NS H4 (pg 1 of 2) **Single Replacement Reactions** Name_____Per___

In a single replacement reaction one lone element replaces another element in a compound.

SR Reaction Written Using Generic Symbols:

$AX + B \rightarrow BX + A$ (for replacement of hydrogen: $HX + B \rightarrow BX + H_2$)

perhaps it would be helpful to show the charges of ions that carry a charge

$A^+X^- + B \rightarrow B^+X^- + A$ (for replacement of hydrogen: $H^+X^- + B \rightarrow B^+X^- + H_2$)

Metal B (which has no charge in element form) replaces metal A (a positive ion in the compound AX) to form a new compound BX and atoms of element A (which has no charge). Remember that in this type of single replacement reaction, A and B are both metals that form cations, positively-charged ions when combined with X which is a nonmetal and has formed an anion, a negatively-charged ion. When A and B are alone or uncombined they are atoms as an element and have NO charge.

Steps to Follow to Successfully Write SR Reactions that Occur in Solution:

Typically, you will be given the reactants and asked to predict the products.

A For the replacement to occur, the <u>reactant compound (AX) must be soluble</u> which allows the compound to separate into parts and therefore allows the "switcheroo" to take place.

B For the replacement to occur the <u>reacting lone element must be "more active"</u> than the cation that is being replaced out of the compound. (If it is hydrogen that is being replaced, pay attention to whether the hydrogen is in water or an acid.) Determining if the reacting element is more active than the cation in the compound can be accomplished by looking at the Activity Series. If the elemental reactant is less active than "who" is being replaced, the replacement cannot occur - write NR for no reaction.

C If steps A + B allow a reaction to occur, write the names for all the substances that are formed.
- Write formulas and set the subscripts in the reactant and product compounds.
  - Remember the subscripts of ionic compounds are a result of the criss-cross of the charges on each ion which is a result of electrons lost and gained.
  - Remember that subscripts should not be used to balance an equation.
  - Remember that any hydrogen gas formed is diatomic.
- Also note that when H is replaced from water, the remaining negative ion is OH^- (not O^{2-}).

D After the subscripts are set forming the skeleton equation, balance the equation.

E Turn the balanced equation into a net ionic equation. Aqueous ions that are in the <u>same form</u> on both sides of the equation are called spectator ions and should be removed.

It is not always metals (or hydrogen) that are doing the replacing:

The Halogens can get in on the action too.

There is a second type of single replacement reaction in which the anion (negative ion) is replaced from the compound. This type of reaction will only be done for compounds involving the halogens (The second last column of elements: F, Cl, Br, I, At). One anion replaces another. Written using generic symbols, the reaction is:

$Y_2 + A^+Z^- \rightarrow A^+Y^- + Z_2$

- Element Y (a halogen) will replace Z (a less active halogen in the compound AZ) to form a new compound AY and the free element Z. Remember that Y and Z have no charge when they are free elements, but they are both anions when combined with A (a cation).
- There is no need for a separate activity series because the order in the periodic chart will serve as the activity series – the higher on the chart, then the more active the halogen.
- The solubility of the reactant compound does not matter since the halogen will be used in either gas or liquid form and therefore can react directly with the solid, liquid, or gaseous compound.

Sample Problems: Determine if a reaction can occur, and if it does, write a balanced chemical equation. *(Answers on pg 2)*

1. nickel (II) sulfide is combined with magnesium

2. magnesium chloride is combined with cobalt

3. nickel (III) chloride is combined with magnesium

4. magnesium is combined with aqueous *strong* hydrochloric acid

5. calcium is dropped into water

6. chlorine gas is bubbled through aqueous *strong* hydrogen bromide

Sample Problems - *ANSWERS*: Determine if a reaction can occur, and if a reaction does occur, write a balanced chemical equation. Then turn the equation into a net ionic equation.

1. nickel (II) sulfide is combined with magnesium
   a. Remember to check solubility of the compound first. No reaction occurs because nickel sulfide is insoluble and if the nickel and sulfide can't separate then no replacement can occur.

2. magnesium chloride is combined with cobalt
   a. magnesium chloride is soluble
   b. Using the activity series cobalt is below magnesium, it is less active and therefore can not replace magnesium.

3. nickel (III) chloride is combined with magnesium
   a. Nickel chloride is soluble. No need to consider the solubility of the metal.
   b. Check the activity series to see if the magnesium is more active than the nickel. It is, so a reaction can occur.
   c. $NiCl_{3(aq)} + Mg_{(s)} \rightarrow Ni_{(s)} + MgCl_2$ this is the unbalanced skeleton equation.
   d. Balance: $2\ NiCl_{3(aq)} + 3\ Mg_{(s)} \rightarrow 2\ Ni_{(s)} + 3\ MgCl_{2(aq)}$
   e. Net ionic: $2\ Ni^{3+} + 3\ Mg \rightarrow 2\ Ni + 3\ Mg^{2+}$

4. magnesium is combined with aqueous *strong* hydrochloric acid
   a. the word "aqueous" tells you that the hydrochloric acid is soluble.
   b. magnesium can replace hydrogen from an acid
   c. $Mg_{(s)} + HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$ *Be sure and note that the hydrogen must form diatomic molecules when it is replaced. Free hydrogen atoms cannot exist*
   d. Balance: $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$
   e. Net Ionic: $Mg + 2H^{+} \rightarrow Mg^{2+} + H_2$

5. calcium is dropped into water
   a. it is silly to even think about if water as aqueous – it's water.
   b. calcium is more active than hydrogen (even hydrogen in water)
   c. $Ca_{(s)} + H_2O \rightarrow Ca(OH)_2 + H_{2(g)}$
   d. Balance: $Ca_{(s)} + 2\ H_2O \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$ *Calcium hydroxide is not so soluble so it can be written as a solid.*
   e. Net ionic: $Ca_{(s)} + 2\ H_2O \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$ *The net ionic equation is the same as the complete equation because no particle is in the same form on both sides of the reaction.*

Halogen Replacement – We will NOT write net ionic equations for these halogen replacement reactions. The halogen that is replacing is more likely to come in as a gas.

Net ionic equations are only written for reactions that occur in solution.

6. chlorine gas is bubbled through aqueous *strong* hydrogen bromide
   a. In this reaction it is the halogens that will exchange places. Because the reacting diatomic halogen will usually be liquid or gas, it can react directly with the compound in whatever form the compound comes in: solid, liquid, aqueous or gas. Thus it is not necessary to concern yourself with the solubility of the reacting compound.
   b. chlorine is more reactive than bromine.
      The halogens are more reactive as you proceed up the periodic chart. (refer back to LAD G1)
   c. $Cl_{2(g)} + HBr_{(aq)} \rightarrow HCl_{(aq)} + Br_{2(L)}$
   d. Balance: $Cl_{2(g)} + 2\ HBr_{(aq)} \rightarrow 2\ HCl_{(aq)} + Br_{2(L)}$
   e. Net Ionic: $Cl_{2(g)} + 2\ Br^{-}_{(aq)} \rightarrow 2\ Cl^{-}_{(aq)} + Br_{2(l)}$