CHAPTER 10
Chemical Reactions

10.1 Reactions & Equations

Chemical Reactions: atoms of one or more substances rearrange to form different substances

- A chemical change has taken place
- What indicates a chemical change has occurred?

Where do Chemical Reactions Occur?

- Everywhere!!!
- Breaking down food
- Making food
- Provide power to vehicles
- In living organisms
- In the air

Evidence of Chemical Reactions

Some reactions are hard to detect, but most provide evidence:

- Temperature change
- Energy Change *(Light)*
- Color Change
- Formation of a precipitate
- Odor production
- Gas Formation or bubbles

Representing Chemical Reactions

Reactants → Products

- Reactant 1 + Reactant 2 → Product 1 + Product 2
- The arrow means "yields" not equals!!!

Physical State of substance: *(Very Important)*
(s)= solid, *(l)* = liquid, *(g)* = gas, *(aq)* = aqueous

Catalyst added: used to speed up a reaction, but not part of the reactants or products. *Written over the yield sign.*

Symbols in Equations

- (*aq*) dissolved in water
- → means yields
- ↔ Reversible Reaction
- $\xrightarrow{\Delta}$ means heat is added and is written over the arrow
- Catalyst is used to speed up a reaction $\xrightarrow{\text{Catalyst}}$

TYPES OF EQUATIONS

Word Equation: names are written, not the formulas.
- Iron(s) + chlorine (g) → Ferric Chloride (s)

Skeleton Equation: Uses chemical formulas, not the words
- Fe (s) + Cl_2 (g) → $FeCl_3$ (s)

Chemical Equation: shows the relative amounts of the substances
- $2Fe\ (s) + 3Cl_2\ (g) \rightarrow 2FeCl_3\ (s)$

Balancing Equations

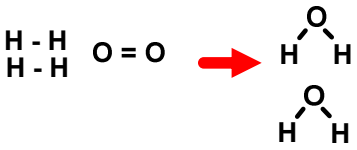
A balanced equation shows the relative amounts of each substance in a chemical reaction.

Coefficients in front of the chemical formulas.

Ex.) ____$CaCO_3$ or _____$Al_2(SO_4)_3$

What does the coefficient mean?

$2H_2 + O_2 \rightarrow 2H_2O$



___ Mg + ___ HCl → ___$MgCl_2$ + ___ H_2

___ KCl + ___ Na_2O → ___K_2O + ___ NaCl

___ C_3H_8 + ___ O_2 → ___CO_2 + ___ H_2O

Rules for Balancing Equations

- hydrogen and oxygen last…
- Make odd amounts even…

- See page 281

1. __ Al + __ FeO → __Al_2O_3 + ___ Fe
2. __ Fe_2O_3 + __ H_2 → __Fe + ___ H_2O
3. __ P + __ O_2 → ___ P_2O_5
4. __ $Al(NO_3)_3$ + __ H_2SO_4 → __$Al_2(SO_4)_3$ + __ HNO_3
5. __ CO_2 + __ H_2O → __ $C_6H_{12}O_6$ + __ O_2
6. __ $FeCl_3$ + __ NaOH → ___ $Fe(OH)_3$ + __ NaCl

10.2 Classifying Chemical Reactions

Chemists classify reactions to organize them.

Knowing the categories of chemical reactions will help you recognize patterns and predict the products of reactants.

You can be certain what the products of a chemical reaction are only by carrying out that reaction in the laboratory.

5 Reaction Types

1. **Synthesis *(aka Combination)***
2. **Combustion**
3. **Decomposition**
4. **Single Replacement**
5. **Double Replacement**

1. Synthesis Reactions

- Two or more substances react to form a single substance
- The product must be a compound!
- Element + Element → Compound
- Nonmetal oxides + water → acid
- Metal oxides + water → base

Synthesis: Element + Element

Can be an atom or an elemental compound
Combines to form 1 compound.

- $2H_2 + O_2 \rightarrow 2H_2O$
- $2Na + Cl_2 \rightarrow 2NaCl$
- $N_2 + 3H_2 \rightarrow 2NH_3$
- $Pb + O_2 \rightarrow PbO_2$

Synthesis: Non-Metal Oxide + Water

- $SO_3 + H_2O \rightarrow H_2SO_4$
- $CO_2 + H_2O \rightarrow H_2CO_3$
- $SO_2 + H_2O \rightarrow H_2SO_3$
- $N_2O_5 + H_2O \rightarrow 2HNO_3$
- $P_2O_5 + H_2O \rightarrow 2H_3PO_4$

Synthesis: Metal Oxide + Water

- $CaO + H_2O \rightarrow Ca(OH)_2$
- $K_2O + H_2O \rightarrow 2KOH$
- $BaO + H_2O \rightarrow Ba(OH)_2$
- $Li_2O + H_2O \rightarrow 2LiOH$

2. COMBUSTION REACTIONS

When oxygen combines with a substance and releases energy.

Some combustion reactions are synthesis reaction

- Hydrocarbons + Oxygen → $CO_2 + H_2O$
- Metals + Oxygen → Metal Oxides
- Nonmetal hydrides + Oxygen → water + nonmetal oxides

2. Hydrocarbons + Oxygen

- **Hydrocarbon + oxygen= carbon dioxide + water**
  - > *complete combustion*
  - > $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + Heat
- **Hydrocarbon + oxygen= carbon monoxide + water**
  - > *incomplete combustion*
  - > $CH_4 + 2O_2 \rightarrow CO + 2H_2O$ + Heat
- Incomplete combustion occurs when there is not enough oxygen available during the reaction, which produces CO.

2. Hydrocarbons + Oxygen

- $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

2. Metals + Oxygen

- $2Mg + O_2 \rightarrow 2MgO$
- $4Na + O_2 \rightarrow 2Na_2O$
- $2Ca + O_2 \rightarrow 2CaO$

2. Nonmetal hydrides + Oxygen

- $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
- $4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$

3. Decomposition Reactions

- A single compound is broken down into two or more products.
- Usually requires energy to break apart the compound.
- Difficult to predict!
- Binary compounds break down into their elements.

Decomposition of Binary Ionic Compounds

- $PbCl_4 \rightarrow Pb + 2Cl_2$
- $2H_2O \rightarrow 2H_2 + O_2$
- $K_2S \rightarrow 2K + S$

Decomposition of Metal Carbonates

- $CaCO_3 \rightarrow CaO + CO_2$
- $Na_2CO_3 \rightarrow Na_2O + CO_2$

Replacement Reactions

An element replaces another element in a compound

1. Single Replacement
2. Double Replacement

For these reactions to occur, the compound must be in aqueous solution. Why do you think this is necessary?

In aqueous solution, ionic compounds are separated. Which allows them to be replaced.

3. Single Replacement Reactions

- Atoms of 1 element replace atoms of another element in a compound.
- How do I know if a metal can replace another metal?
  - > An Activity Series of Metals is needed.
- How do I know if a non metal can replace another nonmetal?
  - > More electronegative nonmetals replace less electronegative nonmetals
- Sometimes there is no reaction because an element is not reactive enough.

Activity Series of Metals

- Determines which metal can replace another
- More reactive metals replace less reactive metals, usually in an aqueous solution.
- The top is the most reactive

Al (s) + $CuCl_2$ (aq) → $AlCl_3$ (aq) + Cu (s)

Al (s) + $LiNO_3$ (aq) → No Reaction

Why is gold, silver, and platinum used in jewelry?

Li
Rb
K
Ca
Na
Mg
Al
Mn
Zn
Fe
Ni
Sn
Pb
H
Cu
Ag
Pt
Au

3. Single Replacement

- K *(s)* + $NaNO_3$ *(aq)* → Na *(s)*+ KNO_3 *(aq)*
- Ag *(s)* + $CaSO_4$ *(aq)* → No Reaction
- Li *(s)* + KCl *(aq)* → K *(s)* + LiCl *(aq)*
- F_2 *(g)* + NaCl *(aq)* → NaF*(aq)* + Cl_2 *(g)*
- Br_2 *(l)* + KCl *(aq)* → No Reaction

4. Double Replacement Reactions

- Involves an exchange of positive ions between two compounds in aqueous solution
- Usually between 2 ionic compounds in aqueous solution.
- Results in the formation of a gas, water, or a precipitate.

4. Double Replacement Reactions

$\_KCl(aq) + \_\_MgO(aq) \rightarrow \_\_K_2O(aq) + \_\_MgCl_2(aq)$

$\_\_NaNO_3(aq) + \_\_CaSO_4(aq) \rightarrow \_\_Na_2SO_4(aq) + \_\_Ca(NO_3)_2(aq)$

Predicting Products

- When looking at the reactants, you should be able to predict the products of that reaction based upon your knowledge of the 5 reaction types.
- When forming ionic compounds, always break up the reactants into IONS, then form the new compound.

Predicting Combination Reactions

$\_\_ Fe + \_\_ O_2 \rightarrow$

$\_\_ K_2O + \_\_ H_2O \rightarrow$

$\_\_ SO_3 + \_\_ H_2O \rightarrow$

Predicting Combustion Reactions

$\_\_ CH_4 + \_\_ O_2 \rightarrow$

$\_\_ C_2H_6 + \_\_ O_2 \rightarrow$

$\_\_ C_3H_8 + \_\_ O_2 \rightarrow$

Predicting Decomposition Reactions

$\_\_Fe_2O_3 \rightarrow$

$\_\_NaCl \rightarrow$

$\_\_H_2O_2 \rightarrow$

Predicting Single Replacement Reactions

__ Zn + __ $FeCl_3$ →

__ F_2 + __ CaO →

__ K + __ HCl →

__ Fe + __ Li_3N →

Activity Series of Metals

- Determines which metal can replace another
- More reactive metals replace less reactive metals, usually in an aqueous solution.
- The top is the most reactive

Al (s) + $CuCl_2$ (aq) → $AlCl_3$ (aq) + Cu (s)

Al (s) + $LiNO_3$ (aq) → No Reaction

Why is gold, silver, and platinum used in jewelry?

Li
Rb
K
Ca
Na
Mg
Al
Mn
Zn
Fe
Ni
Sn
Pb
H
Cu
Ag
Pt
Au

Hydrogen as a metal:

Mg + HCl

Incomplete Combustion:

CH_4 + O_2

Predicting Double Replacement Reactions

__ ZnO + __ $AlCl_3$ →

__ NaF + __ CaO →

__ KNO_3 + __ $Al_2(SO_4)_3$ →

How do you know the charge?

NaCl + $Fe(OH)_3$ →

10.3 Reactions in Aqueous Solution

A solution is when a solute dissolves in a solvent

A solute is the substance that dissolves in the solvent.

The solvent is the substance that the solute dissolves in.

An aqueous solution is a solution in which water is the solvent.

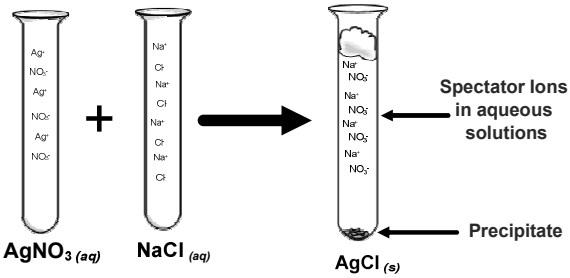
Double Replacement reactions occur in aqueous solution because two ionic compounds need to be separted in order for a reaction to occur.

Reactions that form a Precipitate

- Complete ionic equation
- Net ionic equation
- Spectator ion

- Double Replacement reactions usually occur in water.

(99% = Double Replacement)



Complete Ionic Equations

- **Shows dissolved ionic compounds as dissociated free ions.**
- **$AgNO_{3\,(aq)} + NaCl_{\,(aq)} \rightarrow AgCl_{\,(s)} + NaNO_{3\,(aq)}$**
- **$Ag^+ + NO_3^- + Na^+ + Cl^- \rightarrow AgCl + Na^+ + NO_3^-$**
- **AgCl** forms a precipitate.
- $Na^+ + NO_3^-$ remain dissolved in water and do not participate in the reaction.

Net Ionic Equation

- Shows only those particles involved in the reaction and is balanced with respect to both mass and charge.
- No spectator ions present.

Spectator Ions

- An ion that appears on both sides of a complete ionic equation and is not directly involved in the reaction.
- The ions not forming the precipitate.

$BaCl_{2\,(aq)} + Na_2SO_{4\,(aq)} \rightarrow BaSO_{4\,(s)} + NaCl_{\,(aq)}$

What is the precipitate?

$BaSO_4$

Write the complete ionic equation.

$Ba^{2+} + Cl^- + Na^+ + SO_4^{2-} \rightarrow BaSO_4 + Cl^- + Na^+$

What are the spectator ions?

$Na^+ + Cl^-$

What is the net ionic equation?

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Predicting the Formation of a Precipitate

- You can predict the formation of a precipitate by using the general rules for solubility of ionic compounds.
- Solubility rules on page 920.
- Show which ions dissolve in water and which form precipitates.

Reactions that form Water

- $HBr_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaBr_{(aq)}$
- $H^+ + Br^- + Na^+ + OH^- \rightarrow H_2O_{(l)} + Na^+ + Br^-$
- H^+ and OH^- produce water
- $Na^+ + Br^-$ are spectator ions.

Reactions that form Gases

- $2HI_{(aq)} + Li_2S_{(aq)} \rightarrow H_2S_{(g)} + 2LiI_{(aq)}$
- $H^+ + I^- + Li^+ + S^{2-} \rightarrow H_2S_{(l)} + Li^+ + I^-$
- H^+ and S^{2-} produce H_2S gas which bubbles out of solution
- $Li^+ + I^-$ are spectator ions.