Name: _____ Date: _____ **Class Notes**
Chemistry

Predicting Reactions

In order to successfully predict reactions, you need to know the following:

- Nomenclature
- Types of Reactions
- Solubility Rules
- How to write net ionic equations

Rules for Reaction Prediction:

1. Always write balanced net ionic equations (based on solubility rules),
2. Metals are insoluble and written as solids (s) in equations.
3. Gases such as CO_2 or H_2S are written as gases (g) and will not dissociate into ions.
4. Water is written as a liquid (l) and does not dissociate.
5. Ionic compounds may or may not dissociate depending on solubility rules.
6. Even a soluble ionic compound may NOT dissociate if it is in solid form.
7. Weak acids and bases partly dissociate or ionize and are written with a reversible arrow.
8. Remember H N O F Cl Br I are diatomic. Phosphorus is P_4 and Sulfur is S_8.
9. Remember the difference between Zn and Zn^{2+} and Cl_2 and 2 Cl^-.
10. Strong acids (HCl, HBr, HI, HNO_3, H_2SO_4) first dissociation only!), $HClO_4$ and $HClO_3$) and strong bases (Group 1 alkali metal hydroxide and Ca, Ba, Sr hydroxides from group 2) dissociate in aq. Solutions. Weak acids and bases are **NOT** dissociated in net ionic equations.

Types of Reactions:

I. Synthesis Reaction

A single compound is formed: $A + B \rightarrow C$

1. Metal + Nonmetal → Ionic Compound
   $Na(s) + Cl_2(g) \rightarrow 2NaCl(aq)$

2. Nonmetal + Nonmetal → Molecular Compound
   $S + O_2 \rightarrow SO_2$

3. Special Case: $2SO_2 + O_2 \rightarrow 2SO_3$

4. Metal Oxide + Water → Metal Hydroxide
   $Li_2O + H_2O \rightarrow 2\ LiOH$

5. Nonmetal Oxides + water → Acid
   $SO_2 + H_2O \rightarrow H_2SO_3$ $SO_3 + H_2O \rightarrow H_2SO_4$

6. Metal Oxide + CO_2 → Metal Carbonate
   $CaO + CO_2 \rightarrow CaCO_3$

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II. Decomposition Reaction

A <u>single</u> compound breaks down into <u>two or more</u> products: A → B + C

1. Binary Ionic Compound $\xrightarrow{\Delta}$ Metal + Nonmetal
   $2\ HgO \xrightarrow{\Delta} 2\ Hg + O_2$

2. Metal Hydrogen Carbonates $\xrightarrow{\Delta}$ Metal Carbonates and CO_2 and H_2O
   $2\ NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$

3. Metal Carbonate $\xrightarrow{\Delta}$ Metal Oxide + CO_2
   $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

4. Metal Chlorates $\xrightarrow{\Delta}$ Metal Chloride + Oxygen
   $2\ KClO_3 \xrightarrow{\Delta} 2KCl + 3\ O_2$

5. Special Cases: Unstable compounds, upon formation as products, decompose:

   a) $H_2SO_3 \rightarrow SO_2 + H_2O$
   b) $H_2CO_3 \rightarrow CO_2 + H_2O$
   c) $NH_4OH \rightarrow NH_3 + H_2O$

Decomposition of:

- Carbonates —> CO_2 + Oxide
- Chlorates —> chloride compound + O_2
- Ammonium carbonates —> NH_3+ H_2O + CO_2
- Binary compound —> Two elements
- Hydrogen peroxide —> H_2O + O_2
- Bicarbonates→ CO_2 + H_2O + metal carbonate

Practice Problems:

1. Ammonium carbonate is strongly heated.
2. Potassium Chlorate is strongly heated.
3. Sodium bicarbonate is strongly heated.

III Single Replacement Reactions

Single replacement reactions are always between an element and a compound. The products are also an element and a compound. Driving force: Element with higher order of reactivity or activity series.

Examples:

1. A + BC → AC + B (A and B are metals)
   $Fe + Pb(NO_3)_2 \rightarrow Fe(NO_3)_2 + Pb$ or $2Fe + 3Pb(NO_3)_2 \rightarrow 2Fe(NO_3)_3 + 3Pb$

2. D + EF → ED + F (D and F are halogens)
   $Cl_2 + 2KI \rightarrow 2KCl + I_2$

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3. Metal + Water → Hydroxide + Hydrogen *(if metal is higher than H in activity series)
   e.g. $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

4. Metal + Acid → Salt + Hydrogen
   e.g. $Ca + 2\ HCl \rightarrow CaCl_2 + H_2$

More examples:

Single replacement reactions are always redox reactions.

- "Solid zinc strips are added to a solution of copper(II) sulfate."

  You might write it like this: $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

On the AP test, all reactions must be written as net ionic equations. The words from the instructions are "Omit formulas for any ions or molecules that are unchanged by the reaction."

Therefore, this reaction becomes

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

- "Solid calcium is added to warm water."

  $$Ca + 2H_2O \rightarrow Ca^{2+} + 2OH^- + H_2$$

Practice Problems:

1. Solid calcium is added to hydrobromic acid solution.
2. Calcium is added to water.
3. Solid copper is added to a solution of silver nitrate.

.**IV. Double-Replacement Rxn:** exchange of positive ions between 2 *reacting* compounds

Driving force is formation of solid (precipitate), liquid (molecular compound like water), or gas.
Examples:

1. AB+ CD → AD + CB
   e.g. $K_2CO_3(aq) + BaCl_2(aq) \rightarrow 2KCl\ (aq) + BaCO_3\ (s)$

2. Metal Oxide + Acid → Salt + Water
   e.g. $Li_2O + 2\ HCl \rightarrow 2\ LiCl + H_2O$

3. Acid + Base → Salt + Water
   e.g. $HCl + NaOH \rightarrow NaCl + H_2O$

More examples:

A. Acid-Base reactions

- "Solutions of sodium fluoride and dilute hydrochloric acid are mixed."

  The reaction is obviously double replacement when written like this

  $$NaF + HCl \rightarrow NaCl + HF$$

  However, this reaction must be written as a net ionic equation where it looks like a combination reaction.

  $$F^- + H^+ \rightarrow HF$$

  Hydrolysis reactions are a form of acid-base reaction.

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- "Solid lithium hydride is added to water."

  $LiH + H_2O \rightarrow Li^+ + OH^- + H_2$

If E° for reduction of a metal ion is negative, the metal will produce hydrogen gas when mixed with acid.

- "A strip of zinc is added to a solution of 6.0-molar hydrobromic acid."

  $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$

Acid Bases

- Salts of weak acid + strong base are basic
- Salts of strong acid + strong base are neutral
- Salts of strong acid + weak base are acidic
- Salts of weak acid + weak base can be acidic, basic or neutral depending on Ka and Kb (which ever is greater)

Sample Problems:

1. A solution of lead nitrate is mixed with potassium sulfate.
2. Equal volumes of 0.1 M sodium phosphate is added to hydrochloric acid.
3. Ammonia reacts with acetic acid solution.

B. Precipitation reactions

Know the solubility rules!

- "Hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate."

The reaction can be seen as double replacement when written like this

$H_2S + Pb(NO_3)_2 \rightarrow PbS + 2HNO_3$

However, the net ionic equation is

$H_2S + Pb^{2+} \rightarrow PbS + 2H^+$

- "Solutions of silver nitrate and sodium chromate are mixed."

  $2Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4$

Na^+ and NO_3^- are not shown in the net ionic equation.

V. Combustion Rxn: Element or compound is heated and reacts with Oxygen.; $A + O_2 \rightarrow BC$

Examples:

1. Nonmetal + Oxygen $\rightarrow$ Nonmetal Oxide
   e.g. $S + O_2 \rightarrow SO_2$

1. Metal + Oxygen $\rightarrow$ Metal Oxide

   e.g. $2Mg + O_2 \rightarrow 2\ MgO$

2. Hydrocarbon $C_xH_y + O_2 \rightarrow CO_2 + H_2O$ for complete combustion
   e.g. $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

3. Carbohydrate, alcohols $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$ for complete combustion

   e.g. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

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VI. Redox reactions

Most reactions involving permanganate, dichromate, or chromate are redox reactions.

Examples:

- "A solution of tin(II) chloride is added to an acidified solution of potassium permanganate."

  $5Sn^{2+} + 16H^{+} + 2MnO_4^{-} \rightarrow 5Sn^{4+} + 2Mn^{2+} + 8H_2O$

- "Solid sodium dichromate is added to an acidified solution of sodium iodide."

  $Na_2Cr_2O_7 + 14H^{+} + 6I^{-} \rightarrow 2Na^{+} + 2Cr^{3+} + 7H_2O + 3I_2$

MnO_4^{-} in acidic solution	Mn^{2+}
MnO_2 in acidic solution	Mn^{2+}
$MnO4^{-}$ in neutral or basic solution	MnO_2
$Cr_2O_7^{-}$ in acidic solution	Cr^{3+}
HNO_3 concentrated	NO_2
H_2O_2	O_2, H_2O

VII. Complex ions

Transition metal ions and Al^{3+} combine with ligands to completely surround the metal ion. Often you will see NH_3, OH^{-}, Cl^{-}, SCN^{-}, or CN^{-}, and these will be in excess.

Examples:

- "An excess of ammonia gas is bubbled through a solution saturated with silver chloride."

  $Ag^{+} + 2NH_3 \rightarrow Ag(NH_3)_2^{+}$

When forming complex ions, you will often add double the number of ligands than the oxidation state of the metal.

- "Concentrated (15M) ammonia solution is added in excess to a solution of copper(II) nitrate."

  $Cu^{2+} + 4NH_3 \rightarrow Cu(NH_3)_4^{2+}$

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