Chemical Reactions

Chapter 4

Interpreting a Chemical Equation:

- A chemical equation describes a chemical reaction much like a sentence describes some action.
  - Element Symbols - Letters
  - Formulas - Words
  - Equations - Sentences

- *Consider the following chemical reaction:*

$$2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$$

Sentence form:

Sodium metal reacts with water to form aqueous sodium hydroxide and hydrogen gas.

Symbols in Chemical Reactions

(s)	=	Solid
(l)	=	Liquid
(g)	=	Gas
(aq)	=	Aqueous (dissolved in water)
+	=	"and"
$\longrightarrow$	=	"reacts to form" or "yields"
$\xrightarrow{\Delta}$	=	Heat added
$\xrightarrow{Pt}$	=	Catalyst (in this example, platinum)

Balancing Chemical Equations

- Balancing chemical equations is an application of both the **Modern Atomic Theory** and the **Law of Conservation of Matter.**

- The number of one kind of atom on the reactants side must be equal to the number of the same kind of atom on the product side.

Types of Reactions

Reactions of Ionic compounds:
Double Replacement Reactions

- A double replacement reaction is a reaction in which two ***ionic*** compounds react to form two new compounds by simply trading cations.
- Also known as a *metathesis* reaction.
- In order for a double replacement reaction to actually occur, one of the products must **NOT** be aqueous – a driving force.

Double Replacement Reactions: Precipitation

- Usually, one of the products of a metathesis reaction is a precipitate (solid that falls out of solution).
- A precipitate will form if the ions in solution can combine to make a compound that is not soluble in water.
- Use the solubility chart to determine if one of the possible products is not soluble in water.

Double Replacement Reactions: Precipitation

Solubility Chart

Anions	*Soluble (aq)*	*Precipitate (s)*
nitrate	Most cations	No common cations
acetate	Most cations	Ag^{+}
fluoride chloride bromide iodide	Most cations	Ag^{+}, $Pb^{2+,4+}$, Hg_2^{2+}, Tl^{+}
sulfate	Most cations	Ba^{2+}, Sr^{2+},$Pb^{2+,4+}$, Ag^{+},Ca^{2+}
chromate	Most cations	Ba^{2+}, Sr^{2+}, $Pb^{2+,4+}$, Ag^{+}
sulfide hydroxide oxide	NH_4^{+} & Cations of columns 1 and 2	Most other cations
carbonate phosphate	NH_4^{+} & Cations of column 1 except Li^{+}	Most other cations

A closer look at a precipitation reaction:

Consider the DR reaction of calcium chloride and silver nitrate.

- When dissolved in water, aqueous ionic compounds are generally dissociated and solvated by the water molecules.
- Calcium chloride dissolved in water:

$$CaCl_{2(aq)} \rightarrow Ca^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)}$$

- Silver nitrate dissolved in water:

$$AgNO_{3(aq)} \rightarrow Ag^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$$

Ways of writing the reaction as an equation:

- **Molecular Equation:** A chemical equation that includes the complete, molecular formulas for all compounds in a chemical reaction.
- **Ionic Equation:** A chemical equation in which aqueous, ionic compounds are written as free ions in solution.
- **Net Ionic Equation:** A chemical equation in which only the species (ions, atoms, molecules) involved in the reaction are written. *Spectator ions* are cancelled.

Reaction of $CaCl_2$ with $AgNO_3$:

- Molecular:

  $CaCl_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\ AgCl_{(s)}$

- Ionic:

  $Ca^{+2}_{(aq)} + 2\ Cl^{-}_{(aq)} + 2\ Ag^{+}_{(aq)} + 2\ NO_3^{-}{}_{(aq)} \rightarrow$

  $Ca^{+2}_{(aq)} + 2\ NO_3^{-}{}_{(aq)} + 2\ AgCl_{(s)}$

- Net Ionic:

  $2\ Ag^{+}_{(aq)} + 2\ Cl^{-}_{(aq)} \rightarrow 2\ AgCl_{(s)}$

  $Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

Writing Net Ionic Equations

- The net ionic equations shows only the species involved in a chemical change.
- Ca^{2+} and NO_3^- are **spectator ions**. They do not participate in the reaction.
- When both of the possible ionic products of a double replacement reaction are soluble in water, no reaction occurs, because all of the ions stay in solution.
- *Consider the mixing of a solution of sodium chloride and potassium bromide.*

Double Replacement Reactions: Acid – Base Neutralization

- An acid and a base will react to form a salt and water.

Double Replacement Reactions: Formation of a gas

- In some cases the double replacement reaction is followed by a decomposition reaction that forms a gas.

Oxidation – Reduction Reactions (REDOX)

- *Oxidation-reduction reactions* involve a transfer of electrons from one element to another.
- *Oxidation numbers (oxidation states)* are a way of keeping track of the electrons in a redox reaction.
- In a monatomic ion, the oxidation number is equal to the charge on the atom.
- In compounds and polyatomic ions, oxidation numbers assign electrons that are being shared in a bond to the more *electronegative* atom – the one that has a greater pull on the electron.

Oxidation – Reduction Reactions (cont.)

- *Oxidation* is the loss of electrons.
- *Reduction* is the gain of electrons.
- The *oxidizing agent* is the *species* (element or compound or ion) that is doing the oxidizing. In a redox reaction, the oxidizing agent is the species that is reduced.
- The *reducing agent* is the species that is doing the reducing. In a redox reaction, the reducing agent is the species that is oxidized.

Oxidation – Reduction Reactions (cont.)

- Many oxidation reactions are very easy to analyze and can be balanced by inspection.
- The simple oxidation reactions often fit conveniently into the following common categories:
  1) Synthesis
  2) Decomposition
  3) Single replacement
  4) Combustion
- Other redox reactions are more complex, do not fit these categories, and require more complex analysis to balance.