Types of Chemical Reactions

A) DECOMPOSITION  \( AB \rightarrow A + B \)

During a decomposition reaction, one compound splits into two or more pieces. These smaller pieces can be elements or simpler compounds.

Examples:

- magnesium chloride \(\rightarrow\) magnesium + chlorine  
  \[ 2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2 \]
- calcium carbonate \(\rightarrow\) calcium oxide + oxygen  
  \[ \text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{O} + \text{CO}_2 \]
- potassium chlorate \(\rightarrow\) potassium chloride + oxygen  
  \[ \text{Ba(ClO}_3\text{)}_2 \rightarrow \text{BaCl}_2 + 3 \text{O}_2 \]
- iron(III) hydroxide \(\rightarrow\) iron (III) oxide + water  
  \[ \text{Cu(OH)}_2 \rightarrow \text{CuO} + \text{H}_2\text{O} \]
- carbonic acid \(\rightarrow\) carbon dioxide + water  
  \[ 2 \text{H}_3\text{PO}_4 \rightarrow \text{P}_2\text{O}_5 + 3 \text{H}_2\text{O} \]

The following rules will help when determining the products of a decomposition reaction.

1. All binary compounds will break down into their elements.
2. All carbonates break down to the metal oxide and carbon dioxide gas.
3. All chlorates break down to the metal chloride and oxygen gas.
4. Metal hydroxides break down to the metal oxide and water.
5. Oxy acids break down to the non-metal oxide (with the non-metal having the same valence) and water.

Practice Problems: Provide a completed word and full balanced chemical equation for each reaction.

a) nickel (II) chloride \(\rightarrow\)  

b) silver oxide \(\rightarrow\)  

c) nitrous acid \(\rightarrow\)  

d) iron (III) hydroxide \(\rightarrow\)  

e) zinc carbonate \(\rightarrow\)  

f) carbonous acid \(\rightarrow\)  

g) \(\text{Cs}_2\text{CO}_3\)  

h) \(\text{Al(OH)}_3\)  

i) \(\text{H}_2\text{SO}_4\)  

j) \(\text{RbClO}_3\)  

k) \(\text{LiCl}\)  

l) \(\text{Au(ClO}_3\text{)}_3\)
B) SYNTHESIS  \[ A + B \rightarrow AB \]

During a synthesis reaction, two or more elements or simple compounds come together to form 1 compound. These are the reverse of a decomposition reaction.

Examples:
- sodium + oxygen \( \rightarrow \) sodium oxide
- lead (II) oxide + carbon dioxide \( \rightarrow \) lead(II) carbonate
- iron (II) chloride + oxygen \( \rightarrow \) iron (II) chlorate
- zinc oxide + water \( \rightarrow \) zinc hydroxide
- silicon dioxide + water \( \rightarrow \) silicic acid
- Sn + F\(_2\) \( \rightarrow \) SnF\(_2\)
- K\(_2\)O + CO\(_2\) \( \rightarrow \) K\(_2\)CO\(_3\)
- BeCl\(_2\) + 3 O\(_2\) \( \rightarrow \) Be(ClO\(_3\))\(_2\)
- Na\(_2\)O + H\(_2\)O \( \rightarrow \) 2 NaOH
- SeO\(_2\) + H\(_2\)O \( \rightarrow \) H\(_2\)SeO\(_3\)

Since synthesis reactions are the reverse of decomposition reactions, reverse the rules from above to determine the products of a synthesis reaction.

1. Two elements will react to form the binary compound.
2. A metal oxide and carbon dioxide will react to form the metal carbonate.
3. A metal chloride and oxygen will react to form the metal chlorate.
4. A metal oxide and water will react to form a metal hydroxide.
5. A non-metal oxide and water will react to form the oxy acid (with the non-metal having the same valence).

Practice Problems: Provide a completed word and full balanced chemical equation for each reaction.

a) magnesium chloride + oxygen \( \rightarrow \)  

b) cesium + iodine \( \rightarrow \)  

c) diphosphorus trioxide + water \( \rightarrow \)  

d) potassium oxide + water \( \rightarrow \)  

e) barium oxide + carbon dioxide \( \rightarrow \)  

f) silver + sulfur \( \rightarrow \)  

g) BeO + CO\(_2\) \( \rightarrow \)  

h) Al\(_2\)O\(_3\) + H\(_2\)O \( \rightarrow \)  

i) N\(_2\)O\(_3\) + H\(_2\)O \( \rightarrow \)  

j) NaCl + O\(_2\) \( \rightarrow \)  

k) Ga + Br\(_2\) \( \rightarrow \)  

l) Ca + P\(_4\) \( \rightarrow \)
C) SINGLE DISPLACEMENT  \( AX + Y \rightarrow YX + A \)  or  \( AX + B \rightarrow AB + X \)

During a single displacement (also called single replacement) reaction one element replaces another element in a compound forming a new compound. There are 2 different possibilities.

1. **One cation replaces another:**  \( AX + Y \rightarrow YX + A \), where both A and Y are cations (usually metals and hydrogen).
   
   For an element to displace another in a compound, it must be higher up in the activity series than the element in the compound.

   Examples:
   
   - copper + silver nitrate \( \rightarrow \) silver + copper (II) nitrate
   - Fe + Cu(NO\(_3\))\(_2\) \( \rightarrow \) Fe(NO\(_3\))\(_2\) + Cu
   - calcium + water \( \rightarrow \) calcium hydroxide + hydrogen
   - Zn + HCl\(_{aq}\) \( \rightarrow \) ZnCl\(_2\) + H\(_2\)

2. **One anion replaces another:**  \( AX + B \rightarrow AB + X \), where both X and B are anions (usually non-metals). For an element to displace another in a compound, it must be more reactive than the element in the compound.

   Examples:
   
   - chlorine + sodium bromide \( \rightarrow \) sodium chloride + bromine
   - Br\(_2\) + 2 KI \( \rightarrow \) 2 KBr + I\(_2\)

Practice Problems: Provide a completed word and full balanced chemical equation for each reaction.

- a) aluminum + lead (II) nitrate \( \rightarrow \)
- b) chlorine + lithium iodide \( \rightarrow \)
- c) iron + silver acetate \( \rightarrow \)
- d) aluminum + copper (II) chloride \( \rightarrow \)
- e) bromine + iron (III) chloride \( \rightarrow \)
- f) barium + water \( \rightarrow \)
- g) Al + HCl \( \rightarrow \)
- h) Zn + H\(_2\)SO\(_4\) \( \rightarrow \)
- i) Pb + AgNO\(_3\) \( \rightarrow \)
- j) Fe + CuSO\(_4\) \( \rightarrow \)
- k) Li + H\(_2\)O \( \rightarrow \)
- l) PbI\(_4\) + F\(_2\) \( \rightarrow \)
D) DOUBLE DISPLACEMENT  \( AB + XY \rightarrow AY + XB \)

During a double displacement (also called a double replacement) reaction, the cations and anions of two different compounds switch places.

Examples:  
iron (II) acetate + sodium chloride \( \rightarrow \) iron(II) chloride + sodium acetate

\[ 2 \text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2 \text{HCl} \]

\[ \text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl} + \text{NaNO}_3 \]

When an acid and base react, this is a special case of a double displacement reaction called a neutralization which forms a salt (ionic compound) and water.

Examples:  
potassium hydroxide + sulfuric acid \( \rightarrow \) potassium sulfate + water

\[ 2 \text{H}_3\text{PO}_4 + 3 \text{Ca(OH)}_2 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6 \text{H}_2\text{O} \]

In some cases, a product will form in the double displacement reaction that will then decompose further. Whenever \( \text{H}_2\text{CO}_3, \text{H}_2\text{SO}_3 \) and \( \text{NH}_4\text{OH} \) are formed in the reaction, they will decompose to \( \text{CO}_2 \) and \( \text{H}_2\text{O}, \text{SO}_2 \) and \( \text{H}_2\text{O} \) and \( \text{NH}_3 \) and \( \text{H}_2\text{O} \) respectively.

Examples:

calcium carbonate + hydrochloric acid \( \rightarrow \) calcium chloride + carbon dioxide + water

\[ \text{K}_2\text{SO}_3 + 2 \text{HNO}_3 \rightarrow 2 \text{KNO}_3 + \text{SO}_2 + \text{H}_2\text{O} \]

\[ \text{NH}_4\text{Cl} + \text{NaOH} \rightarrow \text{NaCl} + \text{NH}_3 + \text{H}_2\text{O} \]

Practice Problems: Provide a completed word and full balanced chemical equation for each reaction.

a) calcium hydroxide + carbonic acid \( \rightarrow \)

g) \( \text{Na}_2\text{CO}_3 + \text{H}_2\text{SO}_4 \rightarrow \)

b) potassium carbonate + barium chloride \( \rightarrow \)

h) \( \text{Al(OH)}_3 + \text{HC}_2\text{H}_3\text{O}_2 \rightarrow \)

c) zinc phosphate + ammonium sulfide \( \rightarrow \)

i) \( \text{Al}_2(\text{SO}_4)_3 + \text{Ca}_3(\text{PO}_4)_2 \rightarrow \)

d) cobaltic hydroxide + nitric acid \( \rightarrow \)

j) \( \text{Cr}_2(\text{SO}_3)_3 + \text{H}_2\text{SO}_4 \rightarrow \)

e) silver nitrate + potassium chloride \( \rightarrow \)

k) \( \text{AgC}_2\text{H}_3\text{O}_2 + \text{K}_2\text{CrO}_4 \rightarrow \)

f) ammonium chloride + magnesium hydroxide \( \rightarrow \)

l) \( (\text{NH}_4)_2\text{SO}_4 + \text{KOH} \rightarrow \)
E) COMBUSTION  \( \text{C}_x\text{H}_y + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \) or  \( \text{C}_x\text{H}_y + \text{O}_2(\text{g}) \rightarrow \text{C}(\text{s}) + \text{CO}(\text{g}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \)

In a combustion reaction, a hydrocarbon (a compound made of carbon and hydrogen) reacts with oxygen gas. There are 2 types of combustion.

1. Complete Combustion: \( \text{C}_x\text{H}_y + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \)
2. Incomplete Combustion: \( \text{C}_x\text{H}_y + \text{O}_2(\text{g}) \rightarrow \text{C}(\text{s}) + \text{CO}(\text{g}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g}) \)

Examples:

\[ \text{CH}_4 + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g}) \]
\[ \text{C}_3\text{H}_6 + 3 \text{O}_2(\text{g}) \rightarrow \text{C}(\text{s}) + \text{CO}_2(\text{g}) + \text{CO}_2(\text{g}) + 3 \text{H}_2\text{O}(\text{g}) \]

In some cases the hydrocarbon may also contain nitrogen or sulfur, in which case \( \text{NO}_2 \) or \( \text{SO}_2 \) is also produced.

Examples:

\[ \text{C}_{21}\text{H}_{24}\text{N}_2\text{O}_4 + 27 \text{O}_2(\text{g}) \rightarrow 21 \text{CO}_2(\text{g}) + 12 \text{H}_2\text{O}(\text{g}) + 2 \text{NO}_2(\text{g}) \]
\[ 2 \text{C}_2\text{H}_5\text{SH} + 9 \text{O}_2(\text{g}) \rightarrow 4 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{g}) + 2 \text{SO}_2(\text{g}) \]

Practice Problems: Complete a balanced chemical equation for each reaction. Assume complete combustion in each.

a) \( \text{C}_6\text{H}_6 + \text{O}_2(\text{g}) \rightarrow \)

b) \( \text{C}_{11}\text{H}_{22}\text{O}_{11} + \text{O}_2(\text{g}) \rightarrow \)

c) \( \text{C}_{25}\text{H}_{52} + \text{O}_2(\text{g}) \rightarrow \)

d) \( \text{C}_2\text{H}_5\text{OC}_2\text{H}_5 + \text{O}_2(\text{g}) \rightarrow \)

e) \( \text{C}_4\text{H}_6\text{OH} + \text{O}_2(\text{g}) \rightarrow \)

f) \( \text{C}_6\text{H}_{13}\text{SH} + \text{O}_2(\text{g}) \rightarrow \)
F) EXOTHERMIC AND ENDOThERMIC

Many reactions require or release heat and in addition to being classified as one of the types discussed above can also be classified as exothermic or endothermic. Exothermic reactions are those accompanied by a release of heat (energy)

Example:
\[ 2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\text{g}) + \text{Energy} \]

Endothermic reactions are those that require heat (energy) to be added for the reaction to occur.

Example:
\[ \text{CaCO}_3(\text{s}) + \text{Energy} \rightarrow \text{CaO} (\text{s}) + \text{CO}_2(\text{g}) \]

MAKING CONNECTIONS:

1. Use the textbook and Internet to summarize the following concepts and their applications in everyday life:
   
   a) Catalysts and Catalytic converters (P.201-202)
   
   b) Neutralization Reactions (P. 176 & P. 205-211)
   
   c) Extraction of Metals and Metallurgical Processes (P. 212, 217)
   
   d) Corrosion, Alloys and Corrosion Protection (P. 379)

2. Complete the following Textbook questions.

   P. 155 # 4, 6, 7; P. 204 # 5, 9;
   P. 169 # 5, 7, 9; P. 201 # 3;
   P. 177 # 8; P. 217 # 6;
   P. 188 # 71; P. 221 # 6;
   P. 197 # 6, 8;

REVIEW - CHEMICAL REACTIONS

P. 244- 253- read over all the questions, attempt as many as possible (write solutions to questions you find challenging).
Types of Chemical Reactions

1. For each reaction below, indicate its type and then balance.

a) _____ H₂ + _____ O₂ → _____ H₂O
   Type: ________________________________

b) _____ H₂O₂ → _____ O₂ + _____ H₂
   Type: ________________________________

c) _____ Al + _____ H₂SO₄ → _____ Al₂(SO₄)₃ + _____ H₂
   Type: ________________________________

d) _____ CO + _____ O₂ → _____ CO₂
   Type: ________________________________

e) _____ HgO → _____ Hg + _____ O₂
   Type: ________________________________

f) _____ KBr + _____ Cl₂ → _____ KCl + _____ Br₂
   Type: ________________________________

h) _____ Cr₂O₃ + _____ H₂O → _____ Cr(OH)₃
   Type: ________________________________

i) _____ Pb(NO₃)₂ + _____ NaCl → _____ PbCl₂ + _____ NaNO₃
   Type: ________________________________

j) _____ NaNO₃ → _____ NaNO₂ + _____ O₂
   Type: ________________________________

k) _____ Ba(OH)₂ + _____ H₃AsO₄ → _____ Ba₃(AsO₄)₂ + _____ H₂O
   Type: ________________________________

l) _____ C₅H₁₂O + _____ O₂ → _____ CO₂ + _____ H₂O
   Type: ________________________________

m) _____ As₂O₅ + _____ H₂O → _____ H₃AsO₄
   Type: ________________________________
2. Complete the following word equations by determining the products of the reaction, then write a balanced chemical equation and indicate the type of reaction.

a) strontium bromide + fluorine \(\rightarrow\)

b) magnesium + iron (III) oxide \(\rightarrow\)

c) silver nitrate + zinc chloride \(\rightarrow\)

d) nickel (III) carbonate \(\rightarrow\)

e) tricarbon hexahydride + oxygen gas \(\rightarrow\)

f) barium + water \(\rightarrow\)

g) tin (II) hydroxide + phosphoric acid \(\rightarrow\)

h) calcium chloride + oxygen \(\rightarrow\)

i) tetraphosphorus decaoxide + water \(\rightarrow\)

j) lithium bicarbonate + hydrosulfuric acid \(\rightarrow\)

k) acetic acid + nickel \(\rightarrow\)
Mixed Practice - State the type, predict the products, and balance the following reactions:

1. $\text{BaCl}_2 + \text{H}_2\text{SO}_4 \rightarrow$

2. $\text{C}_6\text{H}_{12} + \text{O}_2 \rightarrow$

3. $\text{Zn} + \text{CuSO}_4 \rightarrow$

4. $\text{Cr}_2(\text{SO}_3)_3 + \text{HNO}_3 \rightarrow$

5. $\text{Cs} + \text{Br}_2 \rightarrow$

6. $\text{FeCO}_3 \rightarrow$

7. $\text{NaClO}_3 \rightarrow$

8. $\text{HCl}_{(aq)} + \text{AgNO}_3_{(aq)} \rightarrow$

9. $\text{Bi}_2\text{O}_3 \rightarrow$

10. $\text{Na}_2\text{O} \rightarrow$

11. $\text{CaCl}_2_{(aq)} + \text{Na}_3\text{PO}_4_{(aq)} \rightarrow$

12. $\text{Na}_2\text{SO}_3 + \text{H}_3\text{PO}_4 \rightarrow$
13. AlCl₃

14. C₂H₄ + O₂

15. Pb(NO₃)₂(aq) + BaCl₂(aq)

16. Zn + AgNO₃

17. Al + P₄

18. H₂SO₄(aq) + NaOH(aq)

19. NaI + MgS

20. Cl₂ + NaBr

21. C₆H₁₂O₆ + O₂

22. KOH(aq) + CuSO₄(aq)

23. Na₂CO₃ + H₂SO₄

24. (NH₄)₂S + Cd₃(PO₄)₂

25. (NH₄)₂S + Co(OH)₃