemical equation is a shorthand way of communicating the reaction that is occurring.
- A chemical equation packs a great deal of information into relatively few symbols.

End Of Slide

Objectives

- **List** three observations that suggest that a chemical reaction has taken place.
- **List** three requirements for a correctly written chemical equation.
- **Write** a word equation and a formula equation for a given chemical reaction.
- **Balance** a formula equation by inspection.

End Of Slide

- A *chemical reaction* is the process by which one or more substances are changed into one or more different substances.
- In any chemical reaction, the original substances are known as the *reactants* and the resulting substances are known as the *products*.
- According to the law of conservation of mass, the total mass of reactants must equal the total mass of products for any given chemical reaction.

End Of Slide

- A **chemical equation** represents, with symbols and formulas, the identities and relative molecular or molar amounts of the reactants and products in a chemical reaction.
  - example: The following chemical equation shows that the reactant ammonium dichromate yields the products nitrogen, chromium(III) oxide, and water.

$$(NH_4)_2Cr_2O_7(s) \longrightarrow N_2(g) + Cr_2O_3(s) + 4H_2O(g)$$

End Of Slide

Chemical Equation

Click below to watch the Visual Concept.

Visual Concept

Indications of a Chemical Reaction

- Certain easily observed changes usually indicate that a chemical reaction has occurred.

1. Evolution of energy as heat and light
2. Production of a gas
3. Formation of a precipitate.
   - A solid that is produced as a result of a chemical reaction in solution and that separates from the solution is known as a **precipitate.**
4. Color change

End Of Slide

Signs of a Chemical Reaction

Click below to watch the Visual Concept.

Visual Concept

Characteristics of Chemical Equations

- The following requirements will aid you in writing and reading chemical equations correctly.

1. The equation must represent known facts.
2. The equation must contain the correct formulas for the reactants and products.
3. The law of conservation of mass must be satisfied.
    - A **coefficient** is a small whole number that appears in front of a formula in a chemical equation.

End Of Slide

Elements That Normally Exist as Diatomic Molecules

Element	Symbol	Molecular formula	Physical state at room temperature
Hydrogen	H	H_2	gas
Nitrogen	N	N_2	gas
Oxygen	O	O_2	gas
Fluorine	F	F_2	gas
Chlorine	Cl	Cl_2	gas
Bromine	Br	Br_2	liquid
Iodine	I	I_2	solid

Characteristics of Chemical Equations, *continued*

Word and Formula Equations

- The first step in writing a chemical equation is to identify the facts to be represented.
- A **word equation** is an equation in which the reactants and products in a chemical reaction are represented by words.
  - A word equation is qualitative
  - example: methane + oxygen ⟶ carbon dioxide + water

End of Slide

Characteristics of Chemical Equations, *continued*

Word and Formula Equations, *continued*

- The next step in writing a correct chemical equation is to replace the names of the reactants and products with appropriate symbols and formulas.

- A **formula equation** represents the reactants and products of a chemical reaction by their symbols or formulas.
  - example: The formula equation for the reaction of methane and oxygen is
  - $CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$ (not balanced)

End Of Slide
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Reading a Chemical Equation

Click below to watch the Visual Concept.

Visual Concept

Characteristics of Chemical Equations, *continued*

Word and Formula Equations, *continued*

- To complete the process of writing a correct equation, the law of conservation of mass must be taken into account.
  - The relative amounts of reactants and products represented in the equation must be adjusted so that the numbers and types of atoms are the same on both sides of the equation.
  - This process is called *balancing an equation* and is carried out by inserting coefficients.

End Of Slide

Characteristics of Chemical Equations, *continued*

Word and Formula Equations, *continued*

- To balance the equation, begin by counting atoms of elements that are combined with atoms of other elements and that appear only once on each side of the equation.

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + 2H_2O(g) \quad \text{(not balanced)}$$

  - Begin by counting carbon atoms.
  - Carbon is already balanced in the equation.
  - Two additional hydrogen atoms are needed on the right side of the equation.

End Of Slide

Characteristics of Chemical Equations, *continued*

Word and Formula Equations, *continued*

$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$ (partially balanced)

- Now consider the number of oxygen atoms.
- Increase the number of oxygen atoms on the left side to four by placing the coefficient 2 in front of the molecular formula for oxygen.

- The correct chemical equation, or *balanced formula equation,* for the burning of methane in oxygen is

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

End Of Slide

Characteristics of Chemical Equations, *continued*

Additional Symbols Used in Chemical Equations

Symbol	Explanation
$\longrightarrow$	"Yields"; indicates result of reaction
$\rightleftharpoons$	Used in place of a single arrow to indicate a reversible reaction
(s)	A reactant or product in the solid state; also used to indicate a precipitate
$\downarrow$	Alternative to (s), but used only to indicate a precipitate
(l)	A reactant or product in the liquid state
(aq)	A reactant or product in an aqueous solution (dissolved in water)
(g)	A reactant or product in the gaseous state

Characteristics of Chemical Equations, *continued*

Additional Symbols Used in Chemical Equations

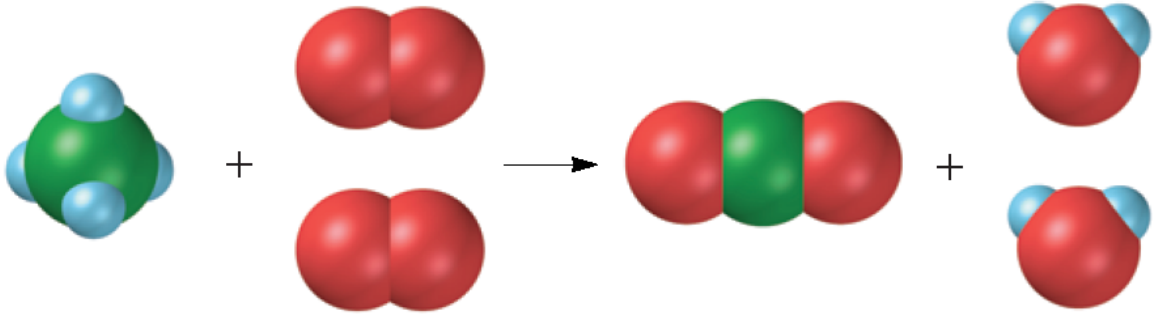
Symbol	Explanation
↑	Alternative to (*g*), but used only to indicate a gaseous product
$\xrightarrow{\Delta}$ or $\xrightarrow{\text{heat}}$	Reactants are heated
$\xrightarrow{\text{2 atm}}$	Pressure at which reaction is carried out, in this case 2 atm
$\xrightarrow{\text{pressure}}$	Pressure at which reaction is carried out exceeds normal atmospheric pressure
$\xrightarrow{\text{0°C}}$	Temperature at which reaction is carried out, in this case 0°C
$\xrightarrow{MnO_2}$	Formula of catalyst, in this case manganese dioxide, used to alter the rate of the reaction

Symbols Used in Chemical Equations

Reactants and Products	
Symbol	***Meaning***
(*s*) or (*cr*)	solid or crystal
(*l*)	liquid
(*g*)	gas
(*aq*)	in aqueous solution (dissolved in water)
↓	solid precipitate product forms
↑	gaseous product forms

Reaction Conditions	
Symbol	***Meaning***
$\longrightarrow$	"produces" or "yields," indicating result of reaction
$\rightleftharpoons$	reaction in which products can re-form into reactants; final result is a mixture of products and reactants
$\xrightarrow{\Delta}$ or $\xrightarrow{\text{heat}}$	reactants are heated
$\xrightarrow{1.0 \times 10^8\ \text{kPa}}$	pressure at which reaction is carried out
$\xrightarrow{0^\circ\text{C}}$	temperature at which reaction is carried out
$\xrightarrow{\text{Pd}}$	chemical formula of a catalyst added to speed up a reaction
$\xrightarrow{e^-}$	electrolysis

Methane Combustion



Molecules	CH_4	+	$2O_2$	→	CO_2	+ $2H_2O$
Atoms	(1C, 4H)	+	(4O)	→	(1C, 2O)	+ (4H, 2O)

In a Bunsen burner, methane combines with oxygen in the air to form carbon dioxide and water vapor. The reaction is represented by both a molecular model and a balanced equation. Each shows that the number of atoms of each element in the reactants equals the number of atoms of each element in the products.

Symbols Used in Chemical Equations

Click below to watch the Visual Concept.

Visual Concept

Characteristics of Chemical Equations, *continued*

Sample Problem A

Write word and formula equations for the chemical reaction that occurs when solid sodium oxide is added to water at room temperature and forms sodium hydroxide (dissolved in the water). Include symbols for physical states in the formula equation. Then balance the formula equation to give a balanced chemical equation.

Characteristics of Chemical Equations, *continued*

Sample Problem A Solution

- The word equation must show the reactants, sodium oxide and water, to the left of the arrow.
- The product, sodium hydroxide, must appear to the right of the arrow.

$$\text{sodium oxide} + \text{water} \longrightarrow \text{sodium hydroxide}$$

- Sodium has an oxidation state of +1, that oxygen usually has an oxidation state of -2, and that a hydroxide ion has a charge of 1-. The unbalanced formula equation is

$$Na_2O + H_2O \longrightarrow NaOH \text{ (not balanced)}$$

End Of Slide

Characteristics of Chemical Equations, *continued*

Sample Problem A Solution, *continued*

Adding symbols for the physical states of the reactants and products and the coefficient 2 in front of NaOH produces a balanced chemical equation.

$$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$$

End Of Slide

Characteristics of Chemical Equations, *continued*

Sample Problem B

Translate the following chemical equation into a sentence:

$$BaCl_2(aq) + Na_2CrO_4(aq) \longrightarrow BaCrO_4(s) + 2NaCl(aq)$$

End Of Slide

Characteristics of Chemical Equations, *continued*

Sample Problem B Solution

Aqueous solutions of barium chloride and sodium chromate react to produce a precipitate of barium chromate plus sodium chloride in aqueous solution.

Significance of a Chemical Equation

- Some of the quantitative information revealed by a chemical equation includes

1. The coefficients of a chemical reaction indicate relative, not absolute, amounts of reactants and products.

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

1 molecule H_2 : 1 molecule Cl_2 : 2 molecules HCl

- This ratio shows the smallest possible relative amounts of the reaction's reactants and products.

End Of Slide

Significance of a Chemical Equation

2. The relative masses of the reactants and products of a chemical reaction can be determined from the reaction's coefficients.

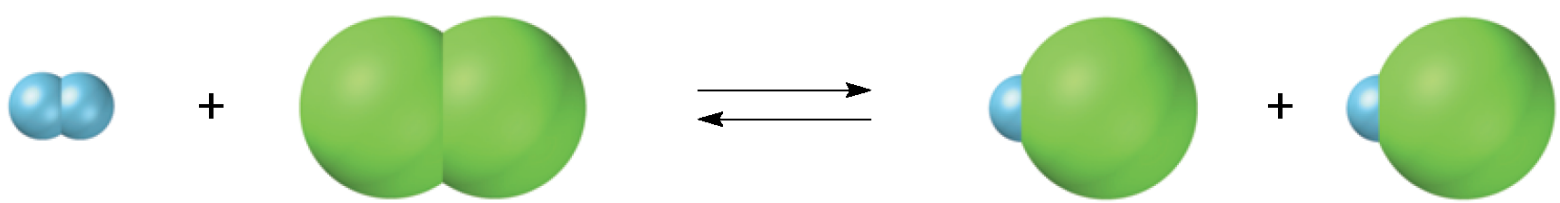
- An amount of an element or compound in moles can be converted to a mass in grams by multiplying by the appropriate molar mass.
- example:

$$1 \text{ mol } H_2 \times \frac{2.02 \text{ g } H_2}{\text{mol } H_2} = 2.02 \text{ g } H_2$$

End Of Slide

Interpreting a Chemical Reaction

$H_2 + Cl_2 \rightleftharpoons 2\ HCl$



1 molecule H_2	1 molecule Cl_2	2 molecules HCl
1 mol H_2	1 mol Cl_2	2 mol HCl
2.02 g H_2	70.90 g Cl_2	$2 \times 36.46\ g = 72.92\ g$ HCl

Significance of a Chemical Equation

3. The reverse reaction for a chemical equation has the same relative amounts of substances as the forward reaction.

- An equation gives no indication of whether a reaction will actually occur.
- Chemical equations give no information about the speed at which reactions occur.
- Equations do not give any information about how the bonding between atoms or ions changes during the reaction.

End Of Slide

Interpreting Chemical Equations

Click below to watch the Visual Concept.

Visual Concept

Balancing Chemical Equations

- The following procedure demonstrates how to master balancing equations by inspection using a step-by-step approach.

1. Identify the names of the reactants and the products, and write a word equation.

$$\text{water} \longrightarrow \text{hydrogen} + \text{oxygen}$$

Balancing Chemical Equations, *continued*

- balancing equations by inspection, *continued*

  2. Write a formula equation by substituting correct formulas for the names of the reactants and the products.

$$H_2O(l) \longrightarrow H_2(g) + O_2(g) \text{ (not balanced)}$$

Balancing Chemical Equations, *continued*

- balancing equations by inspection, *continued*
  3. Balance the formula equation according to the law of conservation of mass.
     - Balance the different types of atoms one at a time.
     - First balance the atoms of elements that are combined and that appear only once on each side of the equation.
     - Balance polyatomic ions that appear on both sides of the equation as single units.
     - Balance H atoms and O atoms after atoms of all other elements have been balanced.

End Of Slide

Balancing Chemical Equations, *continued*

- balancing equations by inspection, *continued*
  3. Balance the formula equation according to the law of conservation of mass.
     - Balance oxygen atoms by increasing the number of H_2O molecules.

$$2H_2O(l) \longrightarrow H_2(g) + O_2(g)$$ (partially balanced)

     - Balance the hydrogen atoms by placing the coefficient 2 in front of hydrogen, H_2.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$ (balanced)

End Of Slide

Balancing Chemical Equations, *continued*

- balancing equations by inspection, *continued*

4. Count atoms to be sure that the equation is balanced.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$

$$(4H + 2O) = (4H) + (2O)$$

- If the coefficients do not represent the smallest possible whole-number ratio of reactants and products, divide the coefficients by their greatest common factor in order to obtain the smallest possible whole-number coefficients.

End Of Slide

Balancing a Chemical Equation by Inspection

Click below to watch the Visual Concept.

Visual Concept

Balancing Chemical Equations, *continued*

Sample Problem C

The reaction of zinc with aqueous hydrochloric acid produces a solution of zinc chloride and hydrogen gas. Write a balanced chemical equation for the reaction.

End Of Slide

Balancing Chemical Equations, *continued*

Sample Problem C Solution

- Write the word equation.

zinc + hydrochloric acid ⟶ zinc chloride + hydrogen

- Write the formula equation.

$Zn(s) + HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$ (not balanced)

End Of Slide

Balancing Chemical Equations, *continued*

Sample Problem C Solution, *continued*

- Adjust the coefficients.
  - Balance chlorine first because it is combined on both sides of the equation.

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

- Count atoms to check balance.

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

$$(1Zn) + (2H + 2Cl) = (1Zn + 2Cl) + (2H)$$

End Of Slide

Balancing Chemical Equations, *continued*

Sample Problem D

Solid aluminum carbide, Al_4C_3, reacts with water to produce methane gas and solid aluminum hydroxide. Write a balanced chemical equation for this reaction.

Balancing Chemical Equations, *continued*

Sample Problem D Solution

- The reactants are aluminum carbide and water.
- The products are methane and aluminum hydroxide.
- The formula equation is

$$Al_4C_3(s) + H_2O(l) \longrightarrow CH_4(g) + Al(OH)_3(s)$$

(not balanced)

- Balance Al atoms

$$Al_4C_3(s) + H_2O(l) \longrightarrow CH_4(g) + 4Al(OH)_3(s)$$

(partially balanced)

End of Slide

Balancing Chemical Equations, *continued*

Sample Problem D Solution, *continued*

- Balance the carbon atoms.

$$Al_4C_3(s) + H_2O(l) \longrightarrow 3CH_4(g) + 4Al(OH)_3(s)$$

(partially balanced)

- Balance oxygen atoms.
  - Oxygen, unlike hydrogen, appears only once on each side of the equation.

$$Al_4C_3(s) + 12H_2O(l) \longrightarrow 3CH_4(g) + 4Al(OH)_3(s)$$

- The hydrogen atoms are balanced.

End Of Slide

Balancing Chemical Equations, *continued*

Sample Problem D Solution, *continued*

- Count atoms to check balance.

$$Al_4C_3(s) + 12H_2O(l) \longrightarrow 3CH_4(g) + 4Al(OH)_3(s)$$

$$(4Al + 3C) + (24H + 12O) = (3C + 12H) + (4Al + 12H + 12O)$$

- The equation is balanced.

End Of Slide

Preview

Lesson Starter

- So many chemical reactions can occur or are occurring that it would be impossible to predict their products if it was not possible to place many of them into categories.

- Synthesis reactions are one class of reactions in which substances combine to form a new compound.

End Of Slide

Objectives

- **Define** and **give** general equations for synthesis, decomposition, single-displacement, and double-displacement reactions.
- **Classify** a reaction as a synthesis, decomposition, single-displacement, double-displacement, or combustion reaction.
- **List** three kinds of synthesis reactions and six kinds of decomposition reactions.

End Of Slide

Objectives, *continued*

- **List** four kinds of single-displacement reactions and three kinds of double-displacement reactions.
- **Predict** the products of simple reactions given the reactants.

End Of Slide

- There are several ways to classify chemical reactions.
- The classification scheme described in this section provides an introduction to five basic types of reactions:
  - synthesis
  - decomposition
  - single-displacement
  - double-displacement
  - combustion reactions

End Of Slide

Synthesis Reactions

- In a **synthesis reaction,** also known as a composition reaction, two or more substances combine to form a new compound.
- This type of reaction is represented by the following general equation.

$$A + X \longrightarrow AX$$

- A and X can be elements or compounds.
- AX is a compound

End Of Slide

Synthesis Reactions

Click below to watch the Visual Concept.

Visual Concept

Synthesis Reactions, *continued*

Reactions of Elements with Oxygen and Sulfur

- One simple type of synthesis reaction is the combination of an element with oxygen to produce an *oxide* of the element.
  - Almost all metals react with oxygen to form oxides.
  - example: $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$
  - Group 2 elements react in a similar manner, forming oxides with the formula MO, where M represents the metal.

End Of Slide

Synthesis Reactions, *continued*

Reactions of Elements with Oxygen and Sulfur, *continued*

- The Group 1 metals form oxides with the formula M_2O.
  - example: Li_2O
- The Group 1 and Group 2 elements react similarly with sulfur, forming *sulfides* with the formulas M_2S and MS, respectively.

$$16Rb(s) + S_8(s) \longrightarrow 8Rb_2S(s)$$

$$8Ba(s) + S_8(s) \longrightarrow 8BaS(s)$$

End Of Slide

Synthesis Reactions, *continued*

Reactions of Elements with Oxygen and Sulfur, *continued*

- Nonmetals also undergo synthesis reactions with oxygen to form oxides.
  - example: Sulfur reacts to form sulfur dioxide.

$$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$$

  - example: Hydrogen reacts with oxygen to form dihydrogen monoxide (water).

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

End of Slide
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Synthesis Reactions, *continued*

Reactions of Metals with Halogens

- Most metals react with the Group 17 elements, the halogens, to form either ionic or covalent compounds.
  - Group 1 metals react with halogens to form ionic compounds with the formula MX, where M is the metal and X is the halogen.
  - example: $2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$

End Of Slide

Synthesis Reactions, *continued*

Reactions of Metals with Halogens, *continued*

- Group 2 metals react with the halogens to form ionic compounds with the formula MX_2.
- example: $Mg(s) + F_2(g) \longrightarrow MgF_2(s)$
- Fluorine is so reactive that it combines with almost all metals.

End Of Slide

Synthesis Reactions, *continued*

Synthesis Reactions with Oxides

- *Active* metals are highly reactive metals.
- Oxides of active metals react with water to produce metal hydroxides.
  - example: Calcium oxide reacts with water to form calcium hydroxide.

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$$

End Of Slide

Synthesis Reactions, *continued*

Synthesis Reactions with Oxides, *continued*

- Many oxides of nonmetals in the upper right portion of the periodic table react with water to produce oxyacids.
  - example: $SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$
- Certain metal oxides and nonmetal oxides react with each other in synthesis reactions to form salts.
  - example: $CaO(s) + SO_2(g) \longrightarrow CaSO_3(s)$

End Of Slide

Decomposition Reactions

- In a **decomposition reaction,** a single compound undergoes a reaction that produces two or more simpler substances.
- Decomposition reactions are the opposite of synthesis reactions.
- They are represented by the following general equation.

$$AX \longrightarrow A + X$$

  - AX is a compound.
  - A and X can be elements or compounds.

End Of Slide

Decomposition Reactions, *continued*

Decomposition of Binary Compounds

- The decomposition of a substance by an electric current is called **electrolysis.**
  - example: $2H_2O(l) \xrightarrow{\text{electricity}} 2H_2(g) + O_2(g)$
- Oxides of the less-active metals, which are located in the lower center of the periodic table, decompose into their elements when heated.
  - example: $2HgO(s) \xrightarrow{\Delta} 2Hg(l) + O_2(g)$

End Of Slide

Electrolysis

Click below to watch the Visual Concept.

Visual Concept

Decomposition Reactions, *continued*

Decomposition of Metal Carbonates

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

Decomposition of Metal Hydroxides

$$Ca(OH)_2(s) \xrightarrow{\Delta} CaO(s) + H_2O(g)$$

Decomposition of Metal Chlorates

$$2KClO_3(s) \xrightarrow[MnO_2(s)]{\Delta} 2KCl(s) + 3O_2(g)$$

End Of Slide

Decomposition Reactions, *continued*

Decomposition of Acids

- Certain acids decompose into nonmetal oxides and water.
  - example: Carbonic acid is unstable and decomposes readily at room temperature to produce carbon dioxide and water.

$$H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)$$

Single-Displacement Reactions

- In a **single-displacement reaction,** also known as a replacement reaction, one element replaces a similar element in a compound.
- Many single-displacement reactions take place in aqueous solution.
- Single-displacement reactions can be represented by the following general equations.

$$A + BX \longrightarrow AX + B \quad \text{or} \quad Y + BX \longrightarrow BY + X$$

- A, B, X, and Y are elements. AX, BX, and BY are compounds.

End Of Slide

Single-Displacement Reactions

Displacement of a Metal in a Compound by Another Metal

- Aluminum is more active than lead.

$$2Al(s) + 3Pb(NO_3)_2(aq) \longrightarrow 3Pb(s) + 2Al(NO_3)_3(aq)$$

Single-Displacement Reactions, *continued*

Displacement of Hydrogen in Water by a Metal

- The most-active metals, such as those in Group 1, react vigorously with water to produce metal hydroxides and hydrogen.

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

- Less-active metals, such as iron, react with steam to form a metal oxide and hydrogen gas.

$$3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$$

End Of Slide

Single-Displacement Reactions, *continued*

Displacement of Hydrogen in an Acid by a Metal

- The more-active metals react with certain acidic solutions, such as hydrochloric acid and dilute sulfuric acid, replacing the hydrogen in the acid.
- The reaction products are a metal compound (a salt) and hydrogen gas.

$$Mg(s) + 2HCl(aq) \longrightarrow H_2(g) + MgCl_2(aq)$$

End Of Slide

Single-Displacement Reactions, *continued*

Displacement of Halogens

- Fluorine is the most-active halogen.
  - It can replace any of the other halogens in their compounds.
- In Group 17 each element can replace any element below it, but not any element above it.

$$Cl_2(g) + 2KBr(aq) \longrightarrow 2KCl(aq) + Br_2(l)$$

$$F_2(g) + 2NaCl(aq) \longrightarrow 2NaF(aq) + Cl_2(g)$$

$$Br_2(l) + KCl(aq) \longrightarrow \text{no reaction}$$

End of Slide

Double-Displacement Reactions

- In **double-displacement reactions,** the ions of two compounds exchange places in an aqueous solution to form two new compounds.
- One of the compounds formed is usually a precipitate, an insoluble gas that bubbles out of the solution, or a molecular compound, usually water.
- The other compound is often soluble and remains dissolved in solution.

End Of Slide

Double-Displacement Reactions, *continued*

- A double-displacement reaction is represented by the following general equation.

$$AX + BY \longrightarrow AY + BX$$

  - A, X, B, and Y in the reactants represent ions.
  - AY and BX represent ionic or molecular compounds.

End Of Slide

Double-Displacement Reactions, *continued*

Formation of a Precipitate

- The formation of a precipitate occurs when the cations of one reactant combine with the anions of another reactant to form an insoluble or slightly soluble compound.
  - example:

$$2KI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + 2KNO_3(aq)$$

  - The precipitate forms as a result of the very strong attractive forces between the Pb^{2+} cations and the I^- anions.

End Of Slide

Double-Displacement Reactions, *continued*

Formation of a Gas

$$FeS(s) + 2HCl(aq) \longrightarrow H_2S(g) + FeCl_2(aq)$$

Formation of Water

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

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Combustion Reactions

- In a **combustion reaction,** a substance combines with oxygen, releasing a large amount of energy in the form of light and heat.
  - example: combustion of hydrogen

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

  - example: combustion of propane
  - $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$

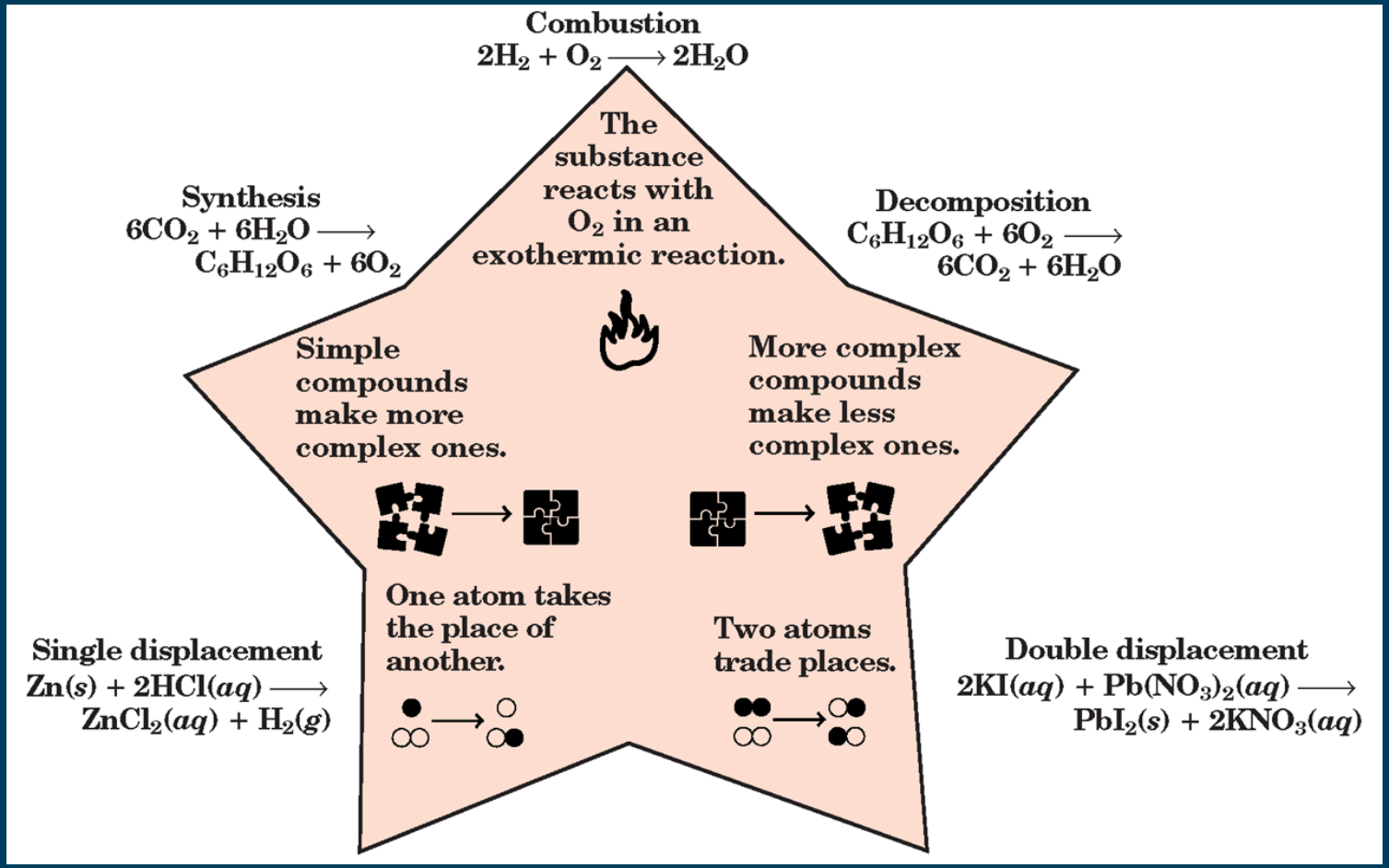
End Of Slide

Combustion Reaction

Click below to watch the Visual Concept.

Visual Concept

Determining Reaction Types



Identifying Reactions and Predicting Products

1. Is there only one reactant?

If the answer is no, go to step 2.

If the answer is yes, you have a decomposition reaction.

- A binary compound generally breaks into its elements.
- A ternary compound breaks according to the guidelines given earlier in this section.

2. Are the reactants two elements or two simple compounds?

If the answer is no, go to step 3.

If the answer is yes, you probably have a synthesis reaction.

- If both reactants are elements, the product is a binary compound. For a metal reacting with a nonmetal, use the expected charges to predict the formula of the compound.

- If the reactants are compounds, the product will be a single ternary compound according to the guidelines given earlier in this section.

Identifying Reactions and Predicting Products

3. Are the reactants oxygen and a hydrocarbon?

If the answer is no, go to step 4.

If the answer is yes, you have a combustion reaction.

- The products of a combustion reaction are carbon dioxide and water.

Charles D. Winters/Photo Researchers, Inc.

4. Are the reactants an element and a compound other than a hydrocarbon?

If the answer is no, go to step 5.

If the answer is yes, you probably have a displacement reaction.

- Use the activity series to determine the activities of the elements.
- If the more active element is already part of the compound, no reaction will occur. Otherwise, the more active element will displace the less active element from the compound.

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Identifying Reactions and Predicting Products

5. Are the reactants two compounds composed of ions?

If the answer is no, go back to step 1 because you might have missed the proper category.

If the answer is yes, you probably have a double-displacement reaction.

- Write formulas for the possible products by forming two new compounds from the ions available.
- Determine if one of the possible products is a solid precipitate, a gas, or a molecular compound, such as water. If neither product qualifies in the above categories, no reaction occurs. Use the rules below to determine whether a substance will be an insoluble solid.

Preview

Lesson Starter

- **Demonstration—Activity Series of Metals**
  - Complete the following table for each of the cations Al^{3+}, Zn^{2+}, Fe^{3+}, Cu^{2+}, and H^{+} based on their reactions with the metal strips.

Metal	3 min	30 min	1 day
Al			
Zn			
Fe			
Cu			

End Of Slide

Lesson Starter, *continued*

- Count the number of reactions for each metal.
- Count the number of reactions for each cation.
- Use this information to develop an activity series.

End Of Slide

Objectives

- Explain the significance of an activity series.
- Use an activity series to predict whether a given reaction will occur and what the products will be.

End Of Slide

- The ability of an element to react is referred to as the element's *activity*.
  - The more readily an element reacts with other substances, the greater its activity is.
- An **activity series** is a list of elements organized according to the ease with which the elements undergo certain chemical reactions.
  - For metals, greater activity means a greater ease of *loss* of electrons, to form positive ions.
  - For nonmetals, greater activity means a greater ease of *gain* of electrons, to form negative ions.

End Of Slide

- The order in which the elements are listed is usually determined by single-displacement reactions.
- The most-active element is placed at the top in the series.
  - It can replace each of the elements below it from a compound in a single-displacement reaction.
- Activity series are used to help predict whether certain chemical reactions will occur.
- Activity series are based on experiment.

End of Slide

Activity Series of the Elements

Activity of Halogens
F_2
Cl_2
Br_2
I_2

Activity of Metals	
Li Rb K Ca Ba Sr Ca Na	react with cold H_2O and acids, replacing hydrogen; react with oxygen, forming oxides
Mg Al Mn Zn Cr Fe Cd	react with steam (but not cold water) and acids; replacing hydrogen; react with oxygen, forming oxides
Co Ni Sn Pb	do not react with water; react with acids, replacing hydrogen; react with oxygen, forming oxides
H_2 Sb Bi Cu Hg	react with oxygen, forming oxides
Ag Pt Au	fairly unreactive, forming oxides only indirectly

Activity Series

Click below to watch the Visual Concept.

Visual Concept

End of Chapter 8 Show