Reaction Types: Double Replacement

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Important notes to remember: (1) NONE of the equations are balanced!! and (2) make sure to write correct formulas. DO NOT just copy the subscripts from the reactants over into the products.

During double replacement, the cations and anions of two different compounds switch places.

Written using generic symbols, it is:

AB + XY ---> AY + XB

A and X are the cations (postively-charged ions) in this example, with B and Y being the anions (negatively-charged ions).

Here is another way to look at the above generic example:

a) the outside portions (the cation A and anion Y) combine to make a formula called AY.
b) The inside portions (the anion B and the cation X) switch order so that X (postively charged) goes first and B (negatively charged) goes second making a formula called XB.

Keep in mind that, when it comes to writing actual formulas, you MUST write chemically correct formulas. Please do not assume from the AY and XB examples that the product formulas will always be one-to-one in terms of positive and negative.

Some examples of actual reactions are:

$KOH + H_2SO_4 \rightarrow K_2SO_4 + H_2O$
$FeS + HCl \rightarrow FeCl_2 + H_2S$
$NaCl + H_2SO_4 \rightarrow Na_2SO_4 + HCl$
$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

Note that none of them are balanced yet.

These three are also examples of double replacement, but there is something special about them:

$CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$
$K_2SO_3 + HNO_3 \rightarrow KNO_3 + SO_2 + H_2O$
$NH_4Cl + NaOH \rightarrow NaCl + NH_3 + H_2O$

Notice how, one of the two product compounds decomposes. Whenever H_2CO_3, H_2SO_3, or NH_4OH is a product formula, the correct technique is to write the products as done in the examples. Don't forget that!!

In other words,

$CaCO_3 + HCl \text{ ---> } CaCl_2 + H_2CO_3$

is incorrect.

One additional comment on the above - a acid or a base is one of the two substances involved in the reactants. If no acid or base, the decomposition does not take place. See practice problem #6 for an example. There is another example in the 10 problems, but you'll have to figure out which one!!

In double replacement, both reactants are compounds, each with a cation part and an anion part. Diatomic elements do not count; they are included in the single replacement category.

Typically, you will be given the left-hand (reactant side) and asked to provide the products to the reaction. You need to be able to recognize double replacement reactions AND be able to break a formula apart into proper cations and anions as well as write correct formulas

Here are several examples which are solved below:

1) $Ca(OH)_2 + HCl \text{ --->}$
2) $Al(NO_3)_3 + H_2SO_4 \text{ --->}$
3) $Pb(NO_3)_2 + K_2S \text{ --->}$
4) $Pb(NO_3)_2 + CuSO_4 \text{ --->}$

Example #1

How to figure out the right (or product side):

(1) Identify the cations and anions in each compound:

$Ca(OH)_2$ has Ca^{2+} and OH^-
HCl has H^+ and Cl^-

All you have to do is identify each, you need not worry about amounts yet.

(2) Pair up each cation with the anion from the OTHER compound:

Ca^{2+} pairs with Cl^-
H^+ pairs with OH^-

(3) Write two new (CORRECT!!) formulas using the pairs from step two.

$CaCl_2$ since Ca is positive 2 and Cl is minus one
H_2O since H is plus one and OH is negative one

So the final answer looks like this:

$Ca(OH)_2 + HCl \text{ ---> } CaCl_2 + H_2O$

One warning - take a look at that word "CORRECT" just above. In these types of problems, many kids (that's you, most likely) tend to just pair up the cation and anion in a one-to-one ratio to get the formulas. In the example above, they would get CaCl (wrong!!) and H_2O (correct, but maybe just lucky!!). Be careful to write correct formulas.

Example #2

How to figure out the right (or product side):

(1) Identify the cations and anions in each compound:

$Al(NO_3)_3$ has Al^{3+} and NO_3^-
H_2SO_4 has H^+ and SO_4^{2-}

All you have to do is identify each, you need not worry about amounts yet.

(2) Pair up each cation with the anion from the OTHER compound:

Al^{3+} pairs with SO_4^{2-}
H^+ pairs with NO_3^-

(3) Write two new (CORRECT!!) formulas using the pairs from step two.

$Al_2(SO_4)_3$ since Al is positive 3 and sulfate is minus 2
HNO_3 since H is plus one and nitrate is negative one

So the final answer looks like this:

$Al(NO_3)_3 + H_2SO_4 \text{ ---> } Al_2(SO_4)_3 + HNO_3$

Make sure that you keep polyatomic ions together (except for the ones that decompose!!)

Example #3

How to figure out the right (or product side):

(1) Identify the cations and anions in each compound:

$Pb(NO_3)_2$ has Pb^{2+} and NO_3^-
K_2S has K^+ and S^{2-}

All you have to do is identify each, you need not worry about amounts yet.

(2) Pair up each cation with the anion from the OTHER compound:

Pb^{2+} pairs with S^{2-}
K^+ pairs with NO_3^-

(3) Write two new (CORRECT!!) formulas using the pairs from step two.

PbS since Pb is positive 2 and sulfide is minus 2
KNO_3 since K is plus one and nitrate is negative one

So the final answer looks like this:

$Pb(NO_3)_2 + K_2S \text{ ---> } PbS + KNO_3$

Example #4

How to figure out the right (or product side):

(1) Identify the cations and anions in each compound:

$Pb(NO_3)_2$ has Pb^{2+} and NO_3^-
$CuSO_4$ has Cu^{2+} and SO_4^{2-}

All you have to do is identify each, you need not worry about amounts yet.

(2) Pair up each cation with the anion from the OTHER compound:

Pb^{2+} pairs with SO_4^{2-}
Cu^{2+} pairs with NO_3^-

(3) Write two new (CORRECT!!) formulas using the pairs from step two.

$PbSO_4$ since Pb is positive 2 and sulfate is minus 2
$Cu(NO_3)_2$ since Cu is plus two and nitrate is negative one

So the final answer looks like this:

$Pb(NO_3)_2 + CuSO_4 \rightarrow PbSO_4 + Cu(NO_3)_2$

Practice Problems

Note that none of the example problems above are balanced. Your teacher may require this, but the ChemTeam will only provide some of the following answers balanced. The rest are up to you!!

Write correct formulas for the products in these double replacement reactions.

1) $Ca(OH)_2 + H_3PO_4 \rightarrow$

2) $K_2CO_3 + BaCl_2 \rightarrow$

3) $Cd_3(PO_4)_2 + (NH_4)_2S \rightarrow$

4) $Co(OH)_3 + HNO_3 \rightarrow$

5) $AgNO_3 + KCl \rightarrow$

6) $Na_2CO_3 + H_2SO_4 \rightarrow$

7) $Al(OH)_3 + HC_2H_3O_2 \rightarrow$

8) $Al_2(SO_4)_3 + Ca_3(PO_4)_2 \rightarrow$

9) $Cr_2(SO_3)_3 + H_2SO_4 \rightarrow$

10) $AgC_2H_3O_2 + K_2CrO_4$ --->

Just a reminder: you probably will not have the different reactions types identified on the test you eventually must take. So you face a two step process - identify the reaction type and then figure out the product formulas.

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