Chapter 8 - Chemical Equations and Reactions

8-1 Describing Chemical Reactions

I. Introduction
   A. Reactants
      1. Original substances entering into a chemical rxn
   B. Products
      1. The resulting substances from a chemical rxn

Reactants → Products

C. Chemical Equation
   1. Represents with symbols and formulas, the identities and relative amounts of the reactants and products in a chemical rxn

II. Indications of a Chemical Reaction
   A. Evolution of Heat and Light
      1. Evidence of energy being released (exothermic rxn)
   B. Production of a Gas
      1. CO$_2$, H$_2$, H$_2$S are some gases produced by chemical rxns

   FeS(aq) + H$_2$SO$_4$(aq) → FeSO$_4$(aq) + H$_2$S(g)

   C. Formation of a Precipitate
      1. Precipitate is a solid that is produced as a result of a chemical rxn in solution

   BaCl$_2$(aq) + Na$_2$SO$_4$(aq) → 2NaCl(aq) + BaSO$_4$(s)

III. Characteristics of Chemical Equations
   A. The equation must represent known facts
      1. This can be done with a word equation

   "hydrogen reacts with oxygen to form water"
   Hydrogen + Oxygen → Water

   B. The equation must contain the correct formulas for reactants and products
      1. This is done with a formula equation

   H$_2$ + O$_2$ → H$_2$O

   C. The law of conservation of atoms must be satisfied
      1. Balancing is done with coefficients - small whole numbers that appear in front of a formula

   2H$_2$ + O$_2$ → 2H$_2$O

D. Additional symbols used in Chemical equations
Table 8-2  Symbols Used in Chemical Equations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;yields&quot;</td>
<td>&quot;yields&quot; ; indicates result of a rxn</td>
</tr>
<tr>
<td>Used in place of a single arrow to indicate a reversible rxn</td>
<td></td>
</tr>
<tr>
<td>(s)</td>
<td>Reactant or product in the solid state. Also a precipitate</td>
</tr>
<tr>
<td>(l)</td>
<td>Reactant or product in the liquid state.</td>
</tr>
<tr>
<td>(aq)</td>
<td>Reactant or product in an aqueous solution (dissolved in water)</td>
</tr>
<tr>
<td>(g)</td>
<td>Reactant or product in the gaseous state</td>
</tr>
<tr>
<td>Can symbolize the formation of a gas, as an alternative to the (g) symbol</td>
<td></td>
</tr>
<tr>
<td>Can symbolize the formation of a precipitate, as an alternative to the (s) symbol</td>
<td></td>
</tr>
<tr>
<td>Reactants are heated</td>
<td></td>
</tr>
<tr>
<td>2 atm</td>
<td>Pressure at which the rxn is carried out, in this case 2 atmospheres</td>
</tr>
<tr>
<td>Pressure</td>
<td>Pressure at which rxn is carried out exceeds normal atmospheric pressure</td>
</tr>
<tr>
<td>25°C</td>
<td>Temperature at which the rxn is carried out, in this case 25 °C</td>
</tr>
<tr>
<td>MnO₂</td>
<td>Formula of catalyst, in this case manganese dioxide, used to alter the rate of the reaction</td>
</tr>
</tbody>
</table>

IV. Significance of a Chemical Reaction
A. Quantitative Information
  1. # of moles, atoms, molecules in a reaction
  2. Equality exists in each direction
  3. The fact that a rxn can be written does not mean that the rxn can take place

V. Balancing Chemical Equations
A. Identify the names of reactants and products, and write a word equation
B. Write a formula equation by substituting correct formulas for the names of the reactants and the products
C. Balance the formula equation according to the law of conservation of atoms
D. Count atoms to be sure that the equation is balanced
A. Synthesis Rxns
   1. Two or more substances combine to form a more complex substance
      \[ \text{A} + \text{X} \rightarrow \text{AX} \]

B. Types of Synthesis Rxns
   1. Metals react with oxygen to form oxides
      \[ 4\text{Al(s)} + 3\text{O}_2(\text{g}) \rightarrow 2\text{Al}_2\text{O}_3(\text{s}) \]
   2. Metals react with sulfur to form
      \[ 8\text{Ba(s)} + \text{S}_8(\text{s}) \rightarrow 8\text{BaS(s)} \]
   3. Nonmetals react with oxygen to form oxides
      \[ \text{C(s)} + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \]
   4. Metals react with halogens to form salts (halogen means "salt maker")
      \[ 2\text{Na(s)} + \text{Cl}_2(\text{g}) \rightarrow 2\text{NaCl(s)} \]
   5. Active metal oxides react with water to form metallic hydroxides
      \[ \text{MgO(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Mg(OH)}_2(\text{s}) \]
   6. Nonmetal oxides react with water to form oxyacids (acid rain)
      \[ \text{SO}_2(\text{g}) + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3(\text{aq}) \]

II. Decomposition Reactions
A. Decomposition Rxns
   1. One substance breaks down to form two or more simpler substances
      \[ \text{AX} \rightarrow \text{A} + \text{X} \]

B. Six Kinds of Decomposition Rxns
   1. Metallic carbonates, when heated, form metallic oxides and carbon dioxide
      \[ \text{CaCO}_3(\text{s}) \rightarrow \text{CaO(s)} + \text{CO}_2(\text{g}) \]
   2. Metallic hydroxides, when heated, decompose into metallic oxides and water
      \[ \text{Ca(OH)}_2(\text{s}) \rightarrow \text{CaO(s)} + \text{H}_2\text{O(g)} \]
   3. Metallic chlorates, when heated, decompose into metallic chlorides and oxygen
      \[ 2\text{KClO}_3(\text{s}) \rightarrow 2\text{KCl(s)} + 3\text{O}_2(\text{g}) \]
   4. Some acids, when heated, decompose into nonmetallic oxides and water
      \[ \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}_2\text{O(l)} + \text{SO}_3(\text{g}) \]
   5. A few oxides, when heated, decompose
      \[ 2\text{PbO}_2(\text{s}) \rightarrow 2\text{PbO(s)} + \text{O}_2(\text{g}) \]
   6. Some decomposition rxns are produced by an electric current
      \[ 2\text{NaCl(s)} \rightarrow 2\text{Na(s)} + \text{Cl}_2(\text{g}) \]

III. Single-Replacement Reactions
A. Single-Replacement Rxns I
   1. One substance is replaced in its compound by another substance
A + BX → AX + B
Y + BX → BY + X

B. Four Types of Decomposition Reactions

1. Replacement of a metal in a compound by a more active metal
   Zn(s) + CuSO₄(aq) → ZnSO₄(aq) + Cu(s)

2. Replacement of hydrogen in water by active metals
   Ca(s) + 2H₂O(l) → Ca(OH)₂(aq) + H₂ (g)

3. Replacement of hydrogen in acids by metals
   Zn(s) + H₂SO₄(aq) → ZnSO₄(aq) + H₂ (g)

4. Replacement of halogens by more active halogens
   Cl₂(g) + 2KBr(aq) → 2KCl(aq) + Br₂ (g)

IV. Double-Replacement Reactions

A. Double-Replacement Reaction

1. The ions of two compounds exchange places in an aqueous solution to form two new compounds

B. Types of Double-Replacement Reactions

1. Formation of a Precipitate
   BaCl₂(aq) + Na₂SO₄(aq) → 2NaCl(aq) + BaSO₄(s)

2. Formation of a Gas
   FeS(aq) + H₂SO₄(aq) → FeSO₄(aq) + H₂S(g)

3. Formation of Water
   NaOH(aq) + HCl(aq) → NaCl(aq) + H₂O(l)

V. Combustion Reactions

A. Combustion Reactions

1. A substance combines with oxygen, releasing a large amount of energy in the form of light and heat
   2H₂(g) + O₂(g) → 2H₂O(g)

B. Hydrocarbon combustion always produces carbon dioxide and water
   2C₂H₆(g) + 7O₂(g) → 4CO₂(g) + 6H₂O(g)

8-3 Activity Series of the Elements

A. Activity Series

1. A list of elements organized according to the ease with which the elements undergo certain chemical reactions
2. Each element in the list displaces any of the elements below it. The larger the interval between elements in a series, the more vigorous the replacement reaction.
3. Metals may replace other metals
4. Halogens may replace other halogens

B. Using the Activity Series (Table 8-3 in your book)

1. All metals above hydrogen displace hydrogen from hydrochloric acid or dilute sulfuric acid
3. Metals above silver combine directly with oxygen; those near the top do so rapidly.
4. Metals below mercury form oxides only indirectly.
5. Oxides of metals below mercury decompose with mild heating.
6. Oxides of metals below chromium easily undergo reduction to metals by heating with hydrogen.
7. Oxides of metals above iron resist reduction by heating with hydrogen.
8. Elements near the top of the series are never found free in nature.
9. Elements near the bottom of the series are often found free in nature.

<table>
<thead>
<tr>
<th>Table 8-3 Activity Series of the Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity of metals</strong></td>
</tr>
<tr>
<td>Li</td>
</tr>
<tr>
<td>Rb</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>Ba</td>
</tr>
<tr>
<td>Sr</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Na</td>
</tr>
<tr>
<td>Mg</td>
</tr>
<tr>
<td>Al</td>
</tr>
<tr>
<td>Mn</td>
</tr>
<tr>
<td>Zn</td>
</tr>
<tr>
<td>Cr</td>
</tr>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>Cd</td>
</tr>
<tr>
<td>Co</td>
</tr>
<tr>
<td>Ni</td>
</tr>
<tr>
<td>Sn</td>
</tr>
<tr>
<td>Pb</td>
</tr>
<tr>
<td>H₂</td>
</tr>
<tr>
<td>Sb</td>
</tr>
<tr>
<td>Bi</td>
</tr>
<tr>
<td>Cu</td>
</tr>
<tr>
<td>Hg</td>
</tr>
<tr>
<td>Ag</td>
</tr>
<tr>
<td>Pt</td>
</tr>
<tr>
<td>Au</td>
</tr>
</tbody>
</table>

- React with cold H₂O and acids, replacing hydrogen. React with oxygen, forming oxides.
- React with steam (but not cold water) and acids, replacing hydrogen. React with oxygen, forming oxides.
- Do not react with water. React with acids, replacing hydrogen. React with oxygen, forming oxides.
- React with oxygen, forming oxides.
- Fairly unreactive, forming oxides only indirectly.