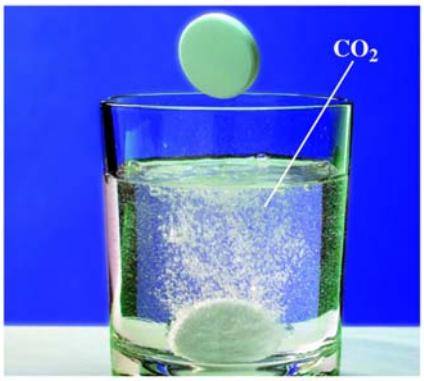
Chapter 7
Chemical Reactions



$NaHCO_3$

Fe Fe_2O_3

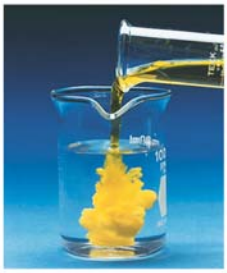
Chemical & Physical Changes

- In a ***physical change***, the chemical composition of the substance remains constant.
  - Examples of physical changes are the melting of ice or the boiling of water.
- In a ***chemical change***, the chemical composition of the substance changes; a chemical reaction occurs.
  - During a chemical reaction, a new substance is formed.

Evidence of a Chemical Change

- Gas release (bubbles).
- Light or release of heat energy.
- Formation of a precipitate.
- A permanent color change.





Writing Chemical Equations

- A ***chemical equation*** describes a chemical reaction using formulas and symbols. A general chemical equation is:

$$A + B \rightarrow C + D$$

- In this equation, A and B are ***reactants*** and C and D are ***products***.
- We can also add a ***catalyst*** to a reaction. A catalyst is written above the arrow and speeds up the reaction without being consumed.

States of Matter in Equations

- When writing chemical equations, we usually specify the physical state of the reactants and products.

$$A(g) + B(l) \rightarrow C(s) + D(aq)$$

What states are these components in?

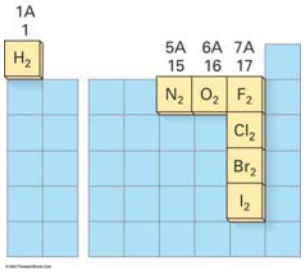
Chemical Equation Symbols

- Here are several symbols used in chemical equations:

Symbol	Interpretation of Chemical Equation Symbol
$\rightarrow$	produces, yields, gives (separates reactants from products)
+	reacts with, added to, plus (separates two or more reactants or products)
$\Delta \rightarrow$	the reactants are heated
$Fe \rightarrow$	metallic iron catalyst is added to the reaction
NR	no reaction
(s)	solid substance or precipitate
(l)	liquid substance
(g)	gaseous substance
(aq)	aqueous solution

Diatomic Molecules

- Seven nonmetals occur naturally as ***diatomic molecules***.
- They are hydrogen (H_2), nitrogen (N_2), oxygen (O_2), and the halogens, F_2, Cl_2, Br_2, and I_2.
- These elements are written as diatomic molecules when they appear in chemical reactions.



Balancing Chemical Equations

- When we write a chemical equation, the number of atoms of each element must be the same on both sides of the arrow.
- This is a ***balanced chemical equation***.
- We balance chemical reactions by placing a whole number ***coefficient*** in front of each substance.
- A coefficient multiplies all subscripts in a chemical formula:
  - 3 H_2O has 6 hydrogen atoms and 3 oxygen atoms

Guidelines for Balancing Equations

Rule 1: Before placing coefficients in an equation, check that the formulas are correct.

Rule 2: **NEVER** change the subscripts in a chemical formula to balance a chemical equation.

Rule 3: Balance each element in the equation starting with the most complex formula.

Rule 4: Balance polyatomic ions as a single unit if it appears on both sides of the equation.

Rule 5: The coefficients in an equation must be whole numbers when you are finished

Rule 6: Check that you have the ***smallest*** whole number ratio of coefficients

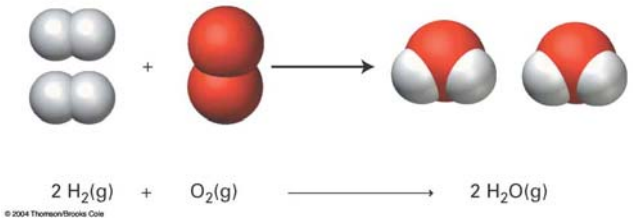
Balancing a Chemical Equation

- Let's balance the following chemical equation:

$$Al_2(SO_4)_3(aq) + Ba(NO_3)_2(aq) \rightarrow Al(NO_3)_3(aq) + BaSO_4(s)$$

Interpreting Chemical Equations

- You can get a lot of information from a balanced chemical equation.



- As shown above, two molecules of H_2 react with one molecule of O_2 to produce two molecules of H_2O
- We can replace the word "molecule" with the term "mole" and get the same interpretation.
- You cannot insert the word "grams" though!

Writing Chemical Equations

- There are three steps for writing chemical equations that describe a reaction:

Step 1: Classify the reaction type.

Step 2: Write a qualitative description of the reaction.

- Here, you will write the formulas for the given reactants to the left of the arrow and the formulas for the given or predicted products on the right side.
- Don't forget your rules for writing formulas for ionic and covalent compounds (Chapter 5) and which elements are always diatomic (Chapter 7)!

Step 3: Balance your final reaction as we did previously.

Types of Chemical Reactions

- We can place chemical reactions into six categories:

Combination (Synthesis) Reactions

Decomposition Reactions

Combustion (Oxidation) Reactions

Single-Replacement

Double-Replacement

Combination Reactions

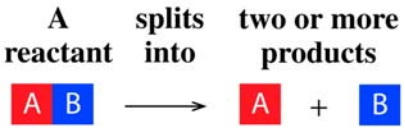
- A ***combination reaction*** is a reaction where two simpler substances are combined into a more complex compound.

$$A + X \rightarrow AX$$

- They are also called *synthesis reactions*.
- Two specific combination reactions are:
  - The reaction of a metal with oxygen
  - The reaction of a metal and a nonmetal

Decomposition Reactions

- In a ***decomposition reaction***, a single compound is broken down into simpler substances.



- Heat or light is usually required to start a decomposition reaction.
- Two specific decomposition reactions are:
  - The breakdown of a metal oxygenate
  - The breakdown of a metal carbonate

Combustion Reactions

- ***Combustion reactions*** (also called oxidation reactions) consist of the burning of carbon/hydrogen (and/or oxygen) compounds in the presence of molecular oxygen.

$$C_XH_Y(s) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$$

- The products of these reactions are always **carbon dioxide and water**.

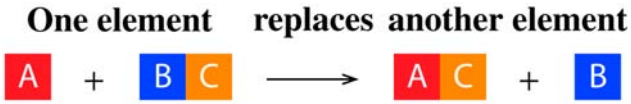
Here's an example:

$$2C_2H_6(s) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

- The only compound that varies from reaction to reaction is the carbon/hydrogen reactant (this reactant can also contain oxygen)

Single-Replacement Reactions

- A ***single-replacement reaction*** is a reaction where a more active element (usually a metal) displaces another, less active element in a compound.



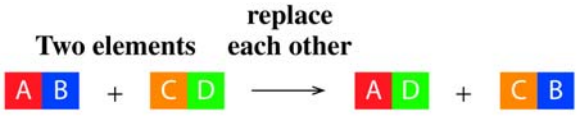
Here are some examples:

$$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$$

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

Double-Replacement Reactions

- In a ***double replacement reaction***, two ionic compounds in aqueous solution switch anions and produce two new compounds



- If either AD or CB is an insoluble compound, a precipitate will appear indicating that a chemical reaction has occured.

Here are some examples:

$$BaCl_2(aq) + K_2CrO_4(aq) \rightarrow \mathbf{BaCrO_4(s)} + 2\ KCl(aq)$$

$$NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$$

Table 8.2 Summary of Types of Reactions and Equations

Reactants	Reaction Type	Equation Type	Products
Any combination of elements and compounds that form one product	Combination	$A + X \rightarrow AX$ Combination	One compound
One compound	Decomposition	$AX \rightarrow A + X$ Decomposition	Any combination of elements and compounds
O_2* + compound of C and H or C, H, and O	Complete oxidation or burning	$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$ Complete oxidation	CO_2* + H_2O*
Element + ionic compound or acid	Oxidation–reduction	$A + BX \rightarrow AX + B$ Single-replacement	Element + ionic compound
Solution of ionic compound + acid or solution of second ionic compound	Precipitation	$AX + BY \rightarrow AY + BX$ Double-replacement	Precipitate of ionic compound + acid or second ionic compound
Acid + hydroxide base	Neutralization	$HX + MOH \rightarrow HOH + MX$ Double-replacement	Ionic compound (salt) + H_2O

*The reactant oxygen and the products carbon dioxide and water are usually not mentioned in the description of a reaction of this kind.