In double replacement reactions, two ions exchange places. One cation exchanges places with another cation, or equivalently, one anion exchanges places with another anion. The driving force for these reactions is the removal of the ions from the reaction mixture. In precipitation reactions, a precipitate (solid) forms which removes the ions from the solution. In acid-base reactions, water or another slightly dissociated compound forms. Hydrogen ions, $H^+$, and hydroxide ions, $OH^-$, are removed when water forms. Another possibility is the formation of a gas which would clearly demonstrate that something had left the reaction mixture. We will focus on precipitation and acid-base reactions in this section.

After exchanging the cations (or anions) in the formulas of the reactants, we check the solubility rules to see whether or not either or both of the products are insoluble. For example, will a precipitate form when solutions of sodium carbonate, $Na_2CO_3($aq$)$, and magnesium sulfate, $MgSO_4($aq$)$ are mixed? When we exchange the cations, we obtain $MgCO_3$ and $Na_2SO_4$ as the possible products of any reaction. From the solubility rules, we know that sodium sulfate is soluble but that magnesium carbonate is insoluble. By applying the solubility rules, we predict that the following precipitation reaction will occur.

$$Na_2CO_3(aq) + MgSO_4(aq) \rightarrow Na_2SO_4(aq) + MgCO_3(s).$$

Notice the (s) after $MgCO_3(s)$ which designates a solid. The (aq) means that the compound is dissolved in water. In other words, the compound is soluble. This reaction resulted in the removal of $Mg^{2+}$ and $CO_3^{2-}$ ions from the solution.

The solubility rules are:

1. Most Group 1 (alkali metals) and ammonium, $NH_4^+$, salts are soluble.
2. Almost all nitrates, $NO_3^-$, and acetates, $C_2H_3O_2^-$ are soluble.
3. All chlorides are soluble except $AgCl$, $PbCl_2$, and $Hg_2Cl_2$.
4. All sulfates are soluble except $BaSO_4$, $SrSO_4$, and $Hg_2SO_4$; $CaSO_4$ and $Ag_2SO_4$ are slightly soluble.
5. All oxides, $SO_2^-$, and hydroxides, $OH^-$, are insoluble except those of the Group 1 and Group 2 metals. $Ca(OH)_2$ is slightly soluble.
6. All sulfides, $S^2-$, are insoluble except those of the Group 1 and Group 2 metals and $NH_4^+$. 
All phosphates, $PO_4^{3-}$, and carbonates, $CO_3^{2-}$, are insoluble except those of the Group 1 metals and $NH_4^+$. With this set of rules, we can predict the outcome of a large number of reactions.

**EXAMPLE** What are the products including the coefficients when $ZnCl_2(aq)$ is mixed with $AgNO_3(aq)$? The outcome of this reaction can be predicted from the solubility rules. We switch the positive ions in the reactants and look at the solubility rules to see whether or not an insoluble compound forms. The solubility rules tell us that $AgCl$ is insoluble in water. The reaction is

$$ZnCl_2(aq) + 2AgNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2AgCl(s).$$