NS G.2 (pg 1 of 2) Reactions in Which Water is Formed

Name________________________

Acid / Base Neutralization − Type of Double Replacement Reaction

In LAD G2and G2 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 and it is usually a soluble salt, although it is possible that it could be insoluble.

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.)*

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)

For now we will define bases as 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 if they do not dissolve very well at all, then they do not form any free OH^- ions.
The heavier alkaline earth metal (group 2A) hydroxides are slightly soluble and will partially dissolve in water. This allows them to react with an acid, because the action of the acid will cause the slightly soluble hydroxide to completely dissolve.

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 rule − 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 slightly 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
   b. and a salt, an ionic compound made of the negative ion from the acid and the positive ion from the base.
3. Look up the solubility of the salt, (the ionic compound) product. (Use the solubility reference chart)
   a. This salt (ionic compound) product may or may not be soluble. If it is an insoluble salt, label it as a $_{(ppt)}$ precipitate,
   b. *Since one of the products is always water, which means a reaction does occur, so proceed with the remainder of the steps.*
4. Make a skeleton equation by writing out the correct chemical formulas of both the reactants and the products
   a. Set the subscripts on the salt (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 salt (ionic compound) product is insoluble, label it $_{(ppt)}$ precipitate. If it is soluble, label it $_{(aq)}$ 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 salt (ionic compound) product is soluble (as it usually will be) those ions can be eliminated for the net equation.
   b. Note that the <u>net ionic equation</u> of an strong acid-strong base reaction is: $H^+ + OH^- \rightarrow H_2O$
   c. If a weak acid is involved, it must be written as a molecule with $_{(aq)}$ to represent dissolved but not so dissociated.
   d. If the other ions formed an insoluble precipitate, then it 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. sodium hydroxide is combined with nitric acid (strong acid).

2. barium hydroxide is combined with hydrochloric acid (strong acid).

3. strontium hydroxide is combined with carbonic acid (weak acid).

NOTE: You will not find the acids on the solubility chart. At this point, we will consider ALL acids to be soluble and seven of them are strong acids. Strong acids will not only dissolve, but they completely break apart in solution and must be written as separated ions in the net ionic equation, the rest of the acids are weak and should be written as a molecule.

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.

1 1 sodium hydroxide – soluble, nitric acid (HNO_3) − all acids considered soluble

2 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 – slightly soluble (thus some does dissociate), hydrochloric acid (HCl) – all acids considered soluble

2 barium chloride + hydrogen hydroxide = 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/could choose to show the strontium hydroxide as separated ions since it is soluble and it is ionized, but carbonic acid is a weak acid and should be represented as a molecule not as separate ions.

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