Chemistry 110 Lecture Unit 4
Chapter 7-CHEMICAL REACTIONS, continued

A chemical reaction occurs when there is a change in chemical composition.

TYPES of REACTIONS:

I. Double Replacement/Double Exchange/Metathesis Reactions

In an double displacement reaction, the positive end and negative end of compounds "change partners" to form new products:

a. PRECIPITATION REACTIONS

*Note: A ppt **must** form for the rxn to occur. (if it doesn't...Then NR!)

SOLUBILITY RULES FOR IONIC COMPOUNDS

Ion contained in the Compound	Solubility	Exceptions
Group IA	soluble	
NH_4^+	soluble	
$C_2H_3O_2^-$	soluble	
NO_3^-	soluble	
Cl^-,Br^-, and I^-	soluble	Ag^+, Pb^{2+}, Hg_2^{2+}
SO_4^{2-}	soluble	Ca^{2+},Sr^{2+},Ba^{2+},Pb^{2+}
CO_3^{2-}, PO_4^{3-}, $CrO4^{2-}$	insoluble	group IA and NH_4^+
S^{2-}	insoluble	group IA,IIA, and NH_4^+
OH^-	insoluble	group IA, Ca^{2+}, Ba^{2+},Sr^{2+}

a. PRECIPITATION REACTIONS, CONTINUED:

b. ACID-BASE AND GAS EVOLUTION REACTIONS (Molecule formation)

(1) Neutralization-

Acid + Base -> Salt + water

(2) A weak acid is formed

STRONG ACIDS	
HNO_3	HCl
$HClO_4$	HBr
H_2SO_4	HI

(3) A gas forms

a. H_2CO_3 decomposition to form CO_2 (g) and H_2O (l)

b. H_2S Formation

NET-IONIC EQUATIONS

Net Ionic equations shows the species that are reacting in solution

Molecular equation - the bookkeeping equation

Total or complete ionic equation - Shows substances in their predominant form

Net-Ionic equation - Shows the only species that underwent a chemical reaction. [Spectator ions have been eliminated]

How to write net-ionic equations

1. Write a balanced equation (correct chemical formulas)
2. Write a total ionic equation:
   a. Write the following in the ionized form:

		Write As:
Soluble Salt	$FeCl_2(aq)$	$Fe^{2+}(aq) + 2Cl^-(aq)$
Strong Acid	$HCl(aq)$	$H^+(aq) + Cl^-(aq)$
Strong Base	$NaOH(aq)$	$Na^+(aq) + OH^-(aq)$

   b. Write the following in the molecular form:
      (1) Weak acids and weak soluble bases:
      H_2CO_3 HCN $NH_3(aq)$
      (2) Insoluble ionic compounds
      $AgCl(s)$, $PbS(s)$, $Fe(OH)_2(s)$, $CrCrO_4(s)$
      (3) Molecules
      $H_2O(l)$ $H_2(g)$ $H_2S(g)$ $CO_2(g)$
3. Write the net-ionic equation by eliminating all spectator ions. (The unreacting species)

The net-ionic equaiton must be in the simplest ratio possible

If all species on both sides are spectator ions → N.R.

EXAMPLES:

1. Oxalic acid is poured into a solution of potassium hydroxide.

Molecular equation_____

Total ionic_____

Net ionic_____

2. Solutions of Iron (II) chloride and cesium hydroxide are mixed together

Molecular equation_____

Total ionic_____

Net ionic_____

3. Sodium nitrate and cupric acetate solutions are mixed together.

Molecular equation_____

Total ionic_____

Net ionic_____

4. Chromium (III) hydroxide is slowly stirred into a solution of acetic acid.

Molecular equation_____

Total ionic_____

Net ionic_____

5. Aqueous sodium phosphate and sulfuric acid are mixed.

Molecular equation_____

Total ionic_____

Net ionic_____

6. lead (II) cyanide and potassium carbonate solutions are mixed

Molecular equation_____

Total ionic_____

Net ionic_____

II. Combustion, Synthesis, decomposition, and Displacement Types of Chemical Reactions

A. Combustion Reactions involves organic compounds:

General Form: $(C_xH_yO_z) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

B. Synthesis/Combination Reactions - One product is formed: **Know these specific cases!!**

1. Metal + Nonmetal combines to form ▶ an Ionic compound

ex.

2. Metal Oxide + H_2O combines to form ▶ a Base

ex.

3. Nonmetal Oxide + H_2O combines to form ▶ an Acid

ex.

C. Decomposition-A single reactant will form two or more products **Know these specific cases**

1. Carbonates (CO_3^{2-}) ~~decomposes~~▶ to oxides and $CO_2(g)$

Ex.

2. Binary Ionic Compounds ~~decomposes~~▶ to Metal + Nonmetal

3. Decomposition of hydroxides to form a metallic oxide and water

4. Decomposition of chlorates to form chlorides and oxygen gas

D. Single displacement Reactions/ Replacement Rxns.

TYPES:

Type 1: Metal + H_2O → Base + $H_2(g)$
(HOH)

Type 2: Metal + Acid → Salt + $H_2(g)$

Type 3: $Metal_1$ + $Salt_1$ → $Metal_2$ + $Salt_2$

Type 4. $Nonmetal_1$ + $Salt_1$ → $Nonmetal_2$ + $Salt_2$

PREDICTING if the Single displacement reaction will occur

USING:

1. Activity table for metals-for Single displacement types 1-->3
    a. Which metals reacts with H_2O
    b. Which metals reacts with hot H_2O, steam
    c. Which metals reacts with acids
    d. Which metals are more reactive
2. Activity series for halogens for single displacement type 4

Type 1. Metal + H_2O → Base + $H_2(g)$

Type 2 Metal + Acid → Salt + $H_2(g)$

Type 3 $Metal_1$ + $Salt_1$ → $Metal_2$ + $Salt_2$

Type 4 $Nonmetal_1$ + $Salt_1$ → $Nonmetal_2$ + $Salt_2$

Examples

1. $Zn(s) + H_2O(g) \rightarrow$

2. $Hg(l) + HNO_3(aq) \rightarrow$

3. $Ca(s) + HNO_3(aq) \rightarrow$

4. $Cu(s) + AlBr_3(aq) \rightarrow$

5. $Ag(s) + HCl(aq) \rightarrow$

6. $Ni(s) + AlCl_3 \rightarrow$

7. $Cl_2 + KI(aq) \rightarrow$

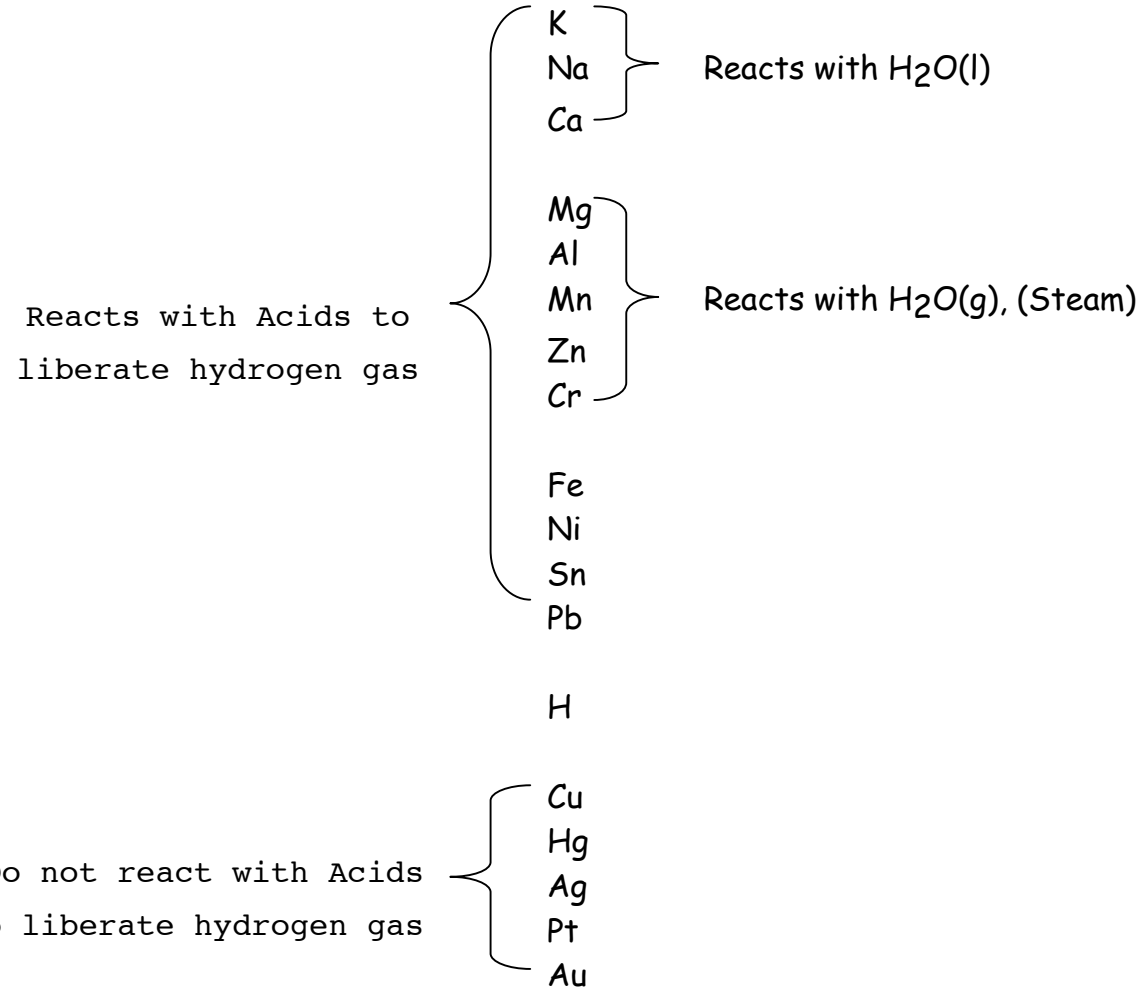
8. $K + H_2O \rightarrow$

9. $Fe(s) + CuSO_{4\,(aq)}$

Use For: Single Replacement Reactions ONLY!!!

ACTIVITY SERIES FOR COMMON METALS

MOST ACTIVE



LEAST ACTIVE

*Note: Other types of rxns may occur with acids but will not produce H_2 gas-you are not responsible to know these 'other' types

III. Predicting, Writing and Balancing Chemical equations

A. Items to be included:

Correct prediction of products using and knowing:

a. Reaction types
b. Activity table
c. Electron affinity
d. Solubility rules
e. Correct Chemical Formulas
f. Diatomic elements
g. Physical states

***NOTE: IONIC COMPOUNDS IN AIR ARE SOLIDS*

B. Practice Problems:

1. Sulfuric acid + aluminum hydroxide

2. Calcium is added to water

3. Zinc + a solution of copper (II) chloride

4. Magnesium + chlorine

5. Sodium Carbonate is heated

6. Solutions of Iron (II) nitrate and sodium carbonate are mixed

Chapter 8-QUANTITIES IN CHEMICAL REACTIONS

STOICHIOMETRY

The numerical relationship among the reactants and products in a balanced equation (Chemical reaction)

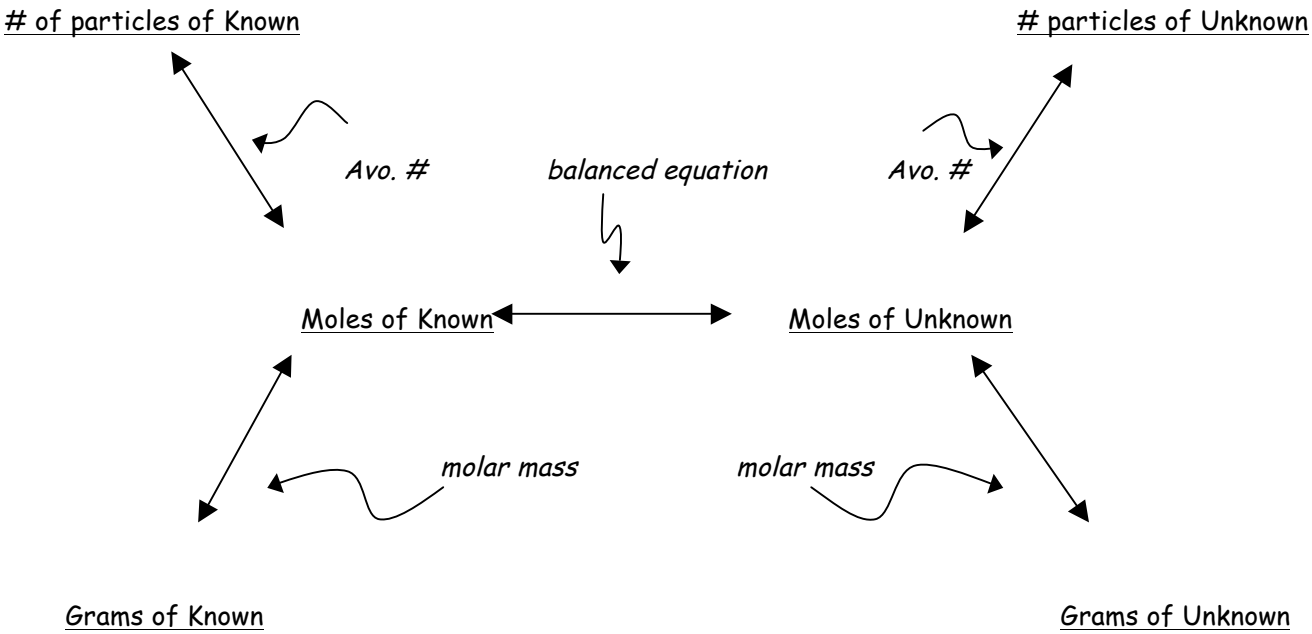
I. The Balanced equation

A balanced equation shows a chemical reaction in shorthand:
For example: Two magnesium atoms (a solid) when ignited, reacts with oxygen atoms to form solid magnesium oxide

The meaning of a balanced Chemical Equation: A bookkeeping system
Example:

The balanced equation - mole to mole ratios
These mole to mole ratios are exact numbers.

II. The Stoichiometric Pathway:



III. Stoichiometric Calculations

The reaction: Chromium metal is reacted with chlorine gas to produce chromic chloride

Key: You must have a balanced equation!!

a) How many moles of chromic chloride is made from 6.0 moles Cr?

b) How many moles of chlorine gas is needed to react with 6.0 moles of Cr?

c) How many grams of chromic chloride is made from 1.60 moles of chlorine gas?

d) How many grams of Cr is needed to produce 36.0 g of chromic chloride

PROBLEMS:

1. Octane or C_8H_{18} (l) is a component of gasoline. If 35.0 mol O_2(g) in the air is used to burn a sample of octane completely.
   a. How many **grams** of carbon dioxide gas are produced?
   b. How many g of water are produced from 54.0 **grams** of octane.

2. A crucial reaction for the maintenance of plant and animal life is the conversion of oxygen gas to ozone gas[O_3(g)] in the lower part of the stratosphere.
How many molecules of oxygen gas are needed to produce 17.0 moles of ozone (O_3)?

3. How many grams of oxygen gas are required for the complete combustion of 694 g of methane CH_4(g) in a sample of natural gas?

4. The percent of aluminum in the compound Al_2X_3 is 18.56%. What is the molar mass of the element represented by X?

5. 75. 0 grams of iron are reacted in chlorine gas to produce 170.2 g the compound FeClx. What is the value of the integer x?

6.

IV. LIMITING REACTANTS

When most reactions are performed, some of the reactants is usually present in excess of the amount needed. If the reaction goes to completion, then some of this *excess reactant* will be left-over. The **limiting reactant** is the reactant used-up completely and it "limits" the reaction.
For example:

PROBLEMS:

1. Calcium hydroxide is reacted with nitric acid.

   a. How many moles of calcium nitrate is produced when 3 moles of calcium hydroxide and 4 moles of nitric acid are mixed?

   How many moles of each product are formed?
   How much excess reactant is left-over?
   BALANCED EQUATION:

What is the maximum moles of calcium nitrate formed?

What is the limiting reactant?_____ What is the excess reactant?_____

How many moles of the excess reactant is left over?

Moles of calcium hydroxide leftover_____ Moles of nitric acid left over_____

Problem 2: 50.0 g of magnesium bromide and 100.0 g of silver nitrate are mixed.

a. How many grams of precipitate are produced?
b. How much excess reactant is left-over?

BALANCED EQUATION:

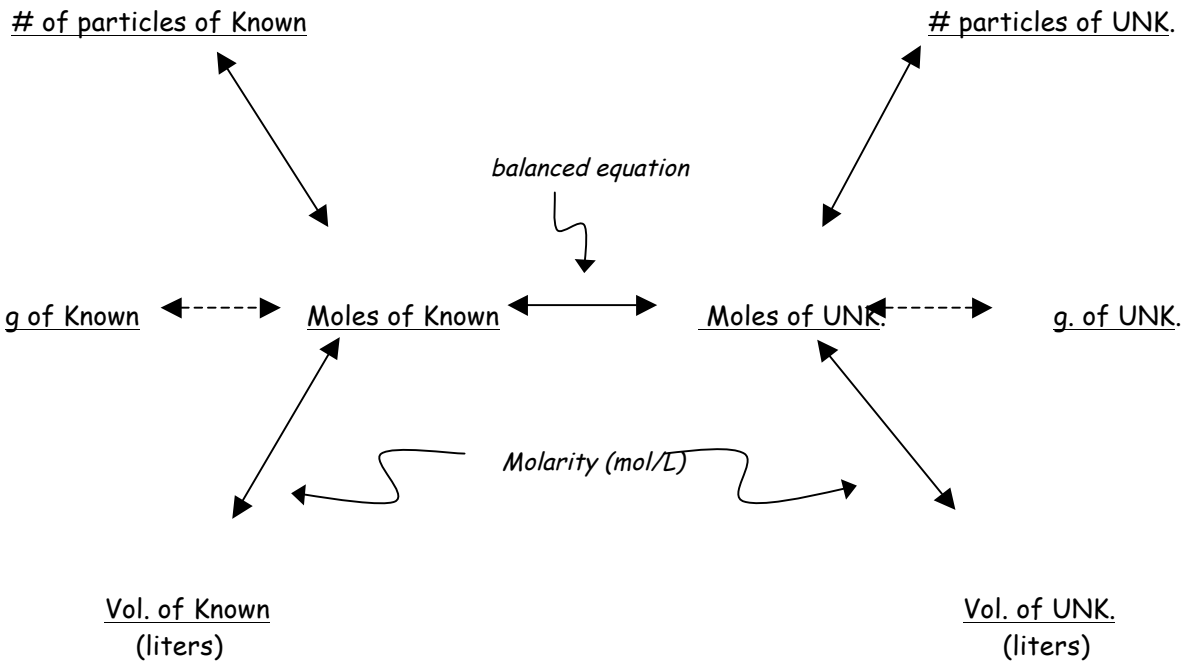
What is the maximum mass of precipitate formed?

What is the limiting reactant?_____ What is the excess reactant?_____

How much of the excess reactant is left over?

Mass of magnesium bromide leftover_____ Mass of silver nitrate left over_____

SOLUTION STOICHIOMETRY



PROBLEMS:

1. $HCl + AgNO_3 \rightarrow$

a. How many moles of AgCl(s) are produced from 30.0 mls of 0.10 M HCl?

b. How many mls of 0.10M HCl is needed to react to produce 17.0 g of AgCl?

2. 25.0 g of zinc are reacted with 1855 mls of 0.250 M hydrochloric acid. How many grams of hydrogen gas are produced? Zinc metal + hydrochloric acid →

3. How many milliliters of 0.500 M H_2SO_4 are required to neutralize 2.50 ml of 2.50 M LiOH?

4. If 25.0 ml of 0.150 M $Ba(OH)_2$ is required to react completely with 45.0 ml HCl solution, what is the molarity of the HCl(aq)?

5. A soda acid (sodium hydrogen carbonate) fire extinguisher makes carbon dioxide by the reaction:

$NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2$ (unbalanced)

Molar Masses are: MM-$NaHCO_3$ =83.91 MM-H_2SO_4-98.07 MM-Na_2SO_4=141.84
MM-H_2O= 18.01 MM-CO_2 =44.01

a. How many mls of 2.50 Msulfuric acid is needed to produce 10.0 g of carbon dioxide

b How many mls of 2.50 Msulfuric acid are needed to react with 1.34×10^{30} units of sodium bicarbonate?

7. How many mls of 6.0 M hydrochloric acid are needed to react to produce 124 mls of hydrogen gas at 1.3 atm and $25^{o}C$

V. PERCENT YIELD

The amount of product that has been previously calculated from chemical equations show the maximum yield (100%). However, many reactions fail to give a 100% yield of product.

The theoretical yield is the calculated amount of product.

The Actual yield is the amount of product actually obtained

$$\text{Percent Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

Example:

PROBLEMS:

1. 28.0 grams of nitrogen gas reacted with hydrogen gas to produce 26.0 grams of ammonia. What is the percent yield of the reaction?

2. How many grams of $XeF_2(g)$ will be produced when xenon reacts with 10.0 g fluorine gas and the percent yield for the reaction is 54%?

Deeper PROBLEMS

1. A 13.20 g sample of a mixture of $CaCO_3$ and $NaHCO_3$ was heated, and the compounds decomposed as follows.

   $Ca\ CO_3 \rightarrow CaO + CO_2$

   $2\ NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

The decomposition of the sample yields 4.35 g of CO_2 and .873 g of H_2O. What percentage, by mass, of the original sample was $CaCO_3$?

2. Determine how many $CoCl_3$ formula units can be produced from a reaction mixture containing 525 cobalt atoms and 525 HCl molecules according to the following reaction.

   $2\ Co + 6\ HCl \rightarrow 2CoCl_3 + 3\ H$

PRACTICE EXAM 4

100 POINTS-There are 5 pages to this exam

SHOW ALL YOUR WORK. YOUR ANSWERS MUST HAVE THE CORRECT NUMBER OF SIGNIFICANT FIGURES AND UNITS. CORRECT SPELLING MUST BE USED.

1. A soda acid (sodium hydrogen carbonate) fire extinguisher makes carbon dioxide by the reaction:

$$NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2 \text{ (unbalanced)}$$

Molar Masses are: MM-$NaHCO_3$ =83.91 MM-H_2SO_4-98.07 MM-Na_2SO_4=141.84
MM-H_2O= 18.01 MM-CO_2 =44.01

a. How many moles of H_2SO_4 are needed to react with 2.78 moles of $NaHCO_3$?

b. How many grams of CO_2 are obtained when 1.37 moles of H_2SO_4 react?

c. How many grams of $NaHCO_3$ must react in order to produce 13.5 grams of Na_2SO_4.

d. How many carbon dioxide molecules are produced from 155 mg of sodium bicarbonate?

e. How many moles of sodium sulfate are produced when 177 g of water is formed?

2. **Complete** and **balance** the following reactions Correct chemical formulas and physical states [(aq),(s),(l), and (g)] must be used:

a. $CaO_2 \xrightarrow{\text{heat}}$

b. C_2H_3OH liquid is burned

c. Aluminum metal is added to a solution containing Plumbic nitrate

d. Solid Manganese (III) oxide is carefully placed in erlenmeyer full of water

e. Iron metal + aqueous silver nitrate →

f. Solutions of sodium sulfide and zinc iodide are mixed

g. $K_2CO_3 \xrightarrow{\text{heat}}$

h. $Al\ (s) + S_8\ (s) \rightarrow$

i. Acetic acid is spilled on a tin can.

j. Chlorine water is added to a ferrous bromide solution.

k. Nickel (III) bromide is heated

l. Zinc is dropped in a beaker of water

m. Aluminum metal is placed in steam.

n. The combustion of C_4H_{10} gas

o. Cobalt metal + nitrogen gas →

p. Sodium bromide (aq) + Manganese (II) nitrate (aq) →

3. The reaction:

$$3CCl_4 + Cr_2O_3 \rightarrow 2CrCl_3 + 3CCl_2O$$

MM-CCl_4=153.8 MM- Cr_2O_3=152.0 MM-$CrCl_3$=158.4 MM-CCl_2O=98.9

is used to make $CrCl_3$. In one experiment 6.37 g of Cr_2O_3 was treated with excess CCl_4 and yielded 8.75 g of $CrCl_3$. Calculate the percent yield of $CrCl_3$.

4 For the following reactions:

a. Complete
b. Balance
c. Write the physical states for the reactants and products
d. Write the net-ionic equations

***NOTE: All the following reactions occur in solution (water!!!!!!)

(1) Zinc acetate + lithium carbonate

(2) Nickel (III) hydroxide + sulfurous acid →

(3) Ammonium phosphate + Cobalt(II) bromide →

(4) Hydrocyanic acid + Nickel (II) chloride →

** Note: ionic compounds of CN^- are soluble*

(5) Acetic acid + Barium hydroxide →

(6) Sodium sulfate + Chlorous acid →

5. A volume of 54.6 ml of 0.100 M HCl solution is required to neutralize 34.0 ml of an NaOH solution of unknown molarity. What is the concentration of the NaOH solution?

6. Nitric oxide (NO) reacts instantly with oxygen gas to give nitrogen dioxide (NO_2) , a dark brown gas. 4677 grams of oxygen gas is reacted with 6555 grams of NO:

$$O_2(g) + NO\,(q) \rightarrow NO_2(g) \text{ [unbalanced]}$$

MM-O_2=32.0 MM-NO=30.0 MM- NO_2=46.0

a) The limiting reactant is _____.

b) How many **kilograms** of NO_2 is produced?

c) How many **kilograms** of the excess reactant will remain after the reaction is completed?

7. Iron (III) oxide can react with aluminum metal to produce aluminum oxide and iron metal *(hint: this is the chemical rxn!!)* This is called the thermit reaction and it produces so much heat that it can be used for incendiary bombs and for welding. How many grams of aluminum oxide will be produced by the reaction of aluminum with 45.8 g of iron(III) oxide?