



Unit 4

Types of Chemical Reactions

Objectives

- Define the observations that indicate a chemical reaction has occurred.
- Classify chemical reactions according to the 5 main categories.
- Discuss the properties of water that make it the most common solvent.
- Identify whether a substance is a strong, weak, or non electrolyte.
- Calculate the concentration of solutes in units of molarity, molality, mass percent and parts per million.
- Perform stoichiometric calculations using solution concentration.
- Recognize the common types of reactions in aqueous solution.
- Write chemical equations for the common types of reactions in aqueous solution.
- Determine the oxidation number of atoms in compounds.
- Balance oxidation-reduction reactions.
- Determine the reducing agent, oxidizing agent, which reactant is being oxidized and which reactant is being reduced in a chemical reaction.
- Predict products of a chemical reaction using solubility rules.
- Write the net ionic equation for a chemical equation.
- Identify a Bronsted-Lowry acid and base.
- Determine the conjugate acid-base pair in a neutralization reaction.

Outline

- I. Chemical Reactions
 - A. Signs of a Chemical Reaction
 - 1. Color Changes
 - 2. Gas Evolving
 - 3. Precipitation
 - 4. Heat Change
 - 5. pH Change
 - B. Types of Chemical Reactions
 - 1. Synthesis
 - 2. Decomposition
 - 3. Combustion
 - 4. Single Replacement
 - 5. Double Replacement
- II. Aqueous Solutions
 - A. Water: The Most Common Solvent
 - B. Types of Aqueous Solutions
 - 1. Electrolyte and Nonelectrolyte Solutions
 - 2. Electrolytic Properties
- III. Stoichiometry in Aqueous Reactions
 - A. Solution Concentration
 - 1. Concentration Units
 - a. Molarity
 - b. Molality
 - c. Mole Fraction
 - d. Percent by Mass
 - e. Parts Per Million
 - 2. Dilutions of Solutions
 - 3. Using Molarity in Calculations of Solutions
 - 4. Solution Stoichiometry
- IV. Reactions in Aqueous Solutions
 - A. Oxidation-Reduction Reactions (Redox)
 - 1. Oxidation States
 - 2. Types of Redox Reactions
 - 3. Balancing Redox Equations
 - 4. Redox Titrations
 - B. Precipitation Reactions
 - 1. Solubility
 - 2. Molecular, Complete Ionic and Net Ionic Equations
 - C. Acid /Base Reactions
 - 1. Properties of Acids and Bases
 - 2. Bronsted Acids and Bases
 - 3. Acid-Base Titrations
 - D. Gas Evolution Reactions

Chemical Reactions

- Process where the starting material (reactants) are chemical composition is changed (to products).

Signs of a Chemical Reaction

- Color Change
- Gas Evolving (bubbling)
- Precipitation
- Heat Change
- pH Change



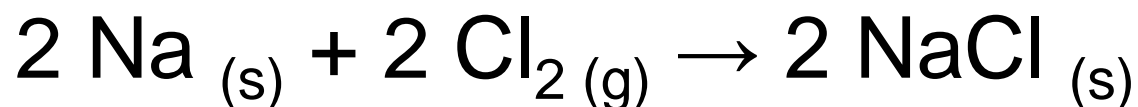
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Hand Warmers.jpg. PB Mann. 2006. PD.
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Types of Chemical Reactions

- 5 main classifications
 - Synthesis
 - Decomposition
 - Combustion
 - Single Replacement
 - Double Replacement

Synthesis

- A reaction where two reactants combine to form 1 product.



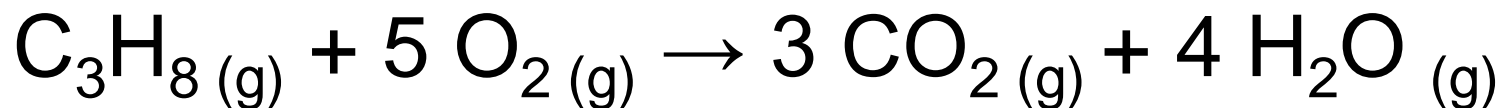
Decomposition

- A reaction where a single reactant separates to form two or more products.



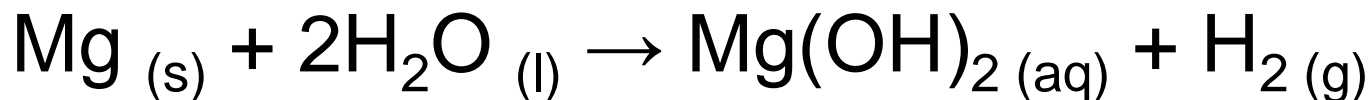
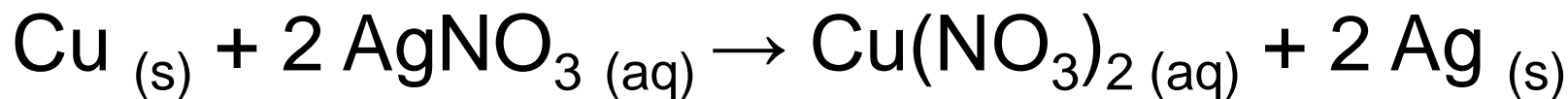
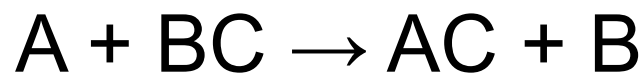
Combustion

- A reaction where a reactant burns in the presence of oxygen to form carbon dioxide and water.



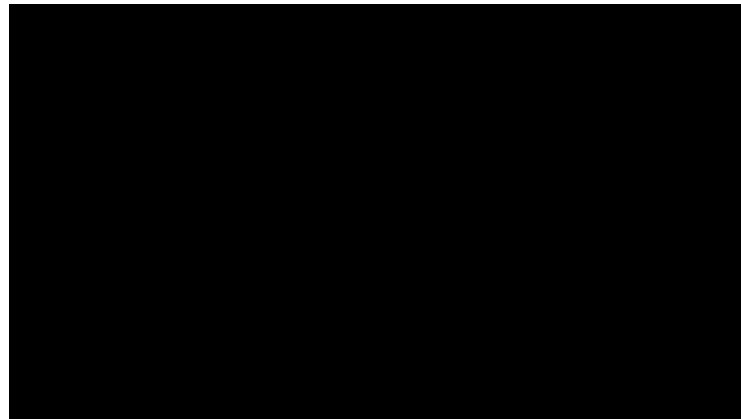
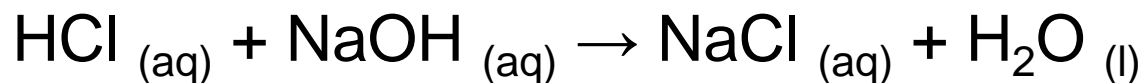
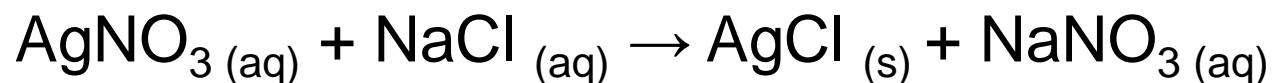
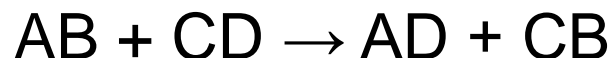
Single Replacement

- A reaction where an element and a compound react. The element replaces a similar element in the compound.



Double Replacement

- A reaction where the elements from two compounds replace one another. (Partners switch).

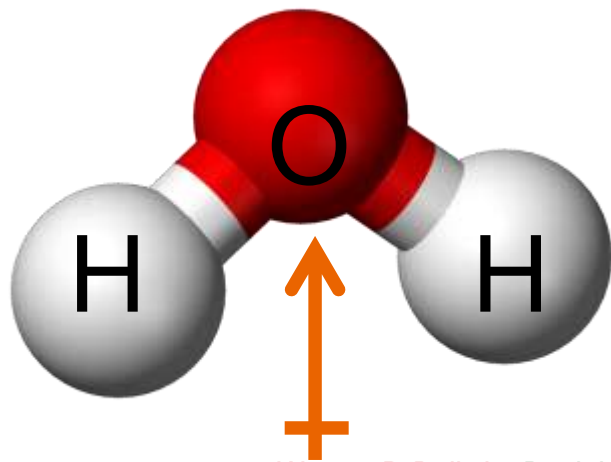


Aqueous Solutions

- Water covers about ~70 percent of the earth's surface.
- Many reactions occur in water.

Water as a Solvent

- Water is a polar molecule (has a dipole).
- Dissolves polar and ionic compounds.
 - Polar molecules that do not break apart in aqueous solutions: nonelectrolytes.
 - Ionic molecules that do break apart into individual ions in solution: electrolytes.

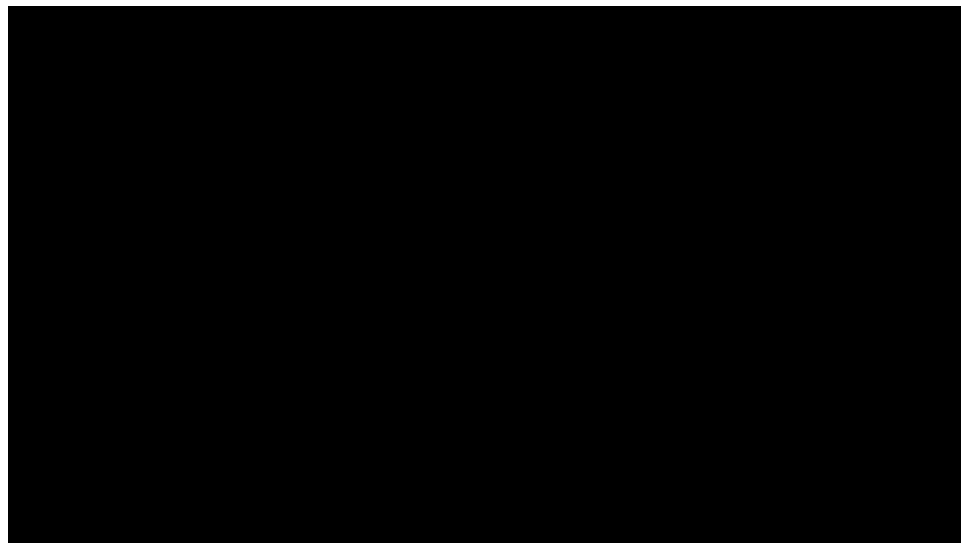
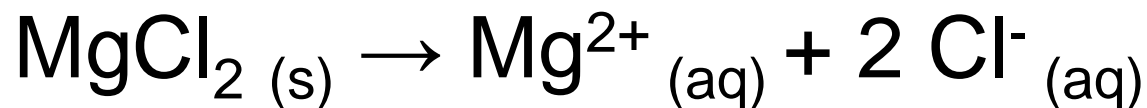


Water-3D-Balls by Benjah-bmm27 PD <http://commons.wikimedia.org/wiki/File:Water-3D-balls.png>

Electrolytes and Non Electrolytes. 2010. TutorVista. Standard YouTube License. <http://youtu.be/Nb1wncj5L6s>

Electrolyte Solutions

- Conduct electricity.
- Have ions in solution.



Electrolyte Solutions

- Strong Electrolytes:
 - Break apart COMPLETELY in solutions.
 - Are always soluble.
 - Make solutions that conduct electricity very well.
- Weak Electrolytes:
 - A small percentage of molecules break into ions in solution.
 - Are slightly soluble.
 - Make solutions that conduct electricity a little.
- Nonelectrolytes:
 - Covalent molecules and nonsoluble ionic compounds that are not soluble.
 - Make solutions that do not conduct electricity.

*Rely on solubility rules to determine whether a compound is an electrolyte or not.

Angie Sadaf. Electrolytes – Testing for Electrolytic Behavior. 2011. Standard YouTube License.

`<iframe width="420" height="315" src="https://www.youtube.com/embed/tZv1I_o74dU" frameborder="0" allowfullscreen></iframe>`

Stoichiometry in Aqueous Reactions

- Solutions
 - Homogeneous mixtures.
 - Solute – dissolved substance.
 - Solvent – substance dissolving the solute.
 - Concentration – given in terms of the amount of solute dissolved.

Solution Concentration

- Molarity
 - Mol solute dissolved per liter solution.

$$M = \frac{\text{Mol solute}}{\text{L Solvent}}$$

Solution Concentration

- Molality
 - Mol solute dissolved per kg solvent.

$$m = \frac{\text{Mol solute}}{\text{kg solvent}}$$

Solution Concentration

- Mol Fraction (X)
 - Mol solute dissolved divided by total mol (mol solute + mol solvent).

$$\frac{\text{Mol Solute}}{\text{Total mol}} = \frac{\text{Mol Solute}}{\text{Mol Solute} + \text{Mol Solvent}}$$

Solution Concentration

- Mass Percent
 - Grams of solute per total grams of solution.

$$(m/m)\% = \frac{\text{g Solute}}{\text{Total grams}}$$

Solution Concentration

- Parts Per Million
 - Individual solute components per 1 million solvent components. (Usually mg solute per L solvent or ppm).

$$\text{ppm} = \text{mg/L} = \frac{\text{mg Solute}}{\text{L Solvent}}$$

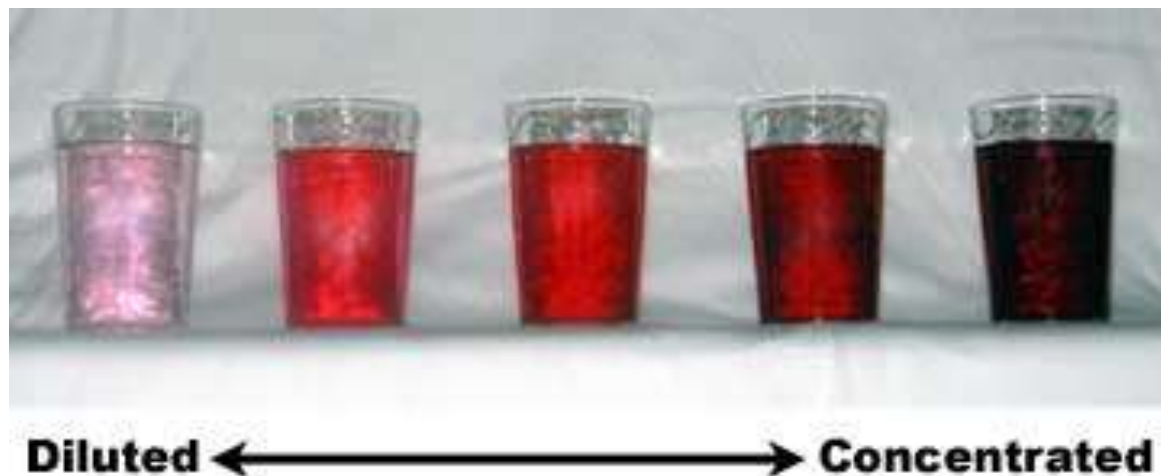
Application Quiz

- Calculate the molarity of a solution made by dissolving 25.0 g of NaCl into 625 mL water.

0.684 M NaCl

Dilutions

- Dilution
 - Taking a concentrated solution to a less concentration solution by increasing the amount of solvent.
 - $M_1V_1 = M_2V_2$



Dilutions

- How much of a 2.0 M NaOH solution is needed to make 50 mL of 0.1 M NaOH?

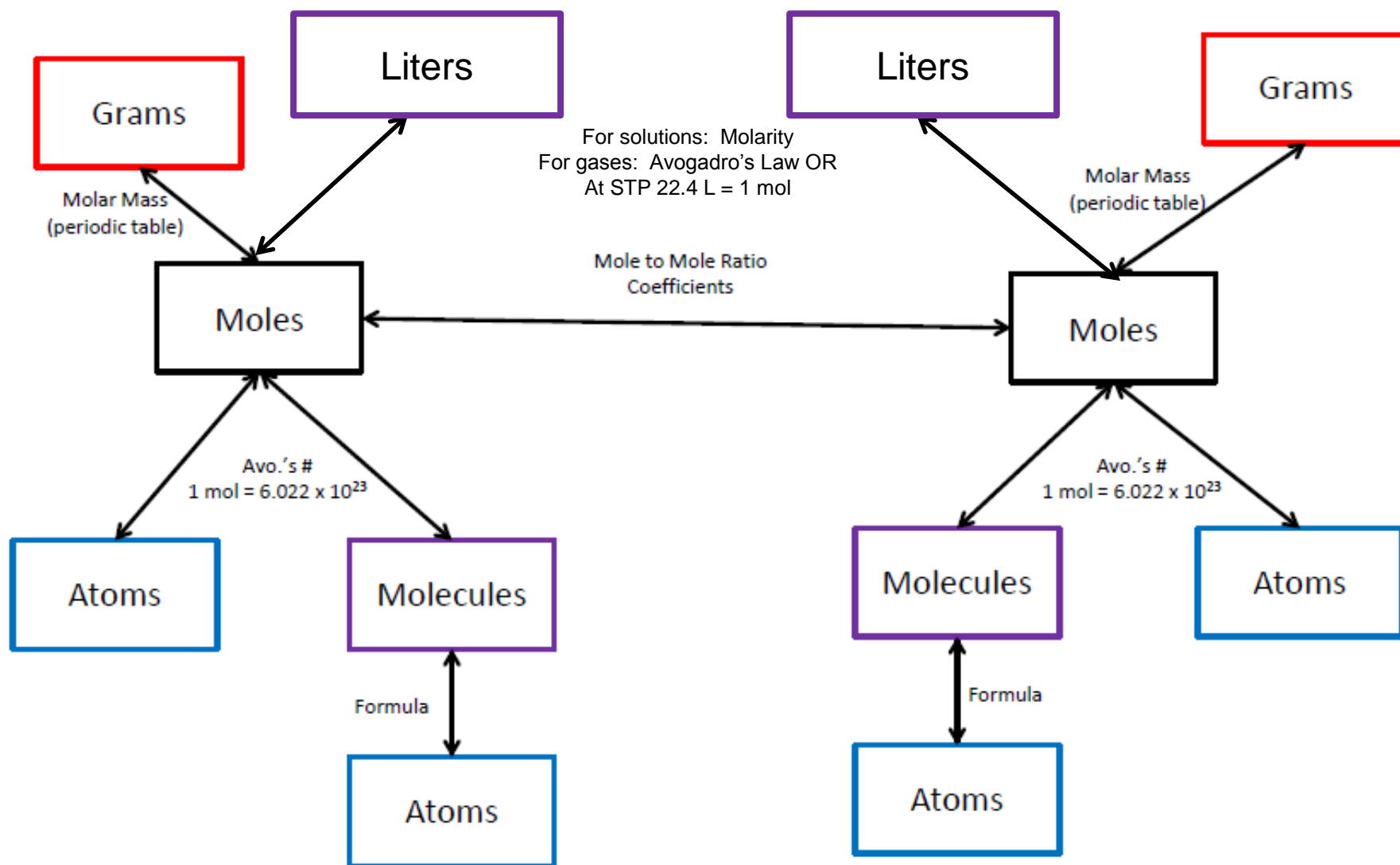
2.5 mL NaOH

Dilutions

- A student needs to make 250 mL of a 0.1 M HCl solution. How much of a 4.10 M HCl solution is needed to make the required solution?

6 mL HCl

Solution Stoichiometry

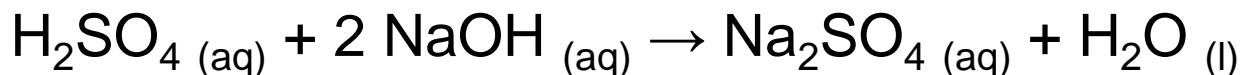


Solution Stoichiometry

- Use Molarity to go between L and mol.
- Perform stoichiometric calculations using the same steps (make a plan, determine your conversion factors, cancel units, use correct sig figs).

Solution Stoichiometry

- 22.15 mL of a 0.109 M NaOH solution was used to completely react with 10.0 mL of a sulfuric acid solution of unknown concentration. What is the molarity of the acid solution? How many grams are dissolved in the solution?



0.121 M H_2SO_4

0.119 g H_2SO_4

Reactions in Aqueous Solutions

- We discussed reaction classification above.
- We can further categorize many of these reactions when they occur in water.
 - For example: Double Displacement reactions can be further categorized as one of several types (acid-base, precipitation etc).
- Four most common types of reactions in aqueous solutions:
 - Oxidation- Reduction (Redox)
 - Precipitation
 - Acid-Base
 - Gas Evolving

Oxidation – Reduction Reactions

- Redox reactions occur when there is a change in the oxidation state of involved elements occurs.
- Redox reactions are often synthesis and single replacement reactions.

Oxidation – Reduction Reactions

- Oxidation
 - Loss of electrons
 - Increase in oxidation number
 - Increase in bonding to oxygen
- Reduction
 - Gaining electrons
 - Decrease in oxidation number
 - Reducing the number of bonds to oxygen
- OIL RIG
- LEO GER

Oxidation – Reduction Reactions

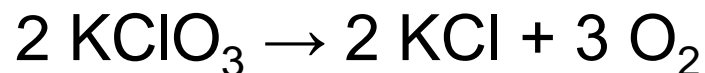
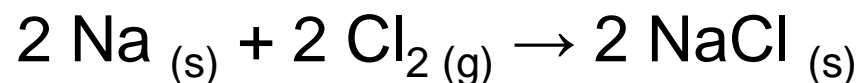
- Oxidizing Agent
 - Substance (reactant) that is being reduced in the chemical equation.
 - Causing another reactant to be oxidized.
- Reducing Agent
 - Substance (reactant) being oxidized in the chemical equation.
 - Causing another reactant to be reduced.

Oxidation Numbers

- The oxidation number of any element in its native state is 0.
- The oxidation number of oxygen in a compound is usually -2 (except for peroxides in which case oxygen's oxidation number is -1).
- The oxidation number of hydrogen is usually +1 (except in metal hydrides in which case hydrogen has an oxidation number of -1).
- The oxidation number of most elements in compounds is the same as the charge of the ion they would form (exceptions include group 4, and 8 –such as C and Xe). Exceptions also include row 3 and down and column 5 and to the right... ie P, S, etc—these exceptions have oxidation numbers that can be several different things and must be solved for).
- The sum of the oxidation numbers for all atoms in a compound **MUST** add up to be 0.
- The sum of the oxidation numbers for all atoms in an ion **MUST** add up to be equal to the charge.

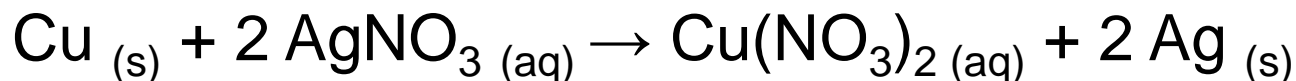
Application Quiz

- Are the following reactions redox reactions? If so, determine the substance being oxidized, the substance being reduced, the oxidizing agent and the reducing agent.



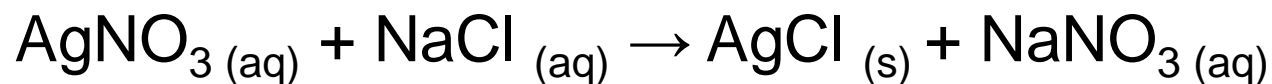
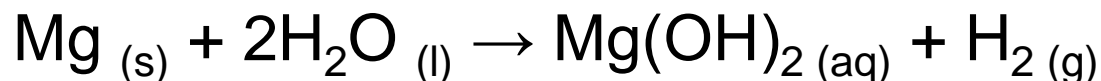
Application Quiz

- Are the following reaction a redox reaction? If so, determine the substance being oxidized, the substance being reduced, the oxidizing agent and the reducing agent.



Application Quiz

- Are the following reactions redox reactions? If so, determine the substance being oxidized, the substance being reduced, the oxidizing agent and the reducing agent.

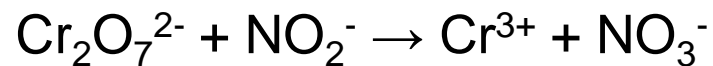


Balancing Redox Reactions

- Write the oxidation and reduction half-reactions.
- Balance both reactions for all elements except oxygen and hydrogen.
- If the oxygen atoms are not balanced in either reaction, add water molecules to the side missing the oxygen.
- If the hydrogen atoms are not balanced, add hydrogen ions (H^+) until the hydrogen atoms are balanced.
- Multiply the half-reactions by the appropriate numbers so that they both have equal numbers of electrons.
- Add the two equations to cancel out the electrons to balance the equation.

Application Quiz

- Balance the following redox reaction using the half-reaction method (acidic solution).



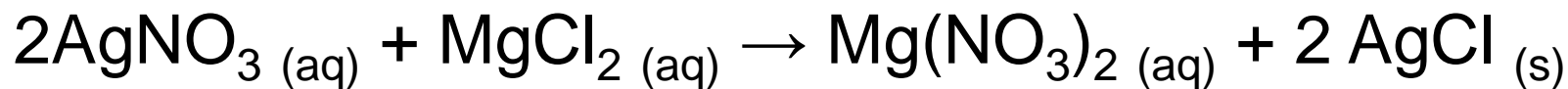
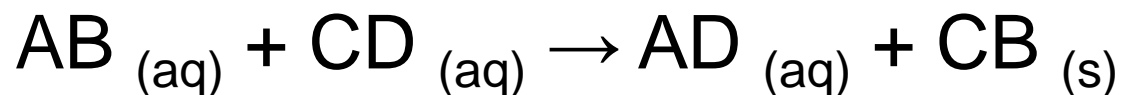
Application Quiz

- Balance the following redox reaction using the half-reaction method (acidic solution).



Precipitation Reactions

- These double displacement reactions occur when one of the products forms an insoluble solute.



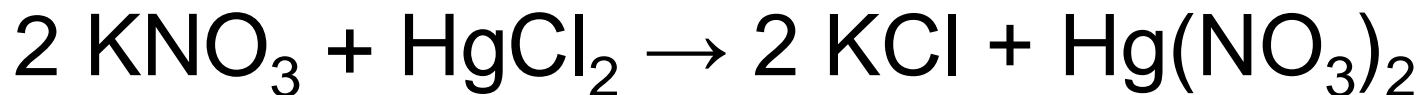
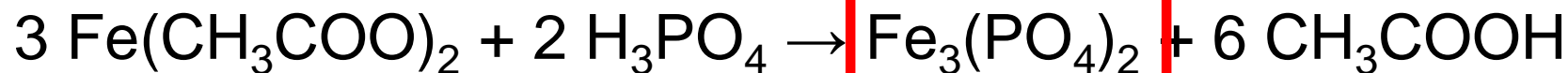
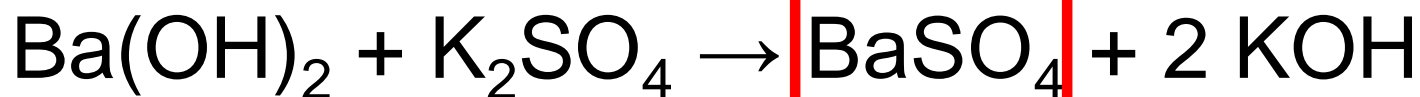
Solubility Rules

- Nitrates, group 1 metals, ammonium and acetate containing compounds are ALWAYS soluble. There are no exceptions.
- Chloride, bromide and iodides are soluble UNLESS paired with silver, mercury or lead in which case they become insoluble.
- Sulfates are soluble unless paired with barium, calcium, mercury or lead, in which case they become insoluble.
- Hydroxides are not soluble UNLESS paired with barium, calcium, or any ion that is always soluble. In these cases hydroxide become soluble.
- Sulfates, carbonates, chromates and phosphates are not soluble UNLESS paired with something that is always soluble in which case they become soluble.

Soluble		Not Soluble
NO_3^-		
Group 1 Metals, NH_4^+ , CH_3COO^-		
Cl^- , Br^- , I^-	→	Ag, Hg, Pb
SO_4^{2-}	→	Ba, Ca, Hg, Pb
Ba, Ca, Group 1 Metals, NH_4^+	←	OH^-
Group 1 Metals, NH_4^+	←	S^{2-} , CO_3^{2-} , CrO_4^{2-} , PO_4^{3-}

Predicting Precipitates

- Use solubility rules to determine the precipitate

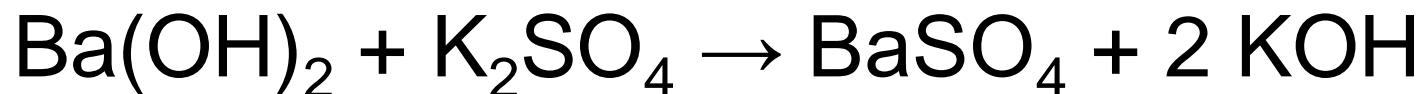


Net Ionic Equations

- Chemical Equations
 - Tell what reacted and what was produced.
- Complete Ionic Equations
 - Give every species in its form in solution.
- Net Ionic Equations
 - Show only what reacts/changes in the chemical equation.

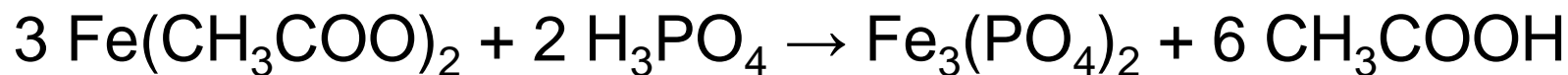
Net Ionic Equations

- Give the net ionic equation for:



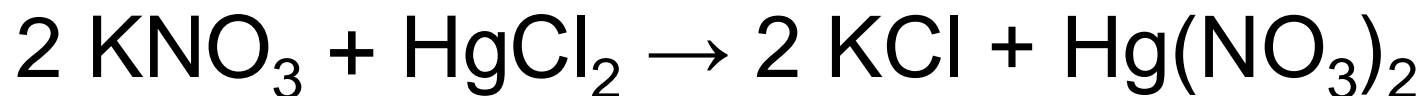
Predicting Precipitates

- Give the net ionic equation for:



Predicting Precipitates

- Give the net ionic equation for:



Acid-Base Reactions

- Neutralization reactions – an acid reacts with a base to produce a salt and water.

Acid – Base Properties

- Acid
 - In Unit 2 defined as a substance that produces H^+ in solution.
 - Bronsted-Lowry expands definition to any species that donates a proton.
 - Dissociates to lower pH of solution
- Base
 - In Unit 2 produces OH^- in solution
 - Bronsted-Lowry expands definition to any species that accepts a proton.
 - ie: NH_3 can also accept a proton = is a base
 - Dissociates in water to increase pH of solution

pH Scale

- A measure of the acidity of a solution
- Logarithmic representation
- $\text{pH} = -\log[\text{H}^+]$
- $\text{pH} < 7 = \text{acidic}$
- $\text{pH} > 7 = \text{basic (alkaline)}$



pH scale. Boundless.com **Connexions**.

http://cnx.org/content/m44392/latest/Figure_02_02_07.jpg

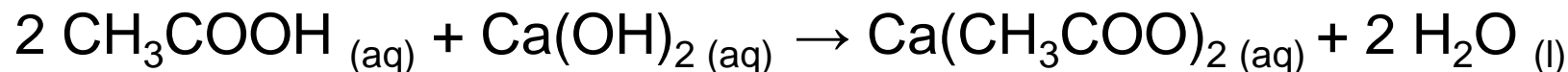
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Acid – Base Strength

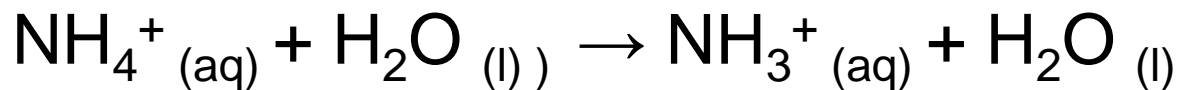
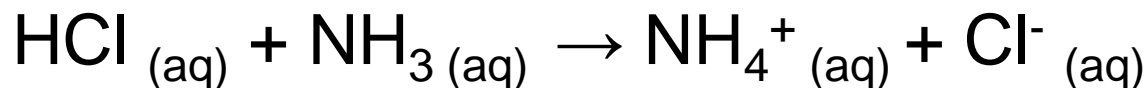
- Strong Acids
 - Completely dissociate
 - Are strong electrolytes
 - HCl, HBr, HI, HClO₃, HNO₃ and H₂SO₄
- Strong Bases
 - Completely dissociate
 - Are strong electrolytes
 - Group 1 metals paired with OH⁻

Acid – Base Reactions

- Weak Acid and Weak Base:

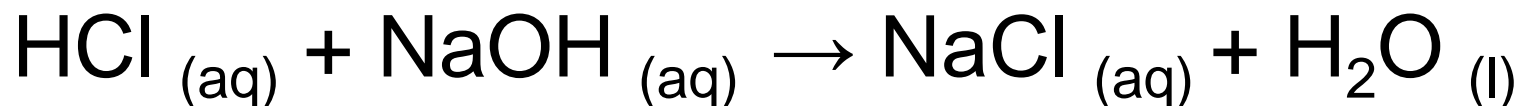


- Strong Acid and Weak Base:

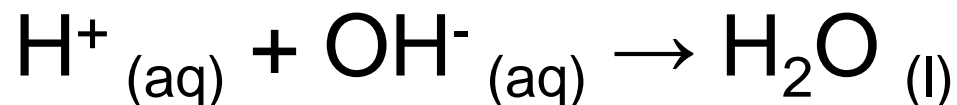


Acid – Base Reactions

- Strong Acid and Strong Base:



- Net ionic equation for strong acid reacting with strong base is always:



Acid-Base Reactions

- Titrations
 - Used to calculate the mol of an unknown (usually acidic) solution (analyte) containing an indicator by delivering a measured volume of a (usually basic) solution with a known concentration of (also called the titrant).
 - Equivalence Point is when $\text{mol acid} = \text{mol base}$
 - End Point is when you see a color change, usually slightly more base than acid present.



Acid-Base Titration Set-up. Boundless.com. CC-BY-SA. 3.0 2015.

<https://www.boundless.com/chemistry/textbooks/boundless-chemistry-textbook/aqueous-reactions-4/acid-base-reactions-47/acid-base-titrations-243-1823/>

Titration Calculations

- How much of a 0.500 M solution of NaOH is needed to react with 0.88 L of 1.2 M HCl?

2.1 L NaOH

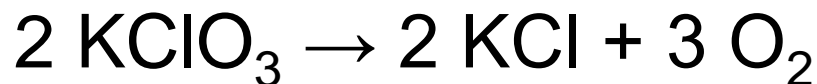
Titration Calculations

- How much of a 0.175 M solution of sodium hydroxide is needed to completely react with 0.062 L of 0.25 M phosphoric acid?

0.27 L NaOH or 270 mL

Gas Evolving Reactions

- Will always produce a gas as a product.
- Usually be combustion, single replacement, or decomposition reactions.
- Are also usually redox reactions.



Summary

- There are 5 signs a chemical reaction has taken place.
- Each reaction can be classified as 1 of 5 main types.
- Solution concentration can be calculated and used in stoichiometric problems.
- Electrolytes (or soluble ionic compounds) cause a solution to conduct electricity.
- Aqueous reactions can be classified further than into the 5 main categories.
- Redox reactions have a change in oxidation number.
- Precipitation reactions produce an insoluble precipitate.
- Neutralization reactions involve acids and bases.
- Gas evolving reactions produce a gas.