Double Replacement Reactions and their Net Ionic Equations

1. ***What is a Double Replacement (DR) reaction and how do you know when one has occurred?***
   A DR reaction in the most general sense involves combining two solutions each containing ions which results in the formation of a solid, a liquid, a gas, or a weak acid. Observing solid formation or gas formation when solutions are mixed is easy to spot. When liquids or weak acids are formed one can typically feel the reaction vessel getting warmer (exothermic) so heat evolution is the sign that a reaction has occurred (yes, sometimes it is endothermic but that still is evidence of a chemical reaction).

2. ***Predict products of a double replacement reaction (use the general solubility chart, Figure 7.3 on p. 172 in Zumdahl-DeCoste). Also know a variety of strong acids and weak acids and strong bases and weak bases (see #7 on guide to memorization).***

3. ***Method:***
   a. Write the balanced **conventional (molecular)** equation including state symbols.
   b. Write the balanced **total (complete) ionic** equation including state symbols.
   c. Write the balanced **net ionic** equation including state symbols.

   Note : Weak acids (aq) ***do not*** get separated into ions. Solids (s), liquids (l), and gases (g) **do not** get separated into ions. Balance both atoms and charge.

Example for a Double Replacement Precipitation (DR-PPT) reaction

Predict the products when aqueous solutions of potassium carbonate and silver nitrate are combined. Write the balanced conventional, total ionic, and net ionic equations for the reaction. Be sure to include state symbols.

$K_2CO_3(aq) + AgNO_3(aq)$ ----------> ?

Given ion pairs: K^+ & CO_3^{2-}, Ag^+ & NO_3^-
New ion pairs: K^+ & NO_3^-, Ag^+ & CO_3^{2-}

Using the crossing rule for the new ion pairs, the products are: KNO_3 & Ag_2CO_3

Now it is time to balance the **conventional** equation and predict the product states

$K_2CO_3(aq) + 2AgNO_3(aq)$ ----------> $2KNO_3(?) + Ag_2CO_3(?)$

The general solubility chart (Figure 9.13) indicates that all K^+ salts are soluble (aq) and all CO_3^{2-} salts are insoluble (s) with the exception of an alkali metal carbonate, i.e. K_2CO_3. If both products had been soluble one would write, no reaction or NR.

The balanced **conventional** equation with state symbols is:

$K_2CO_3(aq) + 2AgNO_3(aq)$ ----------> $2KNO_3(aq) + Ag_2CO_3$**(s)**

The balanced **total ionic** equation is:

$2K^+(aq) + CO_3^{2-}(aq) + 2Ag^+(aq) + 2NO_3^-(aq)$ ----------> $2K^+(aq) + 2NO_3^-(aq) + Ag_2CO_3$(**s**)

Remove spectator ions (ions that do not change state)

~~$2K^+(aq)$~~ $+ CO_3^{2-}(aq) + 2Ag^+(aq) +$ ~~$2NO_3^-(aq)$~~ ----------> ~~$2K^+(aq)$~~ + ~~$2NO_3^-(aq)$~~ $+ Ag_2CO_3$(**s**)

The balanced **net ionic** equation is:

$CO_3^{2-}(aq) + 2Ag^+(aq)$ ----------> **$Ag_2CO_3(s)$** evidence of a reaction: precipitate observed

Example for a Double Replacement Neutralization (DR-N) reaction

$KCH_3COO(aq) + HCl(aq)$ ----------> ?

$KCH_3COO(aq) + HCl(aq)$ ----------> $KCl(aq) + CH_3COOH(aq)$

strong acid weak acid

~~$K^+(aq)$~~ $+ CH_3COO^-(aq) + H^+(aq) +$ ~~$Cl^-(aq)$~~ ---------> ~~$K^+(aq)$~~ + ~~$Cl^-(aq)$~~ $+ CH_3COOH(aq)$

$CH_3COO^-(aq) + H^+(aq)$ ---------> **$CH_3COOH(aq)$** evidence of a reaction: exothermic

Example for a Double Replacement Neutralization (DR-N) reaction

$KOH(aq) + HCl(aq)$ ----------> ?

$KOH(aq) + HCl(aq)$ ----------> $KCl(aq) + H_2O$(**l**)

strong base strong acid salt water

~~$K^+(aq)$~~ $+ OH^-(aq) + H^+(aq) +$ ~~$Cl^-(aq)$~~ ---------> ~~$K^+(aq)$~~ + ~~$Cl^-(aq)$~~ $+ H_2O$(**l**)

$OH^-(aq) + H^+(aq)$ ---------> **$H_2O(l)$** evidence of a reaction: exothermic

Example for a Double Replacement Neutralization (DR-N) reaction

$K_2CO_3(aq) + HCl(aq)$ ----------> ?

$K_2CO_3(aq) + 2HCl(aq)$ ----------> $2KCl(aq) + H_2CO_3(aq)$ --------> $2KCl(aq) + H_2O$(**l**) + CO_2(**g**)

carbonate base strong acid weak acid, unstable salt water

~~$2K^+(aq)$~~ $+ CO_3^{2-}(aq) + 2H^+(aq) +$ ~~$2Cl^-(aq)$~~ ----------> ~~$2K^+(aq)$~~ + ~~$2Cl^-(aq)$~~ $+ H_2O$(**l**) $+ CO_2$(**g**)

$CO_3^{2-}(aq) + 2H^+(aq)$ ----------> **$H_2O(l) + CO_2(g)$** evidence of a reaction: gas evolution

Example for a Double Replacement Precipitation (DR-PPT) reaction

$CaCl_2$(**s**) + $FeSO_4$(aq) ----------> ?

$CaCl_2$(**s**) + $FeSO_4$(aq) ----------> $CaSO_4$(**s**) + $FeCl_2$(aq)

$CaCl_2$(**s**) + ~~Fe^{2+}(aq)~~ + SO_4^{2-}(aq) ----------> $CaSO_4$(**s**) + ~~Fe^{2+}(aq)~~ + $2Cl^-$(aq)

$CaCl_2$(s) + SO_4^{2-}(aq) ----------> **$CaSO_4$(s) + $2Cl^-$(aq)** evidence of a reaction: precipitate observed,

although it would be hard to distinguish from the initial solid, yet it can be done

Single Replacement Reactions and their Net Ionic Equations

A single replacement (SR) reaction an element becomes a compound and a compound becomes an element. SR reactions are always redox reactions. For predicting single replacement (SR) reactions use activity series table on web site.

Examples of **net ionic** single replacement equations:

Fe(**s**) + $Cu(NO_3)_2$(aq) ----------> ?

Fe is above Cu on the activity series table. Thus Fe solid will replace Cu in solution.

Fe(**s**) + $Cu(NO_3)_2$(aq) ----------> $Fe(NO_3)_2$(aq) + Cu(**s**)

Fe(**s**) + Cu^{2+}(aq) + ~~$2NO_3^-$(aq)~~ ----------> Fe^{2+}(aq) + ~~$2NO_3^-$(aq)~~ + Cu(**s**)

Fe(s) + Cu^{2+}(aq) ----------> **Fe^{2+}(aq) + Cu(s)**

Ni(**s**) + HCl(aq) ----------> ?

Ni is above H_2 on the activity series table. Thus Ni solid will replace H^+ in solution.

Ni(**s**) + 2HCl(aq) ----------> $NiCl_2$(aq) + H_2(**g**)

Ni(**s**) + $2H^+$(aq) + ~~$2Cl^-$(aq)~~ ----------> Ni^{2+}(aq) + ~~$2Cl^-$(aq)~~ + H_2(**g**)

Ni(s) + $2H^+$(aq) ----------> **Ni^{2+}(aq) + H_2(g)**

Ag(**s**) + $Cu(NO_3)_2$(aq) ----------> ?

Ag is below Cu on the activity series table. Thus Ag solid will not replace Cu in solution.

$Ag(s) + Cu(NO_3)_2(aq)$ ----------> NR
$Ca(\mathbf{s}) + H_2O(\mathbf{l})$ ----------> ?

Ca is above H_2 on the activity series table. Thus Ca solid will replace "H^+" in water.
This is typical behavior of the alkali and alkaline earth metals only.
$Ca(s) + 2H_2O(l)$ ----------> $Ca(OH)_2(s) + H_2(g)$

$NaCl(aq) + F_2(\mathbf{g})$ ----------> ?

F_2 is a better oxidant than Cl_2 and will oxidize Cl^- to Cl_2.

$2NaCl(aq) + F_2(\mathbf{g})$ ----------> $2NaF(aq) + Cl_2(\mathbf{g})$

~~$2Na^+(aq)$~~ + $2Cl^-(aq) + F_2(\mathbf{g})$ ----------> ~~$2Na^+(aq)$~~ + $2F^-(aq) + Cl_2(\mathbf{g})$

$2Cl^-(aq) + F_2(g)$ ----------> $2F^-(aq) + Cl_2(g)$