Chemical Reactions

Objectives

- State four observations that are evidence for a chemical reaction:
  - Release of a gas.
  - Production of an insoluble substance.
  - Permanent color change.
  - Heat released or absorbed.
- Identify seven elements that occur naturally as diatomic molecules: H2, N_2, O_2, F_2, Cl_2, Br_2, I_2.
- Write a chemical equation from the description of the equation.
- Balance a chemical equation.

Objectives

- List 5 types of chemical reactions:
  - Combination reaction.
  - Decomposition reaction.
  - Single-replacement reaction.
  - Double-replacement reaction.
  - Neutralization reaction.
- Write a balance chemical equation for a reaction between a metal and a nonmetal.
- Write a balanced chemical equation for the

Objectives

- Write a balanced chemical equation for the decomposition of a metal carbonate.
- Write a balanced chemical equation for the decomposition that releases oxygen gas.
- Use the activity series to predict whether a single replacement reaction will occur.
- Write a balanced chemical equation for the reaction of a metal in an aqueous solution.
- Write a balanced chemical equation for the reaction of a metal in an acid.

- Write a balanced chemical equation for the reaction of an active metal in water.
- Use the general solubility rules to predict whether an ionic compound dissolves in water.
- Predict the products that result from a double replacement reaction.
- Write a balanced chemical equation for the reaction between two aqueous solutions.
- Write a balanced chemical equation for the reaction between an acid and a base.

Evidence for Chemical Reactions

- Release of a gas.
- Production of an insoluble substance (**precipitate**).
- A permanent color change.
- Heat being given off or absorbed
  - **Exothermic** – A reaction in which heat is given off.
  - **Endothermic** – A reaction in which heat is absorbed.

Chemical Equations

- An equation for a general chemical reaction:

  $A + B \xrightarrow{\Delta} C + D$

  - A and B are **reactants**.
  - C and D are **products**.
  - $\rightarrow$ is the **yields** sign. It points from the reactants to the products.
  - + indicates that two or more reactants are involved, or that two or more products are produced.
  - Δ indicates that heat is given off or absorbed.

Diatomic Molecules

- Diatomic Molecules:
  - H_2
  - N_2
  - O_2
  - F_2
  - Cl_2
  - Br_2
  - I_2

Balancing Equations

- The number of atoms of each element must be the same on each side of the yields sign.
  - Write the reactants and products.
  - Add coefficients to balance the equation.
- Example:
  - Write the reactants and products:
    - $H_2(g) + Cl_2(g) \rightarrow HCl(g)$
  - Add coefficients to balance the equation:
    - $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Balancing Equations

- Example:
  - Write the reactants and products:
    - $Al(s) + O_2(g) \rightarrow Al_2O_3(s)$
  - Add coefficients to balance the oxygen:
    - $Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
  - Add coefficients to balance the aluminum:
    - $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

Balancing Equations

- Example:
  - Write the reactants and products:
    - $Pb(NO_3)_2(aq) + KI(aq) \rightarrow PbI_2(s) + KNO_3(aq)$
  - Add coefficients to balance the nitrate:
    - $Pb(NO_3)_2(aq) + KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$
  - Add coefficients to balance the potassium:
    - $Pb(NO_3)_2(aq) + 2\,KI(aq) \rightarrow PbI_2(s) + 2\,KNO_3(aq)$

Balancing Equations

- A method for balancing equations:
  - Check to make sure that the formula subscripts are correct.
  - Balance each element in the equation by placing a coefficient in front of each substance. Coefficients of 1 are assumed and do not appear in the balanced chemical equation.
    - Begin balancing the equation with the most complex formula.
    - Balance polyatomic ions as a single unit unless the ion decomposes.
    - Use only whole number coefficients.
  - Check each element or polyatomic ion to verify that the same number of atoms appear on both sides of the equation.

Balancing Equations

- Examples:
  - $Ca(C_2H_3O_2)_2(aq) + K_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + KC_2H_3O_2(aq)$
  - $3Ca(C_2H_3O_2)_2(aq) + 2K_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6KC_2H_3O_2(aq)$
  - $Al_2(SO_4)_3(aq) + Ba(NO_3)_2(aq) \rightarrow BaSO_4(s) + Al(NO_3)_3(aq)$
  - $Al_2(SO_4)_3(aq) + 3Ba(NO_3)_2(aq) \rightarrow 3BaSO_4(s) + 2Al(NO_3)_3(aq)$
  - $H_2SO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + HOH(l)$
  - $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2HOH(l)$
  - $H_2CO_3(aq) + NH_4OH \rightarrow (NH_4)_2CO_3(aq) + HOH(l)$
  - $H_2CO_3(aq) + 2NH_4OH \rightarrow (NH_4)_2CO_3(aq) + 2HOH(l)$

Classifying Chemical Reactions

- Combination Reactions: $A + Z \rightarrow AZ$
  - Metal and oxygen gas:
    - $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
  - Nonmetal and oxygen gas:
    - $S(s) + O_2(g) \rightarrow SO_2(g)$
  - Metal and nonmetal:
    - $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

Classifying Chemical Reactions

- Decomposition Reactions:
  - Decomposition of a Hydrogen Carbonate:
    - $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$
  - Decomposition of a Carbonate:
    - $Na_2CO_3(s) \rightarrow Na_2O(s) + CO_2(g)$
  - Decomposition of an oxide:
    - $2HgO(s) \rightarrow 2Hg(s) + O_2(g)$

Classifying Chemical Reactions

- Single Replacement Reactions: $A + BZ \rightarrow AZ + B$
  - The activity series for metals: Li > K > Ba > Sr > Ca > Na > Mg > Al > Mn > Zn > Fe > Cd > Co > Ni > Sn > Pb > (H) > Cu > Ag > Hg > Au
  - Active metals series: Li > K > Ba > Sr > Ca > Na
  - Activity series for the halogens: F > Cl > Br > I
  - Metal and aqueous solution:
    - $Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$
  - Metal and aqueous acid solution:
    - $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$
  - Active metal and water:
    - $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

Classifying Chemical Reactions

- Double Replacement Reactions:
  $AX + BZ \rightarrow AZ + BX$
  $2AgNO_3(aq) + Na_2CO_3(aq) \rightarrow Ag_2CO_3(s) + 2NaNO_3(aq)$

Solubility Rules

1. Alkali metals ions and the ammonium ion are generally soluble.
2. The acetate ion is generally soluble.
3. The nitrate ion is generally soluble.
4. Halide ions except silver, mercury, and lead are generally soluble.
5. The carbonate ion is generally insoluble except for rule 1.
6. The chromate ion is generally insoluble except for rule 1.
7. The phosphate ion is generally insoluble except for rule 1.
8. The sulfide ion is generally insoluble except for rule 1 and cadmium, barium, and strontium.
9. The hydroxide ion is generally insoluble except for rule 1 and calcium, strontium, and barium.

Classifying Chemical Reactions

- Neutralization Reactions:
  $HX + BOH \rightarrow BX + HOH$
  $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + HOH(l)$