SYNTHESIS RXNS:

- Look for UNCOMBINED elements; combine them!
- Just make sure that you give each element in the product compound a sensible oxidation number.
- Oxide formation falls under this category! (ch 8)

EX:
- A piece of barium is placed in oxygen gas.
  $Ba + O_2 \rightarrow BaO$

* *Every element, whether metal or nonmetal, can form an oxide if reacted with oxygen or air!*

- A piece of solid sodium is placed in hydrogen gas.
  $Na + H_2 \rightarrow NaH$

- Solid magnesium is heated in nitrogen gas.
  $Mg + N_2 \rightarrow Mg_3N_2$

DECOMPOSITION RXNS:

- Look for just ONE reactant and break it apart.
- Common gases and simple salts are very stable and are, hence, very common decomposition products.

EX:
- Solid calcium carbonate is heated.
  $CaCO_3 \rightarrow CaO + CO_2$

* *Carbonates always decompose into the metal oxide and CO_2!!*

- A sample of solid ammonium carbonate is heated.
  $(NH_4)_2CO_3 \rightarrow NH_3 + CO_2 + H_2O$

* *You see? In decomposition rxns, COMMON substances are usually formed.*

* *It's called – MAKE AN EDUCATED GUESS!!*

- Solid calcium sulfite is heated in a vacuum.
  $CaSO_3 \rightarrow CaO + SO_2$

**** NOTICE, DECOMP & SYNTHESIS RXNS <u>DON'T</u> OCCUR IN AN AQ SOLN!! <u>NO</u> SEPARATING INTO IONS!!!!!!**

GAS FORMATION & REGULAR PRECIPITATION RXNS:

- Look for the combination of TWO compounds.
- For a reaction to occur, a PRECIPITATE or a GAS must be produced.
- The following two tables should help you recognize and predict products.

Review of Solubility Rules

<u>SOLUBLE CMPDS</u>:

1. ALL alkali metals are soluble.
2. ALL ammonium salts (NH_4^+) are soluble.
3. ALL salts containing the nitrate (NO_3^-), chlorate (ClO_3^-), perchlorate (ClO_4^-), bicarbonate (HCO_3^-) and acetate (CH_3COO^-) ions are soluble.
4. Most chlorides (Cl^-), bromides (Br^-), and iodides (I^-) are soluble. *Exceptions*: cmpds containing Ag^+, Pb^{2+}, and Hg_2^{2+}(PMS).
5. Most sulfates (SO_4^{2-}) are soluble. *Exceptions:* sulfates of Pb, Hg, Ba, Sr. $CaSO_4$ and Ag_2SO_4 are slightly soluble. (PMS CaBaSr, not so soluble)

<u>INSOLUBLE CMPDS</u>:

1. Most metal oxides and hydroxides are insoluble. (Unless bonded with Alkali metals, Ba^{2+} and Sr^{2+}) *Exceptions:* CaO and $Ca(OH)_2$ are slightly soluble.
2. Most metal carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), sulfides (S^{2-}) are insoluble. (Unless bonded with soluble compounds 1-2 above).

Common Gases Formed

GAS	Formed by rxn of Acids with…	Equation for formation:
H_2S	Sulfides	$2H^+ + S^{2-} \rightarrow H_2S$ (g)
CO_2	Carbonates	$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$ (g)
	Bicarbonates	$H^+ + HCO_3^- \rightarrow H_2O + CO_2$ (g)
SO_2	Sulfites	$2H^+ + SO_3^{2-} \rightarrow H_2O + SO_2$ (g)
	Hydrogen Sulfites	$H^+ + HSO_2^- \rightarrow H_2O + SO_2$ (g)
HCN	Cyanides	$H^+ + CN^- \rightarrow HCN$ (g)

GAS	Formed by rxn of Bases with…	Equation for formation:
NH_3	Ammonium salts	$NH_4^+ + OH^- \rightarrow NH_3$ (g) + H_2O

EX:
- Solutions of cobalt (II) nitrate and sodium hydroxide are mixed.
  $Co^{2+} + OH^- \rightarrow Co(OH)_2$

- Sodium hydrogen sulfite is added to a vinegar soln.
  $NaHSO_{3-} + HCH_3COO \rightarrow H_2SO_3 + NaCH_3COO$
  $HSO_{3-}^- + HCH_3COO \rightarrow H_2O + SO_2 + CH_3COO^-$

- Ammonium nitrate is mixed with barium hydroxide.
  $NH_4NO_3 + Ba(OH)_2 \rightarrow NH_4OH + Ba(NO_3)_2$
  $NH_4^- + OH^- \rightarrow NH_3 + H_2O$

SINGLE REPLACEMENT RXNS:

- Look for an element reacting with a cmpd.
- Two different types:

1. **Metal Replacements** - a more reactive metal (in the free state) displaces a less reactive metal in a salt (ion form) or hydrogen from water or an acid

** *in the equation section, all reaction proceeds, so you don't have to worry too much about consulting the activity series.*

EX:
- A bar of zinc is immersed in a solution of silver nitrate.
  $Zn + Ag^+ \rightarrow Zn^{2+} + Ag$

- Iron filings are placed in a solution of iron (III) sulfate.
  $Fe + Fe^{3+} \rightarrow Fe^{2+}$
  * *A little bizarro! Differing oxidation states of iron are both changed to an intermediate state.*

> * *JUST WATCH YOUR CHARGES WITH SINGLE REPLACEMENT!! Free Metals <u>do</u> <u>not</u> have a charge!!*

<u>NOTE</u>: *The following* transition metals, **Cu, Ag, Pb, Au, and Pt**, are NOT REACTIVE ENOUGH to displace H from acids (or water). They undergo a fancy, *gas forming*, redox reactions with oxoacids:

Metal + Oxoacid → Metal ion + Oxide gas +

EX:
A piece of copper is immersed in <u>*dilute*</u> nitric acid.
$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO + H_2O$
* *NO_2 would have been produced in a concentrated soln.*

A piece of lead is placed in concentrated warm H_2SO_4.
$Pb + H^+ + HSO_4^- \rightarrow Pb^{2+} + SO_2\,(g) + H_2O$ *or*
$Pb + H^+ + SO_4^{2-} \rightarrow Pb^{2+} + SO_2\,(g) + H_2O$
* *not so picky about how you dissociate diprotic acids….*

2. **Nonmetal displacements** - a more reactive nonmetal in free state displaces a less reactive nonmetal in a compound.

EX:
- Bromine was added to a solution of potassium iodide.
  $Br_2 + I^- \rightarrow Br^- + I_2$

* *Halogen activity series: F>Cl>Br>I….this explains why you virtually never find pure, elemental fluorine!*

<u>REACTIONS THAT INVOLVE WATER</u>:

1. A pure metal or a metal hydride will react with water to produce a BASE and hydrogen gas.

- Just hydrogen displacement reactions!
- Hydrides react the same way free metals do! *Just accept it, man!!!*

EX:
- Sodium metal is added to distilled water.
  $Na + H_2O \rightarrow Na^+ + OH^- + H_2$

* *any of the alkali metals and most alkaline Earth metal would react the same!*
* *such metals are high enough on activity series to displace hydrogen from water.*

- Solid calcium hydride is added to water.
  $CaH_2 + H_2O \rightarrow Ca(OH)_2 + H_2$

* See! *Hydrides DO react just like the neutral metals!*

2. A metal oxide in water will produce a BASE.

Metal oxides are called BASIC ANHYDRIDES.
EX:
- Solid potassium oxide is added to water.
  $K_2O + H_2O \rightarrow K^+ + OH^-$

- Solid calcium oxide is added to distilled water.
  $CaO + H_2O \rightarrow Ca(OH)_2$ (strong, but not very soluble – Confused? Ask me!)

* *notice the role of solubility rules in the following two examples!*

3. A nonmetal oxide in water will produce an ACID.

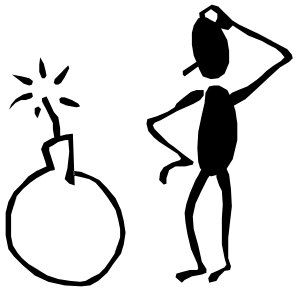
- Nonmetal oxides are called ACID ANHYDRIDES.
- As you hopefully remember from your notes, nonmetal oxides + water produce the common acids. YOU NEED TO KNOW THESE! Refer to your book and your notes!!!!

EX:
- Solid dinitrogen pentoxide is added to water.
  $N_2O_5 + H_2O \rightarrow H^+ + NO_3^-$

* *formation of nitric acid!*

- Carbon dioxide is bubbled through water.
  $CO_2 + H_2O \rightarrow H_2CO_3$

* *formation of carbonic acid.*
* *Notice how strong acid dissociate 100% and weak acids don't,*



<u>ACID-BASE REACTIONS</u>:

1. Acid + Base Neutralization

- Really just DOUBLE DISPLACEMENT RXNS.
- Always involves a proton transfer. Acid donates an H^+ to a base!

EX:
- Equal molar amounts of potassium hydroxide and hydrochloric acid are mixed.
  $KOH + HCl \rightarrow KCl + H_2O$
  $K^+ + OH^- + H^+ + Cl^- \rightarrow K^+ + Cl^- + H_2O$
  $\mathbf{H^+ + OH^- \rightarrow H_2O}$

* *Strong acid + strong base will <u>always</u> react this way.*
* *Just a double replacement…..*

- A soln of sodium hydroxide is added to a solution of acetic acid.
  $NaOH + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O$
  $Na^+ + OH^- + HC_2H_3O_2 \rightarrow Na^+ + C_2H_3O_2^- + H_2O$
  $OH^- + HC_2H_3O_2 \rightarrow C_2H_3O_2^- + H_2O$

* *Weak acid + strong base.*
* *Just a double replacement keeping in mind weak acids don't dissociate all the way.*

- Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed.
  $H_3PO_4 + OH^- \rightarrow H_2PO_4^- + H_2O$

* *Weak acid + strong base*
* *"Equimolar" means 1:1, So, in this case, only enough OH^- to neutralize ONE of H_3PO_4 acidic protons. "An excess" amount of KOH would offer enough OH^- to neutralize ALL of the H^+.....get it???*

- Solutions of ammonia and sulfuric acid are mixed.
  $NH_3 + H^+ \rightarrow NH_4^+$

* *Strong acid + weak base.*

- Solutions of ammonia and carbonic acid are mixed.
  $H_2CO_3 + NH_3 \rightarrow$???
  Remember…$NH_3 + H_2O \rightarrow NH_4OH$
  So it's really…
  $NH_4OH + H_2CO_3 \rightarrow H_2O + NH_4^+ + HCO_3^-$

* *Weak acid and weak base.*

2. Acid + Basic Salt Neutralization

EX:
- Excess hydrochloric acid is added to a solution of potassium sulfide.
  $H^+ + S^{2=} \rightarrow H_2S$

* *"excess" indicates that there is enough H^+ to form H_2S instead of just HS^-….seems logical, don't you think?*

3. Acid Anhydride + Base Neutralization:

- We did these reactions in class
- Reactions occur in TWO steps.
- Acid anhydrides will become acids in solution.
- This is as hard as Acid-Base rans can get!

EX:
- Carbon dioxide gas is bubbled through a potassium hydroxide solution.
  1. *What will carbon dioxide do in water?*
     $CO_2 + H_2O \rightarrow H_2CO_3$
  2. React acid with base like normal.
     $H_2CO_3 + KOH \rightarrow H_2O + KHCO_3$ (or K_2CO_3)
     $H_2CO_3 + OH^- \rightarrow H_2O + HCO_3^-$ (or CO_3^{2-})

- Carbon dioxide gas and ammonia gas are bubbled into distilled water.
  1. $CO_2 + H_2O \rightarrow H_2CO_3$
  2. $H_2CO_3 + NH_3 \rightarrow NH_4^+ + HCO_3^-$ (or CO_3^{2-})

4. Lewis Acid-Base Rxns

- Lewis Acid-Base reactions involve the transfer of a pair of e^-s.
- They result in the formation of a coordinate covalent bond.
- B and Al cmpds often act as LEWIS ACIDS b/c they are e^- deficient. N family cmpds often act as LEWIS BASES cuz they have a extra lone pair of e^- to donate.

EX:
- phosphine (phosphorus trihydride) gas is bubbled into liquid boron trichloride.
  $PH_3 + BCl_3 \rightarrow H_3P{:}BCl_3$

- The gases boron trifluoride and ammonia are mixed.
  $BF_3 + NH_3 \rightarrow F_3B{:}NH_3$

COMBUSTION RXNS:

- A cmpd reacting with oxygen (air).
- The cmpd is often a hydrocarbon.

EX:
- Ethane is burned in air.
  $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

- Carbon disulfide is burned in excess oxygen.
  $CS_2 + O_2 \rightarrow CO_2 + SO_2$

* *the word "excess" indicates that there is enough oxygen to form CO_2 rather than CO.*

***Note**: If you know a reaction is a combustion reaction but you are not sure of the formula for the reactant, just write the products which you know to be $CO_2 + H_2O$….*

OR, sometimes products will appear as . . .
$XO_2 + H_2O$

EX: Hydrogen sulfide is combusted in excess oxygen.

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$

Common Oxidizers

Oxidizer	**What it turns into:**
MnO_4^- acid soln	Mn^{2+}
MnO_2 acid soln	Mn^{2+}
MnO_4^- neut or basic soln	MnO_2
$Cr_2O_7^{2-}$ acid	Cr^{3+}
$Cr_2O_7^{2-}$ base	CrO_4^{2-}
HNO_3, conc.	NO_2
HNO_3, dilute	NO
H_2SO_4, hot, conc.	SO_2
Free Halogens	Halide ion
Na_2O_2	NaOH
$HClO_4$	Cl^-

FUNKY REDOX: *OIL-RIG (LEO SAYS GER)*

- If the reaction doesn't fit any of the above categories, Funky Redox is probably the call.
- Being familiar with the following lists of COMMON OXIDIZERS and COMMON REDUCERS will help
- you recognize funky redox rxns and predict products.
- JUST REMEMBER, ONE ATOM GETS OXIDIZED, AND ONE ATOM GET REDUCED!!

Common Reducers

Reducers	**What it turns into…**
Halide ions	Free halogen
Free Metals	Metal ions
Sulfite ions (or SO_2)	Sulfate ions
Nitrite ions	Nitrate ions
Free halogens, Br_2 (dil. Basic soln)	Hypohalite ions, BrO^-
Free halogen, Br_2 (conc. Basic soln)	Halate ions, BrO_3^-
Oxalate ion, $C_2O_4^{2-}$	CO_2
H_2O_2	O_2

EX:

- an acidified solution of potassium permanganate is added to a solution of sodium sulfite.
  $H^+ + MnO_4^- + SO_3^{2-} \rightarrow Mn^{2+} + SO_4^{2-} + H_2O$
  Oxidizing agent: MnO_4^- (Mn^{7+} to Mn^{2+})
  Reducing agent: SO_3^{2-} (S^{4+} to S^{6+})

- A solution of potassium permanganate is mixed with an alkaline solution of sodium nitrite.
  $MnO_4^- + OH^- + NO_2^- \rightarrow NO_3^- + H_2O + MnO_2$ (s)

* *Notice, the effect of being in an acidic vs basic soln!*

- A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.
  $Cl_2 + OH^- \rightarrow OCl^- + Cl^- + H2O$

* *This is an example of a disproportionation reaction!*

SUGGESTIONS:

- Try to figure out what type of soln – acidic, basic, or neutral – the redox reaction is taking place in.
- If acidic, add H^+; if basic, add OH^-
- Add a water molecule to the side *opposite* the H^+ or OH^- (usually the product side).

COMPLEX ION FORMATION:

- Transition metal ions commonly form complex ions with the following molecules or ions: NH_3, CN^-, I^-, Br^-, OH^-, SCN^- (thiocyanate ion), H_2O.
- How many molecules or ions that will bond to the metal is twice that of the metal's charge.
- These rxns are sort a like a single replacement rxn. A molecule or ion replaces another molecule or ion on the transition metal. Note this as you look at the examples!

EX:

- Excess sodium cyanide solution is added to a solution of silver nitrate.
  $CN^- + Ag^+ \rightarrow Ag(CN)_2^-$

* *Notice, a CHARGED ion does affect the charge of the transition metal.*

- Excess concentrated ammonia solution is added to a suspension of silver chloride.
  $AgCl + NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^=$

* *A neutral molecule, such as NH_3, has no affect on the charge of the metal or the resulting complex ion's charge.*

- A concentrated solution of ammonia is added to a solution of zinc iodide.
- $Zn^{2+} + NH_3 \rightarrow [Zn(NH_3)_4]^{2+}$

ORGANIC:

- We will not have much time in class to focus on organic at all. You will come across some organic rxns for sure but only a very small percentage.
- A lot of organic is just memorization and proper naming of HYDROCARBONS.

Naming of Hydrocarbons Summary

ALKANES

Hydrocarbons that contain only single bonds. Known as SATURATED hydrocarbons.

Alkane (C_nH_{2n+2})	**Formula**
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Pentane	C_5H_{12}

ALKENES

Hydrocarbons that contain double bonds. Known as UNSATURATED hydrocarbons.

Alkene (C_nH_{2n})	**Formula**
Ethylene	C_2H_4
Propene (propylene)	C_3H_6

Naming of Hydrocarbons Summary Cont.

ALKYNES

Hydrocarbons that contain triple bonds. Considered Unsaturated hydrocarbons as well.

Alkyne (C_nH_{2n-2})	**Formula**
Ethyne (acetylene)	C_2H_2
Propyne	C_3H_4

ALCOHOLS

Alcohols are hydrocarbons where one of the hydrogens has been replaced by a hydroxyl group (-OH).

Alcohol	**Formula**
Methanol	CH_3OH
Ethanol	C_2H_5OH
Propanol	C_3H_7OH

* *Hopefully, you are starting to get a feel for the PREFIXES that are used. 1 C = Meth-; 2 C's = Eth-; 3 C's = Prop-; 4 C's = But-; 5 C's = Pent-; 6 C's =Hex-; 7 C's = Hept; 8 C's = Oct*

* As for reactivity, combustion of such organic cmpds are very common.

YOU ARE ALL WINNERS. . . The End!!!

P.S. PLEASE DO NOT FORGET TO ACTUALLY USE THIS HANDOUT!