Chapter 8
Chemical Equations

Objectives:

- Be able to identify chemical equations
- Write and balance chemical equations
- Describe the information given in any chemical equation
- Identify types of chemical equations
- Understand and describe the roles of heat in chemical reactions

Chemical Reactions

- A chemical reaction is a process in which one or more substances are converted into new substances with different physical and chemical properties
- Why do chemical reactions occur?
  - Stability
  - Interactions between valence electrons

The Chemical Equation

- ***In a chemical reaction atoms are neither created nor destroyed. All atoms present in the reactants must also be present in the products.***
  - Reactants: substances entering a reactions
  - Products: substances formed in a reaction
  - Reactions involve change, rearrangement, etc. of compounds but NOT of individual atoms

The Chemical Equation

- Word Equation: gives names of reactants and products
  - "reacts with" use + sign
  - "yields" or "produces" use →
- Example: Sodium metal reacts with chlorine gas to produce sodium chloride
  - Sodium + chlorine → sodium chloride

The Chemical Equation

- Formula Equation (chemical equation):
  - Chemical symbols & formulas replace words
  - Be sure to use correct symbols and formulas!
- Example: Sodium metal reacts with chlorine gas to produce sodium chloride
  - sodium + chlorine → sodium chloride
  - Na + Cl → NaCl

The Chemical Equation

- Magnesium reacts with nitrogen to produce magnesium nitride (remember diatomic molecules)

$$Mg + N_2 \rightarrow Mg_3N_2$$

- Silver (I) nitrate reacts with copper to form copper (II) nitrate and silver

$$AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + Ag$$

- When heated, calcium carbonate decomposes to form calcium oxide and carbon dioxide

$$CaCO_3 \rightarrow CaO + CO_2$$

- Ammonia reacts with hydrogen chloride to form ammonium chloride

$$NH_3 + HCl \rightarrow NH_4Cl$$

The Chemical Equation

- Conditions required to carry out the reaction sometimes included
  - Show heat is produced, etc.
- Physical state of substances often included
  - (*s*) = solid
  - (*l*) = liquid
  - (*g*) = gas
  - (*aq*) = aqueous solution (substance dissolved in water)
- See table 8.1

Writing and Balancing Equations

- Equations must be BALANCED
  - Same number of each kind of atom on each side of the reaction
  - NEVER CHANGE FORMULAS – just change coefficients
- Steps to follow:
  1. Write a word equation for the reaction
  2. Write the unbalanced (skeleton) equation

Writing and Balancing Equations

3. Balance the equation
    a. Count and compare the number of atoms of each element on each side of the equation
    b. Balance each element, one at a time, by placing whole numbers (coefficients) in front of the formulas
    c. Check all other elements and make adjustments as needed
    d. Do a final check – all atoms should be balanced
        a. Use smallest whole numbers

Writing and Balancing Equations

- Balance the following:

$3\ Mg + N_2 \rightarrow Mg_3N_2$

$2\ AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2\ Ag$

$CaCO_3 \rightarrow CaO + CO_2$

$NH_3 + HCl \rightarrow NH_4Cl$

What Information Does an Equation Tell Us?

- What the reactants are and what the products are
- The formulas of the reactants and products
- The number of molecules or formula units of reactants and products in the reaction
- The number of atoms of each element involved in the reaction
- The number of moles of each substance

What Information Does an Equation Tell Us?

- $P_4O_{10} + 12HClO_4 \rightarrow 6Cl_2O_7 + 4H_3PO_4$
  - 1 mol P_4O_{10}
  - 12 mol $HClO_4$
  - 6 mol Cl_2O_7
  - 4 mol H_3PO_4
- We will use this information in Chapter 9…

Types of Chemical Equations

- Reactions are classified based on how atoms or groups of atoms are rearranged during the reaction
  - Book lists 4 types
  - I want you to know 5 types
    - Synthesis (combination)
    - Decomposition
    - Single-Replacement (single-displacement)
    - Double-Replacement
    - Combustion (this is the one not covered in your book)

Synthesis (Combination) Reaction

- Two (or more) substances combine to form a new compound

$$A + X \rightarrow AX$$

A and X are both elements or compunds

AX is a new compound formed

** Only ONE product***

Synthesis (Combination) Reaction

- Metal + Oxygen → Metal oxide
  - $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$
- Nonmetal + Oxygen → Nonmetal oxide
  - $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$
- Metal + Nonmetal → Salt
  - $2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$
- Metal Oxide + Water → Metal hydroxide
  - $Na_2O_{(s)} + H_2O_{(l)} \rightarrow 2NaOH_{(aq)}$
- Nonmetal Oxide + Water → Oxy-acid
  - $SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$

Decomposition Reaction

- A single compound reacts to give two or more substances
- Usually requires heat and/or a catalyst

$AX \rightarrow A + X$

Decomposition Reaction

- Metal Oxides. Some decompose to yield free metal plus oxygen; others given another oxide, and some resist decomposition by heating
  - $2HgO_{(s)} \rightarrow 2Hg_{(l)} + O_{2(g)}$
  - $2PbO_{2(s)} \rightarrow 2PbO_{(s)} + O_{2(g)}$
- Carbonates and hydrogen carbonates decompose to yield CO_2 when heated
  - $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
  - $2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$
- Miscellaneous reactions in this category:
  - $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$
  - $2NaNO_{3(s)} \rightarrow 2NaNO_{2(g)} + O_{2(g)}$
  - $2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$

Single-Replacement Reaction

- An element reacts with a compound displacing an element from it

  $A + BX \rightarrow AX + B$

  $Y + BX \rightarrow BY + X$

- If A is a metal, A will replace B to form AX, provided A is a more reactive metal than B
- If Y is a halogen, it will replace X to form BY, provided Y is a more reactive halogen than C
- Activity series can help make predictions
  - Table 8.2

Single-Replacement Reaction

- Metal + Acid → Hydrogen + Salt
  - $Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$
- Metal + Water → Hydrogen + metal hydroxide or metal oxide
  - $2Na_{(s)} + 2H_2O \rightarrow H_{2(g)} + 2NaOH_{(aq)}$
- Metal + Salt → Metal + Salt
  - $Fe_{(s)} + CuSO_{4(aq)} \rightarrow Cu_{(s)} + FeSO_{4(aq)}$
- Halogen + Halide Salt → Halogen + Halide Salt
  - $Cl_{2(g)} + 2NaBr_{(aq)} \rightarrow Br_{2(l)} + 2NaCl_{(aq)}$

Single-Replacement Reactions

- K, Ca, and Na displace hydrogen from cold water, steam, and acids
- Mg, Al, Zn, and Fe displace hydrogen from steam and acids
- Ni, Sn, and Pb displace hydrogen only from acids
- Cu, Ag, Hg, and Au do not displace hydrogen

Double-Replacement Reaction

- Appears to involve the exchange of parts of the reactions
- Ions of two compounds exchange places in an aqueous solution to form 2 new compounds
- A precipitate (an insoluble solid compound formed during a reaction in solution) is often formed
- Heat may be produced
- Gas bubbles may be produced

$$AX + BY \rightarrow AY + BX$$

Double-Replacement Reaction

- Neutralization of an acid and a base
  - Acid + Base → Salt + Water
  - $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
- Formation of a precipitate
  - Solubility Table in Appendix V
  - $BaCl_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgCl_{2(s)} + Ba(NO_3)_{2(aq)}$
- Metal oxide + acid → salt + water (and heat)
  - $CuO_{(s)} + 2HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + H_2O_{(l)}$

Double-Replacement Reaction

- Formation of a gas
  - $H_2SO_{4(l)} + NaCl_{(s)} \rightarrow NaHSO_{4(s)} + HCl_{(g)}$
  - $2HCl_{(aq)} + ZnS_{(s)} \rightarrow ZnCl_{2(aq)} + H_2S_{(g)}$
- Gas can be produced indirectly
  - Unstable compounds (H_2CO_3, H_2SO_3, NH_4OH) will decompose to form water and a gas

$2HCl_{(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaCl_{(aq)} + H_2CO_{3(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

Combustion Reactions

- A reaction of a substance with oxygen, usually with the rapid release of heat to produce a flame
- Organic compounds (with carbon) usually produce CO_2
- If a compound contains hydrogen, water is a product
- Hydrocarbon or compound + O_2 → CO_2 + H_2O
- $C_3H_{8(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$

5 Types of Reactions

- Identify each:
  - AX + BY → AY + BX **Double-Replacement**
  - A + B → AB **Synthesis (Combination)**
  - A + BX → AX + B **Single-Replacement**
  - AX → A + X **Decomposition**
  - Hydrocarbon + O_2 → CO_2 + H_2O **Combustion**

Heat in Chemical Reactions

- Energy changes always accompany chemical reactions
- Exothermic reactions
  - Release heat
  - Heat is a product – written on right side of equation
- Endothermic reactions
  - Absorb heat
  - Heat is a reactant – written on left side of equation

Heat in Chemical Reactions

- Heat of Reaction
  - Quantity of heat produced in a reaction
- Activation energy
  - The amount of energy that must be supplied to start a chemical reaction
    - Even exothermic reactions require a little heat to get started…but then continue on their own
- See figures 8.1 & 8.2