NS H3 (pg 1 of 2) **DR Reactions in Which Water is Formed** Name_____Per____

Acid / Base Neutralization

In Lab H1 we worked with double replacement reactions in which a solid is formed when two soluble ionic compounds react to form an insoluble ionic compound. There is a second type of double replacement reaction in which the reactants are an acid and a base and one of the products formed is water. The other compound formed is an ionic compound that is usually a soluble salt, although an insoluble salt can result.

As you may recall, acids are compounds which produce H^+ ions in solution. All acids have negative ions attached to hydrogen:
(All acids we work with will be soluble, seven are strong and the rest are weak, and all will be labeled as appropriate.)

HCl	hydrochloric acid (SA)	HNO_3	nitric acid (SA)	$HClO_4$	perchloric acid (SA)	H_2CO_3	carbonic acid (WA)
HBr	hydrobromic acid (SA)	H_2SO_4	sulfuric acid (SA)	H_2SO_3	sulfurous acid (WA)	$HC_2H_3O_2$	acetic acid (WA)
HI	hydroiodic acid (SA)	$HClO_4$	perchloric acid (SA)	H_3PO_4	phosphoric acid (WA)	H_3PO_3	phosphorous acid (WA)

All of the bases we work with will be *strong* bases as they are ionic compounds that produce OH^- ions when dissolved in water:

LiOH	lithium hydroxide	$Ca(OH)_2$	calcium hydroxide
NaOH	sodium hydroxide	$Sr(OH)_2$	strontium hydroxide
KOH	potassium hydroxide	$Ba(OH)_2$	barium hydroxide

Don't miss the note at the bottom about strong vs weak acids.

Use your solubility chart to notice that many compounds that contain OH^- are insoluble (except of course the alkali hydroxides). These insoluble hydroxide compounds would not be considered strong bases because since these insoluble hydroxide compounds do not dissolve very well at all, then they do not form many separated OH^- ions.
The heavier alkaline earth metal (Sr, Ba, Ra) hydroxides are soluble enough and will mostly dissolve in water.
You can react solid insoluble hydroxides with acid, the acid will be aggressive enough break apart the insoluble base.

The specific steps for writing and balancing double replacement reactions involving an acid and a base are exactly the same as precipitation reactions, but include one extra step − part 3b:

1. All of the reactant acids and bases we will work with in this first year course will be soluble (or at least mostly soluble.)
2. Determine the identity of the products by making the "switcheroo".
   a. Notice that acids reacting with bases will always make water, H_2O (or HOH)
   b. Also an ionic compound made of the negative ion from the acid and the positive ion from the base will be in solution.
3. Look up the solubility of the other ions. (Use the solubility reference chart.)
   a. These other ions may or may not be soluble. If the ions form an insoluble salt, label the compound as a $_{(ppt)}$ precipitate.
   b. Since one of the products is always water, which means a reaction does occur, proceed with the remainder of the steps.
4. Write a skeleton equation.
   a. Set the subscripts on the ionic compound as a result of the charges of the individual ions using the criss-cross method.
   b. As stated the other product is always HOH, water, H_2O.
5. Balance the skeleton equation changing only the coefficients out in front of the formulas.
6. Put on the appropriate physical state labels
   a. The acid and base can be labeled $_{(aq)}$ aqueous.
   b. If the ionic compound product is insoluble, use the label $_{(ppt)}$ precipitate. If the substance is soluble, label $_{(aq)}$ aqueous.
   c. Since water is molecular, label it $_{(L)}$ liquid.
7. Turn the overall reaction into a net ionic equation by eliminating spectator ions.
   a. If the ionic compound is soluble (as it usually will be) those ions can be eliminated for the net equation.
   b. Note that the net ionic equation of an *strong* acid-*strong* base reaction is always: $H^+ + OH^- \rightarrow H_2O$
   c. If a *weak* acid is involved, the *weak* acid must be written as a molecule to represent dissolved but not dissociated and thus no part of the weak acid will drop out of the net ionic equation.
   d. If the other ions formed an insoluble precipitate, then the precipitate would also be part of the net ionic equation.

Practice - *Use the steps above to avoid making mistakes. Know your strong and weak acids.*

1. A sodium hydroxide solution is combined with *strong* nitric acid solution.

2. A solution of soluble barium hydroxide is combined with *strong* hydrochloric acid solution

3. A solution of soluble strontium hydroxide is combined with *weak* carbonic acid solution

NOTE: *You will not find the acids on the solubility chart. At this point, we will consider ALL acids to be soluble. Strong acids not only dissolve, but they completely break apart in solution and must be written as separated ions in the net ionic equation, the weak acids will be soluble but do not break apart in solution and should be written as a molecule. Base added to acid will rip the H's off*

Reactions in Which Water is Formed
Strong Acids reacting with Strong Bases
Double Replacement Reactions

ANSWERS the steps suggested on the first page are referenced in the answers below.

1 1 sodium hydroxide is soluble, nitric acid (HNO_3) is soluble (all acids we work with will be soluble)

2 products: sodium nitrate + hydrogen hydroxide = water

3 even though sodium chloride is soluble, the formation of $H^+ \ OH^- = H_2O$ means that a reaction has occurred.

4 $Na^+ + OH^- + H^+ + NO_3^- \rightarrow Na^+ + NO_3^- + H^+ + OH^-$

$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

(no ppt is formed, but a reaction occurs because of the formation of the molecular compound, water)

5+6 $NaOH_{(aq)} + HNO_{3(aq)} \rightarrow NaNO_{3(aq)} + H_2O_{(L)}$

7 $OH^- + H^+ \rightarrow H_2O_{(L)}$

2 1 barium hydroxide is soluble (thus some does dissociate), hydrochloric acid (HCl) – all acids considered soluble

2 barium chloride + hydrogen hydroxide, which is water

3 barium chloride is soluble, $H^+ + OH^- = H_2O$ thus a reaction occurs since water is formed.

4 $Ba^{2+} + OH^- + H^+ + Cl^- \rightarrow Ba^{2+} + Cl^- + H^+ + OH^-$

$Ba(OH)_2 + HCl \rightarrow BaCl_2 + H_2O$

(no ppt is formed, but a reaction occurs because of the formation of the molecular compound − water)

5+6 $Ba(OH)_{2(aq)} + 2\ HCl_{(aq)} \rightarrow BaCl_{2(aq)} + 2\ H_2O_{(L)}$

7 $OH^- + H^+ \rightarrow H_2O_{(L)}$

3 1 strontium hydroxide − soluble, carbonic acid (H_2CO_3), all acids considered soluble, but not all ionize, carbonic acid is a weak acid.

2 strontium carbonate + hydrogen hydroxide = water

3 strontium carbonate − insoluble $_{(ppt)}$ and $H^+ \ OH^- = H_2O$ thus a reaction occurs

4 $Sr^{2+} + OH^- + 2\ H_2CO_3 \rightarrow Sr^{2+} + CO_3^{2-} + H^+ + OH^-$

$Sr(OH)_2 + H_2CO_3 \rightarrow SrCO_3 + H_2O$

5+6 $Sr(OH)_{2(aq)} + H_2CO_{3(aq)} \rightarrow SrCO_{3(ppt)} + 2\ H_2O_{(L)}$

(both water and a precipitate form)

7 The net ionic equation include ALL the components so it really is essentially the same.

$Sr(OH)_{2(aq)} + H_2CO_{3(aq)} \rightarrow SrCO_{3\ (ppt)} + 2\ H_2O_{(L)}$

You should show the strontium hydroxide as separated ions since it is soluble and is ionized, but carbonic acid is a weak acid and should be represented as a molecule not as separate ions.

$Sr^{2+} + 2\ OH^- + 2\ H_2CO_{3(aq)} \rightarrow SrCO_{3(ppt)} + 2\ H_2O_{(L)}$