Chemical Reactions **Name**_____

Double Replacement Reactions

Read from Lesson 2 Classifying Chemical Reactions in the Chemistry Tutorial Section Chapter 8 of The Physics Classroom Part d: Double Replacement Reactions Part e: Predicting Products

Part 1: Double Replacement Reactions

In a double replacement reaction, the cations and anions of two different compounds switch places. The generic form of a double replacement reaction is AB + CD → AD + CB

There are two types of double replacement reactions:

1. Two soluble ionic compounds react to form an insoluble precipitate (s) and a soluble ionic compound (aq).
   e.g. $2\ Al(NO_3)_3(aq) + 3\ Na_2SO_4(aq) \rightarrow Al_2(SO_4)_3(s) + 6\ NaNO_3(aq)$
   AB + CD → AD + CB
2. An acid and a base react to form water (H_2O can be written as HOH) and a salt (an ionic compound).
   e.g. $HNO_3(aq) + NaOH(aq) \rightarrow HOH(l) + NaCl\ (aq)$
   AB + CD → AD + CB

All of the reactions mentioned above will take place, but not every possible reaction will actually occur. If all reactants and predicted products are soluble ionic compounds, meaning they are all aqueous, the reaction does not take place.

How to Determine If a Double Replacement Reaction Occurs:

1. Write out the reactants' formulae (if not given).
2. Determine the ions initially present in the solution. These are the ions that make up the two reactants.
3. Predict the formulae of the two possible products by swapping the cations of the reactants with different anions.
4. Apply solubility rules (listed on the left) to check if either of the products is insoluble. The insoluble product will precipitate as a solid, while the soluble one will be aqueous.
5. Write the skeleton equation using the reactant and product formulae, along with their states (aq or s).
6. Balance the equation by adding appropriate coefficients in front of the formulae.

Solubility Rules

Soluble compounds include ionic compounds containing …
1. … alkali metal ions (such as Na^+, K^+, etc.).
2. … the ammonium ion (NH_4^+).
3. … chloride, bromide, or iodide ions **EXCEPT** when paired with Ag^+, Pb^{2+}, or Hg_2^{2+} ions.
4. … nitrate, acetate, or chlorate ions **EXCEPT** $AgC_2H_3O_2$.
5. … the sulfate ion **EXCEPT** when paired with Pb^{2+}, Ca^{2+},Sr^{2+}, Ba^{2+}, or Ra^{2+} ions.

Insoluble compounds include ionic compounds containing …
6. … the sulfide ion **EXCEPT** when paired with alkali metal, alkaline earth metal, or ammonium ions.
7. … the hydroxide ion **EXCEPT** when paired with alkali metal, ammonium, or Sr^{2+}, or Ba^{2+} ions.
8. … phosphate, carbonate, or sulfite ions **EXCEPT** when paired with alkali metal or ammonium ions.

Example: A sodium sulfate solution is added to a solution of barium nitrate. Does this reaction occur?

1. Write out the reactants' formulae. $Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq)$
2. Identify the ions present in solution: Na^+, SO_4^{2-}, Ba^{2+}, NO_3^-
3. Predict the formulae of the two possible products by swapping the cations of the reactants with different anions: $NaNO_3$ and $BaSO_4$
4. Apply solubility rules: $NaNO_3$ is soluble and $BaSO_4$ is insoluble. Since there **is** an **insoluble** product, this reaction will occur!
5. Write the skeleton equation: $Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq) \rightarrow NaNO_3\ (aq) + BaSO_4(s)$
6. Balance the equation: $Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq) \rightarrow 2\ NaNO_3\ (aq) + BaSO_4(s)$

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This equation is called the "molecular" equation:

$$Na_2SO_4\ (aq) + Ba(NO_3)_2\ (aq) \rightarrow 2\ NaNO_3\ (aq) + BaSO_4(s)$$

If ions are shown as being dissociated – meaning that the soluble compounds are split into their ions as they would appear in solution … it would look like this:

Complete ionic equation:

$$2Na^+\ (aq) + SO_4^{2-}\ (aq) + Ba^{2+}\ (aq) + 2NO_3^-\ (aq) \rightarrow 2Na^+\ (aq) + 2NO_3^-\ (aq)\ + BaSO_4(s)$$

Notice how there are ions that are aqueous on both sides of the equation. A spectator ion is an ion that is aqueous on both sides of the arrow. The ion can be "canceled out" on both sides of the equation.
The resulting equation is called the "net ionic" equation.

$$\text{Net ionic equation: } SO_4^{2-}\ (aq) + Ba^{2+}\ (aq) \rightarrow BaSO_4(s)$$

Only the ions that are part of the precipitate are included in the net ionic equation. The spectator ions drop out.

This is the answer to what happens when a sodium sulfate solution is added to a solution of barium nitrate.
Answer: $SO_4^{2-}\ (aq) + Ba^{2+}\ (aq) \rightarrow BaSO_4(s)$

Part 2: Questions

1. Which of the following ionic compounds are soluble in water? Insoluble in water?

   $AgC_2H_3O_2$ KNO_3 $Fe(OH)_3$ $SrSO_4$ $Sn(ClO_3)_4$ $PbCl_4$ Na_2CO_3 AgI $FeSO_3$ NH_4F BaO $Zn_3(PO_4)_2$ Al_2S_3 Cs_2S

   Soluble compounds:

   Insoluble compounds:

2. Write the dissociation equations for each soluble compound listed in question 1.
   e.g. $Na_2SO_4\ (aq) \rightarrow 2Na^+\ (aq) + SO_4^{2-}\ (aq)$

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3. For the following reactions, write the molecular equation and the net ionic equation. If there is no reaction, state "NR" and don't bother with any of the equations.

   a. Aqueous solutions of sodium carbonate and calcium chloride are combined.

   b. Aqueous solutions of silver nitrate and potassium iodide are combined.

   c. Aqueous solutions of calcium chlorate and potassium sulfite are combined.

   d. Aqueous solutions of barium hydroxide and potassium phosphate are combined.

   e. Aqueous solutions of strontium bromide solution and rubidium sulfide are combined.

   f. Aqueous solutions of lead (II) nitrate and copper (II) sulfate are combined.

The next two reactions are the second type of double replacement reactions, acid-base reactions.

   g. Aqueous solutions of hydrochloric acid and ammonium hydroxide are combined.

   h. Aqueous solutions of phosphoric acid and strontium hydroxide are combined.