Steps to Predicting the Products of Chemical Reactions

CP Chemistry
TYPES OF REACTIONS REVIEW

- $2 \text{NaNO}_3 + \text{PbO} \rightarrow \text{Pb(NO}_3)_2 + \text{Na}_2\text{O}$
  Double Displacement

- $\text{C}_2\text{H}_4\text{O}_2 + 2 \text{O}_2 \rightarrow 2 \text{CO}_2 + 2 \text{H}_2\text{O}$
  Combustion

- $\text{ZnSO}_4 + \text{Li}_2\text{CO}_3 \rightarrow \text{ZnCO}_3 + \text{Li}_2\text{SO}_4$
  Double Displacement

- $\text{V}_2\text{O}_5 + 5 \text{CaS} \rightarrow 5 \text{CaO} + \text{V}_2\text{S}_5$
  Double Displacement

- $\text{S}_8 + 8 \text{O}_2 \rightarrow 8 \text{SO}_2$
  Synthesis
Organize Your Thoughts

Chemical reactions

- Synthesis
- Decomposition
- Single replacement
- Double replacement
- Combustion

- Balancing equations
- Predicting products from reactants

We want to be able to predict the products for the following reaction types:

- Combustion
- Single Displacement
- Double Displacement
Here are a few important things to remember when predicting products:

- The compounds form must be **neutral ionic compounds** (which means you’ll be paying attention to their charges)
- You do **NOT carry subscripts** from the reactants to the products.
- You always balance your equation **LAST**
PREDICTING REACTION PRODUCTS: COMBUSTION REACTIONS

- A hydrocarbon and oxygen \((O_2)\) indicate a combustion reaction.
- If it is combustion, then just write \(H_2O\) and \(CO_2\) as products.
- Then, balance the equation (can be tricky).
- Examples:
  - \(\underline{\phantom{0}} \text{CH}_4 + \underline{2} \text{O}_2 \rightarrow \underline{\phantom{0}} \text{CO}_2 + \underline{2} \text{H}_2\text{O}\)
  - \(2 \text{C}_4\text{H}_{10} + \underline{13} \text{O}_2 \rightarrow \underline{8} \text{CO}_2 + \underline{10} \text{H}_2\text{O}\)
PREDICTING REACTION PRODUCTS: REPLACEMENT REACTIONS

- A metal will not always replace a metal in a compound dissolved in water because of differing reactivities.

- An activity series can be used to predict if reactions will occur.
  - To replace a metal, the other metal must be more reactive.
  - Same applies for halogens.
To predict the products: Replace the single element with the corresponding element in the compound.

- A metal will replace the cation in the compound.
- A non-metal will replace the anion in the compound.

If the element is more reactive than the one it attempts to replace, then the reaction will be spontaneous and exothermic.

Otherwise, it will not be spontaneous and will be endothermic (NO REACTION).
3 Mg + 2 AlCl$_3$ → 2 Al + 3 MgCl$_2$

**Can magnesium replace aluminum?**

- Activity Series: **YES**, magnesium is more reactive than aluminum.

**Can aluminum replace magnesium?**

- Activity Series: **NO**, aluminum is less reactive than magnesium.

Therefore, *no reaction* will occur.

The question we must ask is can the single element replace its counterpart? metal replaces metal or nonmetal replaces nonmetal. Order of reactants **DOES NOT** determine how they react.
PREDICTING REACTION PRODUCTS: SINGLE REPLACEMENT REACTIONS

Fe + CuCl₂ → FeCl₂ + Cu

Can Fe replace Cu? Yes

Zn + HNO₃ → Zn(NO₃)₂ + H₂

Can Zn replace H? Yes

MgCl₂ + Br₂ → MgBr₂ + Cl₂

Can Br replace Cl? No

Activity Series

Li Rb K Ba Ca Na Mg Al Mn Zn Cr Fe Ni Sn Pb H₂ Cu Hg Ag Pt Au
PREDICTING REACTION PRODUCTS: DOUBLE REPLACEMENT REACTIONS

- If it is **double replacement**, then the **cation and anions** switch places.
- It is helpful to separate each compound into their cation and anionic parts with their charges.
- Then switch places, and **criss cross the new compounds** to make sure they are the correct neutral compound formulas.

\[ AX + BY \rightarrow AY + BX \]

\[ Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l) \]
AB and CD are both ionic compounds

Separate each compound & write their charges

Switch places and re-write new compounds

Example:

\[ \text{Pb(NO}_3\text{)}_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KNO}_3 \]

\[ \text{Pb}^{2+} \text{ NO}_3^- + 2\text{K}^+ + 2\text{I}^- \]

\[ \text{Pb}^{2+} + 2\text{I}^- \rightarrow \text{PbI}_2 \]

\[ 2\text{K}^+ + 2\text{KNO}_3^- \]

Balance at the end!!
Not all double replacement reactions will occur.

In order for a double replacement reaction to take place:

- Both of the reactants must be soluble in water.
  - If a compound contains at least one of the ions that is proven soluble, then the compound will be at least moderately soluble.

- One product must be soluble and one product must be insoluble.
  - The insoluble product is the precipitate that forms when the reaction takes place.
  - Usually a precipitate is a solid, but it doesn't have to be.
## SOLUBILITY TABLE

<table>
<thead>
<tr>
<th>Compounds of:</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li⁺, Na⁺, K⁺, or NH₄⁺</td>
<td>Always soluble</td>
</tr>
<tr>
<td>NO₃⁻ or C₂H₃O₂⁻</td>
<td>Always soluble</td>
</tr>
<tr>
<td>Cl⁻, Br⁻, or I⁻</td>
<td>Insoluble with Ag⁺, Hg₂²⁺, or Pb²⁺. Soluble with any other ion.</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>Soluble with all the ions except Sr²⁺, Ba²⁺, Ag⁺, Hg₂²⁺, or Pb²⁺.</td>
</tr>
<tr>
<td>CO₃²⁻ or PO₄³⁻</td>
<td>Soluble with Li⁺, Na⁺, K⁺, or NH₄⁺. Insoluble with any other ion.</td>
</tr>
<tr>
<td>OH⁻ or S²⁻</td>
<td>Soluble with Ca²⁺, Sr²⁺, Ba²⁺, Li⁺, Na⁺, K⁺, or NH₄⁺. Insoluble with any other ion.</td>
</tr>
</tbody>
</table>
Predicting Reaction Products: Double Replacement Reactions

Predict if a reaction will occur when you combine aqueous solutions of iron (II) chloride with aqueous sodium carbonate solution.

If the reaction does occur, write a balanced chemical equation showing it.

iron (II) chloride + sodium carbonate → ????

FeCl₂(aq) + Na₂CO₃(aq) → 2 NaCl (aq) + FeCO₃ (ppt)

Using a SOLUBILITY TABLE:
Both reactants are soluble
SO REACTION OCCURS!

Using a SOLUBILITY TABLE:
sodium chloride is soluble
iron (II) carbonate is insoluble so reaction occurs!!