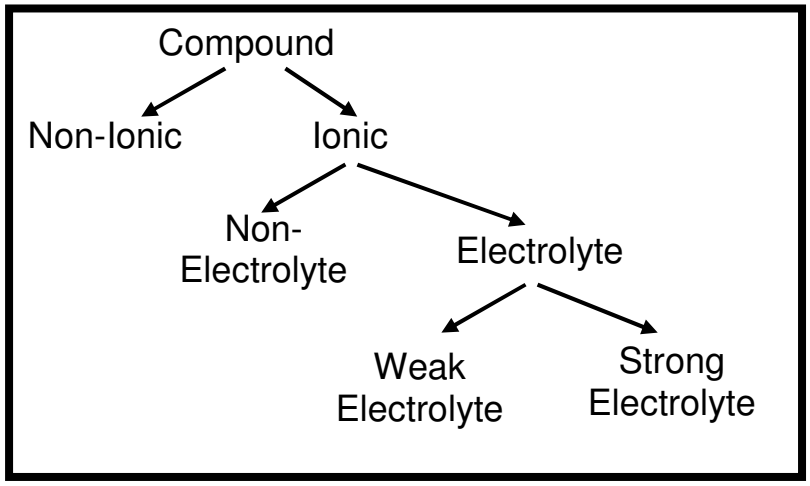
Chapter 4: Chemical Reactions

These Notes are to SUPPLIMENT the Text, They do NOT Replace reading the Text Material. Additional material that is in the Text will be on your tests!

To get the most information, READ THE CHAPTER prior to the Lecture, bring in these lecture notes and make comments on these notes. These notes alone are NOT enough to pass any test!

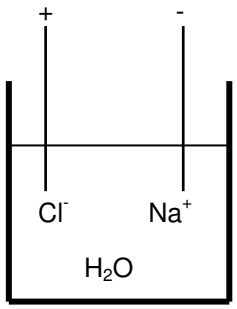
Ionic Theory



Don't operate electrical equipment while standing in water. If the water were pure, ions would not flow.

1884 Arrhenius Ionic Theory of Solutions: Certain substances produce freely moving ions when dissolved in water and these IONS conduct an electric current in an aqueous solution.

NaCl put into water and a direct current applied. Sodium Chloride completely ionizes. The Positive Sodium Ions are attracted to the negative pole and the Negative Chloride Ions to the positive pole. This solution then conducts electricity.

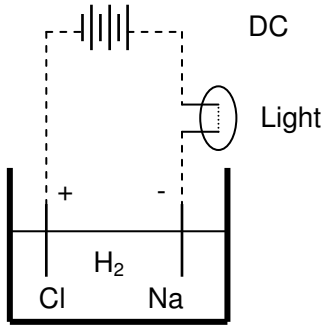


Electrolyte – substance that dissolves in water to give an electrically conductive solution. E.g. NaCl
Most Ionic Solids that dissolve in water are electrolytes.

Not all Electrolytes are Ionic Substances. HCl is not an Ionic Solid, it is a Molecular Substance or a Non Ionic Solid Compound, but ionizes to H^+ and Cl^- almost completely.

NonElectrolyte is a substance that dissolves in water to give a nonconducting or poorly conducting solution. Methanol CH_3CH_2OH is one.

Experiment to show the conduction of electricity. Put 2 electrodes into water and attach to a battery and to a light bulb. Bulb will light if electricity is flowing.



Strong Electrolyte – an electrolyte that exists in solution almost entirely as ions – NaCl

$$NaCl_{\ solid} \rightarrow Na^+ + Cl^-$$

Weak Electrolyte – an electrolyte that dissolves in water to give a relatively small percentage of ions

$$NH_3 + H_2O \underset{\leftarrow}{\overset{3\%}{\rightarrow}} NH_4^+ + OH^-$$

Double Arrow = Reversible Reaction

Most water soluble substances are non or weak electrolytes.
Most Weak electrolytes are Molecular Substances and not Ionic.

Solubility – ability do dissolve in water. Solubility Rules for Ionic Compounds [Table 4.2]

STUDENTS MUST MEMORIZE THESE

#	Applies to	Statement	Exceptions
1.	Li^+, Na^+, K^+, NH_4^+	Group 1A and Ammonium cpds **are soluble**	
2.	$C_2H_3O_2^-$, NO_3^-	Acetates & Nitrates **are soluble**	
3.	Cl^-, Br^-, I^-	Most Chloride, Bromide & Iodides **are soluble**	AgX, Hg_2X_2, PbX_2 X = Cl, Br, I
4.	SO_4^{-2}	Most Sulfates **are soluble**	$CaSO_4$, $SrSO_4$, $BaSO_4$ Ag_2SO_4, Hg_2SO_4, $PbSO_4$
5.	CO_3^{-2}	Most carbonates **are INSOLUBLE**	Grp 1A, $(NH_4)_2CO_3$
6.	PO_4^{-3}	Most phosphates **are INSOLUBLE**	Grp 1A, $(NH_4)_3PO_4$
7.	S^{-2}	Most sulfides **are INSOLUBLE**	Grp 1A, $(NH_4)_2S$
8.	OH^-	Most hydroxides **are INSOLUBLE**	Grp 1A, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$, NH_4OH

Compounds that dissolve in water **<u>are soluble</u>**.
Compounds that dissolve only a little **<u>are INSOLUBLE</u>**
Soluble compounds are Electrolytes or Non-Electrolytes
Electrolytes can be Strong or Weak
Non-Electrolytes form non electrical conducting solutions.

What is the Solubility of NaBr $Ba(OH)_2$ Calcium Carbonate

Molecular and Ionic & Complete Ionic Equations

Molecular Equation: a chemical reaction in which the reactants and products are written as if they were molecular substances

Calcium Hydroxide and Sodium Carbonate → Calcium Carbonate (ppt) and Sodium Hydroxide

$Ca(OH)_2 + Na_2CO_3 \rightarrow Ca\,CO_{3\,(ppt)} + 2\,NaOH$

Calcium Carbonate (ppt) is used to brighten paper, as Tums Antacid and as a toothpaste abrasive.

Complete Ionic Equation represents each substances by it's predominant form in the reaction mixture and where strong electrolytes are written as separate ions:

$Ca^{+2} + 2\,OH^- + 2\,Na^+ + CO_3^{-2} \rightarrow Ca\,CO_{3\,(ppt)} + 2\,Na^+ + 2\,OH^-$ **[5-June-08]**

Net Ionic Equation is an ionic equation where Spectator Ions are removed
Spectator Ion does not take part in the reaction [is on both sides]

$Ca^{+2} + CO_3^{-2} \rightarrow Ca\,CO_{3\,(ppt)}$ **[5-June-08]**

<u>EXAMPLE:</u> Calcium Nitrate [$Ca(NO_3)_2$] and Potassium Carbonate [K_2CO_3] give the same Net Ionic Equation – ***PROVE IT!***
The **value of the Net Ionic Equation** is its GENERALITY.

Do some examples from the table of solubility. Write Net Ionic Equations
Example 4.2

Perchloric Acid [$HClO_4$] and Calcium Hydroxide [$Ca(OH)_2$] forms water

Acetic Acid [$HC_2H_3O_2$] and Sodium Hydroxide [NaOH] forms water.

Exercise 4.2

Nitric Acid [HNO_3] and Magnesium Hydroxide [$Mg(OH)_2$] forms water.

Lead Nitrate [$Pb(NO_3)_2$] and Sodium Sulfate [Na_2SO_4] forms $PbSO_{4\,ppt}$

Driving Forces in a Chemical Reaction

1. Formation of a precipitate
2. Formation of Water – H2O, such as in an Acid Base Reaction
3. Transfer of electrons – REDOX Reaction
4. Combustion Reaction – $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$
5. Synthesis / Combination – $2\,H_2 + O_2 \rightarrow 2\,H_2O$
6. Decomposition – $2\,H_2O \rightarrow$ electrolysis $\rightarrow 2\,H_2 + O_2$

Types of Chemical Reactions

1. **Precipitation Reactions:** mix 2 ionic substances and a solid ionic ppt forms
2. **Acid – Base Reactions:** Acid reacts with a base – transfer of protons
3. **Oxidation – Reduction Reactions:** transfer electrons - **REDOX**

1. Precipitation – a precipitate is an insoluble solid compound formed during a chemical reaction in solution

An **Exchange Reaction** when written as a molecular reaction appears to involve the exchange of parts between the 2 reactants.

$MgCl_2 + 2\ AgNO_3 \rightarrow 2\ AgCl + Mg(NO_3)_2$ All but AgCl is soluble [see table]

The reaction occurs because the silver chloride is insoluble. Write the Net Ionic
If silver chloride was soluble, there would be no reaction.

Example 4.3

Sodium Chloride and Iron (II) Nitrate → ?	no ppt = nr	[nr = No reaction]
Aluminum Sulfate and Sodium Hydroxide → ?	ppt = r	[r = Reaction]

See also **Concept Check 4.2** on page 136

2. Acid Base
Acids – have a sour taste
Bases – bitter taste and feel soapy

Common Acids and Bases Table 4.2 STUDENTS DO NOT HAVE TO MEMORIZE

	Name	Formulae	Remarks
Acid	Acetic Acid	$HC_2H_3O_2$	Vinegar
	Acetylsalicylic Acid	$HC_9H_7O_4$	Aspirin
	Ascorbic Acid	$H_2C_6H_6O_6$	Vitamin C
	Citric Acid	$H_3C_6H_5O_7$	In Lemon Juice
	Hydrochloric Acid	HCl	Stomach Acid
	Sulfuric Acid	H_2SO_4	Battery Acid
Base	Ammonia	NH_3 [NH_4OH]	Water solution is a household cleaner
	Calcium Hydroxide	$Ca(OH)_2$	Lime use in construction mortar
	Magnesium Hydroxide	$Mg(OH)_2$	Mild of magnesia – antacid
	Sodium Hydroxide	NaOH	Drain and oven cleaner

Acid Base Indicator is a dye used to distinguish between acidic and basic solutions by means of a color change it undergoes.

Arrhenius Acid is a substance that produces hydrogen ions H^+

$HNO_3 \rightarrow H^+ + NO_3^-$ dissolve in water

Arrhenius base is a substance that produces hydroxide ions OH^-

$NaOH \rightarrow Na^+ + OH^-$ dissolve in water

Bronsted Lowry Acid / Base are proton transfers.
Bronsted Lowry Acid: donates a proton to another species in a proton transfer reaction.
Bronsted Lowry Base: Accepts a proton from another species

$NH_3 + H_2O \rightarrow NH_{4+} + OH^-$ Water donates the proton = acid
$\leftarrow H+ \leftarrow$ Ammonia accepts the proton = base

H^+ really exists in solution as $H3O^+$ = the **Hydronium Ion**
$HNO_3 \rightarrow H+ + NO_3^-$ **really is** $HNO_3 + H_2O \rightarrow H_3O+ + NO_3^-$
Reaction is a transfer of a proton from Nitric Acid to water.
Nitric Acid is the proton donor – the acid
Water is the proton acceptor – base

Name	**Acid**	**Base**
Arrhenius	Produces H^+	Produces OH^-
Bronstead	Donates H^+	Accepts H^+

STUDENTS NEED TO KNOW THESE

Strong Acid – completely ionizes in water HCl HNO_3 H_2SO_4 **[5-June-08]**

Weak Acid – partly ionizes in water, a weak electrolyte HCN HF

Strong Base – exists in water entirely as ions, one of which is OH NaOH

Weak Base – partially ionizes in water, weak electrolyte NH_3 NH_4OH

Common Strong	**Acids**	**Base**
	$HClO_4$	LiOH
	H_2SO_4	NaOH
	HI	KOH
	HBr	$Ca(OH)_2$
	HCl	$Sr(OH)_2$
	HNO_3	$Ba(OH)_2$

Neutralization Reaction: reaction of an acid and a base that results in an ionic compound and possibly water. The ionic compound produced is called a **salt**

$2\ HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2\ H_2O$

$HCN + KOH \rightarrow KCN + H_2O$

Write Molecular, Ionic and Net Ionic

Water product exception is H_2SO_4 and $NH_3 \rightarrow (NH_4)_2SO_4$ Do Net Ionic

Example 4.5
Write all equation for the Neutralization of Nitrous Acid HNO_2 and Sodium Hydroxide. Show H+ Xfer

Polyprotic Acid is an acid that yields two or more acidic hydrogen's per molecule

$H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

$H_3PO_4 + 2\ NaOH \rightarrow Na_2HPO_4 + 2\ H_2O$

$H_3PO_4 + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$

Exercise 4.6

Write Mole, Ionic and Net ionic for successive neutralization of Sulfuric Acid and Potassium Hydroxide

<u>Acid Base reactions with Gas Formation</u>

$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2CO_3 \rightarrow H_2O + CO_2$

Carbonic Acid

Reaction of a carbonate and an acid to yield a gas is a test for carbonate minerals.
Sulfites behave the same as carbonates

Write the NET IONIC equation for the above reaction?

Sodium Sulfite acid sulfur dioxide

$Na_2SO_3 + HCl \rightarrow SO_2 + NaCl + H_2O$

Sodium Sulfide

$Na_2S + HCl \rightarrow H_2S + Na_2SO_4$

$ZnS + HCl \rightarrow ?$

Generalize Formula

$MOH \rightarrow M^+ + OH^-$ in water

$HA + H2O \rightarrow H_3O^+ + A^-$

$H_2A + 2\ H_2O \rightarrow H_3O^+ + HA^-$

Ionic – Table 4.4 Ionic Compounds that Evolve Gas with an Acid

$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H2O + CO_2$ $\quad CO_3^{-2} \rightarrow CO_2$

$Na_2SO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2O + SO_2$ $\quad SO_3^{-2} \rightarrow SO_2$

$Na_2S + H_2SO_4 \rightarrow Na_2SO_4 + H_2S$ $\quad S^{-2} \rightarrow H_2S$

<u>3. Oxidation Reduction Reactions [Redox]</u> are reactions that involve transfer of electrons form one species to another or in which the oxidation number changes.

An Iron nail in Copper (II) Sulfate: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

The Net Ionic is

$Fe + Cu^{+2} \rightarrow Fe^{+2} + Cu$

$Fe^0 \rightarrow Fe^{+2} + 2\ e^-$

$Cu^{+2} + 2\ e^- \rightarrow Cu^0$

Oxidation Number is the actual charge of the atom if it exists as a monoatomic ion – or hypothetical charge.
The Oxidation Number: **Rules 4 Assigning Oxidation Numbers – Table 4.5**

1. an atom / element is ZERO. Na = Metallic Sodium = 0
2. of an atom that exists in a compound as a monoatomic ion equals the charge on that ion.
   NaCl Na = +1, Cl = -1
3. Oxygen in a compound has an Oxidation Number of -2. e.g. In SO_2, O = -2 each, S = +4
   Exception is H_2O_2 where H = +1 and O = -1 each
4. Hydrogen in a compound has an Oxidation Number of +1
   Exception is when combined with a metal to form a Hydride NaH Na = +1, H = -1
5. Halogens in a compound have an Oxidation Number of -1.
   Except when combined with a halogen above it in the PT. [Never saw one yet thought!]
   Or when combine with Oxygen.
6. The sum of the Oxidation Numbers in a compound is ZERO.
   The sum of the Oxidation Numbers in a polyatomic ion equals it's charge.

Oxidation Numbers > +6 or < -4 are probably in error.

	2 Ca	+	O_2	→	2 CaO		**Calcium is Oxidized**
Ox Number	0		0		+2 -2		**Oxygen is Reduced**

Calcium goes from an Oxidation Number of 0 to +2
Oxygen goes from an Oxidation Number of 0 to -2

Problem: Determine the Oxidation Number of Chlorine in:

A. Perchloric Acid	$HClO_4$	H = +1, O = 4 * -2	Cl = +7
B. Chlorate Ion	ClO_3^-	O = 3 * -2, Net Charge = -1	Cl = +5

Half Reactions is one of the two parts of a Redox Reaction.
One part has loss of e- or gain of oxidation number, one gain of e- or decrease of oxidation number.

An Iron nail in Copper (II) Sulfate:	Fe	+	$CuSO_4$	→	$FeSO_4$	+	Cu		
The Net Ionic is	Fe	+	Cu^{+2}	→	Fe^{+2}	+	Cu		
OXIDATION	Fe^0			→	Fe^{+2}	+	$2\ e^-$	**electrons lost by Fe**	
REDUCTION	Cu^{+2}	+	$2\ e^-$	→	Cu^0			**gained by Cu**	

Oxidation is a **LOSS OF ELECTRONS.** **Reduction** is a **GAIN OF ELECTRONS**

Oxidation Agent – a compound that oxidizes another compound

Reducing Agent – a compound that reduces another compound

	|<-	**Oxidation**		**->|**		
Fe	+	Cu^{+2}	→	Fe^{+2}	+	Cu
		|<-	**Reduction**			**->|**

Common Oxidation – Reduction Reactions

1. Combination
2. Decomposition
3. Displacement
4. Combustion

1. Combination Reaction is one in which two substances combine to form a third compound

$2\ Na + Cl_2 \rightarrow 2\ NaCl$	Sodium and Chlorine
$2\ Sb + 3\ Cl_2 \rightarrow 2\ SbCl_3$	Antimony and Chlorine
$CaO + SO_2 \rightarrow CaSO_3$	There is no change in Oxidation Numbers But this is still a Combination Reaction

2. Decomposition Reaction is one in which a single compound reacts to give two or more substances. Check Oxidation Number to see if they are Redox – some are not!

$2\ HgO \xrightarrow{Heat} 2\ Hg + O_2$	Heat Mercury (II) Oxide
$2\ KClO_3 \xrightarrow[MnO_2\ Cat]{Heat} 2\ KCl + 3\ O_2$	Heat Potassium Chlorate with MnO2 Cat Redox
$CaCO_3 \xrightarrow{Heat} CaO + CO_2$	Head Calcium Carbonate not Redox

3. Displacement or Single Displacement is were an Element reacts with Compound, displacing an element from the compound. If an element is involved, the reaction is a Redox.

$Cu + 2\ AgNo_3 \rightarrow Cu(NO_3)_2 + 2\ Ag$

$Cu + 2\ Ag+ \rightarrow Cu^{+2} + 2\ Ag$	Net Ionic shows electron transfer
$Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$	Zinc and HCl yields Hyrdorgen Gas
$Zn + 2\ H^+ \rightarrow Zn^{+2} + H_2$	Net Ionic

Activity Series of the Elements [Table 4.6]

Li > K > Ba > Ca > Na >	Reacts violently with water to give H_2
Mg > Al > Zn > Cr > Fe > Cd >	Reacts slowly with water to give H_2
Co > Ni > Sn > Pb	
H2 > Cu > Hg > Ag > Au	Do not react with acids to give H_2

4. Combustion Reactions a substance reacts with oxygen usually with the rapid release of heat to produce a flame. Butane

$2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$ + Heat

$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$ Metals burn in air, iron rusts in oxygen

Balancing Redox Equations

1st Glance $Zn + Ag+ \rightarrow Zn^{+2} + Ag$

But the charge is not balanced. Do it by Half Reactions

ON 0 +1 +2 0

$Zn + Ag^{+} \rightarrow Zn+2 + Ag$

$Zn \rightarrow Zn^{+2} + 2e^{-}$ Oxidation

$Ag^{+} + 1\ e^{-} \rightarrow Ag$ Reduction

Balance the electrons

$Zn \rightarrow Zn^{+2}\ 2e^{-}$ Oxidation

$2\ Ag^{+} + 2\ e^{-} \rightarrow 2\ Ag$ Reduction

$Zn + 2\ Ag^{+} \rightarrow 2\ Ag + Zn^{+2}$ **BALANCE ELECTRONS**

0 0 +2 -3

$Mg + N2 \rightarrow Mg_3N_2$ Magnesium metal and Nitrogen Gas react

$Mg \rightarrow Mg^{+2} + 2\ e^{-}$ Oxidation – Need 3 of these

$N_2 + 6\ e^{-} \rightarrow 2\ N^{-3}$ Reduction

$3\ Mg + N_2 \rightarrow 3\ Mg^{+2} + 2\ N^{-3}$ [+ / - 6 e^{-}] **BALANCE ELECTRONS**

Molar Concentrations

Molar Concentration or **Molarity [M]** is the number of moles of solute dissolved in one liter of solution

Molarity = M = Moles of Solute / Liters of Solution **M = g /Mw / Liter**

0.15 M NH_3 contains 0.15 Moles of NH_3 per liter Show calculation of Mw

Problems: 0.38 g of $NaNO_3$ is added to 50.0 ml of water. What is the molarity? = 0.089 M

0.0678 g of NaCl is added to 25.0 ml of water. What is the molarity?

An experiment call for using 0.184 g of NaOH. How many mls of 0.150M NaOH will be needed? 30.7 mL

How many ml of 0.163 M NaCl is needed to give 0.0958 g of NaCl?

How many moles and grams of NaCl is need to be put in a 50.0 mL flask to give 0.15 M.

Diluting Solutions $\mathbf{Moles^1 * Volume^1 = Moles^2 * Volume^2}$ **[5-June-08]**

28.0 % NH_3 is 1.48 M in NH_3. Want 100 ml of 1.00 M NH_3.

$Volume^1 = Moles^2 * Volume^2 / Moles^1$ = 1.00 M x 100 mL / 14.8 M = 6.76 mL

Quantitative Analysis is the determination of the amount of a substance or species present in a material

Gravimetric Analysis is a type of Quantitative Analysis where the amount of a species in a material is determined by converting the species to a product that can be isolated and weighted [form a precipitate]. For Gravimetric Analysis, **a precipitate is usually generated and weighed** and then the amount of starting material is determined.

Lead in drinking water.

Na_2SO_4 + $Pb(NO_3)_2$ → 2 $NaNO_3$ + $PbSO_4$ ppt separate by filtration

Pb = 207.2 g/M 303.26 g/M

1.000 L of water was reacted with Xcs Sodium Sulfate. The mass of Lead (II) Sulfate was 229.8 mg. What is the concentration of Lead in the water?

Pb = 207.2 g/M Lead in Lead Sulfate = 207.2 g/M / 303.26 g/M * 100% = 68.32 %

1.000 L contains 68.32 % * 229.8 mg $PbSO_4$ = 157.0 mg of Pb

Volumetric Analysis is a method of analysis based on **Titration**

Titration is a procedure for determining the amount of Substance A by adding a carefully measured volume of a solution with known concentration of B until the reaction of A and B is JUST COMPLETE.

NaOH + HCl → NaOH + H_2O + Phenolphthalein Indicator,
4.47 ml of. How much HCl in grams it's Pink in Basic solution
0.207 M NaOH

[5-June-08]

Molarity = Moles / Volume **Therefore: Moles = Volume * Molarity**

Moles of NaOH = Moles of HCl

	Volume in L		**Molarity**			
1 Liter	* 4,47 ml	*	0.207 M NaOH	* 36.5 g HCl	* 1 M HCl	= **0.0338 g**
1000 ml	1 Liter		1 M	1 M HCl	1 M NaOH	

Problem: 5.00 g of Vinegar is titrated with 39.1 ml 0.108 M NaOH. What is the Mass % of acetic acid – $HC_2H_3O_2$ in the vinegar

[5-June-08

5.00 g 39.1 ml 0.180 M
$HC_2H_3O_2$ + NaOH → $NaC_2H_3O_2$ + H_2O
60.0526 g/mol 39.9971 g/mol

$$0.0391 \text{ L NaOH} * \frac{0.108 \text{ M NaOH}}{1 \text{ L}} * \frac{1 \text{ mole } HC_2H_3O_2}{1 \text{ mole NaOH}} * \frac{60.05 \text{ g } HC_2H_3O_2}{1 \text{ mol } HC_2H_3O_2} = 0.254 \text{ g } HC_2H_3O_2$$

Mass Percent of acedic acid in the vinegar = 100 % * 0.254 g $HC_2H_3O_2$ / 5.00 g vinegar = 5.07 %

Book 8th ed Homework do p 169, problem 477

Practice Questions:

Review Questions **p 165**
4.2 4.3 4.5 4.9 4.10 4.11
Conceptual Problems **p 165 - 166**
4.15 4.18 4.21
Practice Problems **p 166 - …**
Solubility 4.23 4.24
Ionic Equations 4.27
Precipitation 4.31
Strong / Weak Acids / Bases 4.35 4.36
Neutralization 4.37 4.41
Reactions Evolving a Gas 4.45
Oxidation Numbers 4.49 4.51 4.53
Balancing Redox 4.59
Molarity 4.61 4.63 4.65 4.73
Gravimetric 4.77 4.78 [Calculation of Mass Percent will not be on a test, but calculation of the amount of a starting material from the amount of a ppt will be]
Volumetric Analysis 4.83 4.85
General Problems 4.89 4.99 4.101 4.105 4.109
Cumulative Skills 4.121 4.127 4.129 4.139