Types of Chemical Reactions

Chemical reactions can be classified on the basis of what processes occur during the reaction. You will be required to be able to identify what type of reaction has occurred and to predict the products of the reaction. There are four basic types of reactions as listed below.

1) **Direct Combination** (synthesis) $A + B \rightarrow AB$
   a) Two elements → a binary compound
   b) Two compounds (with a common ion) → one compound
   Example: $2H_2\,(g) + O_2\,(g) \rightarrow 2\,H_2O$

2) **Single Replacement** $A + BX \rightarrow AX + B$
   a) Element + compound → different element + different compound
   b) Strong metals (Groups I & IIA) + Water → metallic hydroxide + hydrogen
   Example: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

3) Double Replacement $AX + BY \rightarrow AY + BX$
   a) Two compounds → two different compounds
   Example: $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$
   b) Special : combustion of hydrocarbons $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

4) Decomposition $AB \xrightarrow{\Delta} A + B$
   a) One compound $\xrightarrow{\Delta}$ two or more products
   b) Rules for Decomposition Rxns.
      i) Binary compounds (with heat or electricity) → free elements
      Example: $H_2O \xrightarrow{\Delta} H_2 + O_2$
      ii) Some oxides (when heated) → free elements
      Example: $2\,HgO \xrightarrow{\Delta} 2\,Hg + O_2$
      iii) Metallic carbonates (when heated) → metallic oxides + CO_2
      Example: $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
      iv) Metallic chlorates (when heated) → metallic chlorides + O_2
      Example: $2\,KClO_3 \xrightarrow{\Delta} 2\,KCl + 3\,O_2$
      v) Metallic hydroxides (when heated) → metallic oxides + H_2O
      Example: $Ca(OH)_2 \xrightarrow{\Delta} CaO + H_2O$
      vi) Oxyacids (when heated) → nonmetallic oxides + H_2O
      Example: $H_2SO_4\,(aq) \xrightarrow{\Delta} H_2O + SO_3$
   c) MEMORIZE: $NH_4OH \xrightarrow{\Delta} NH_3 + H_2O$

* Reminders: The physical state of the substance is often indicated by a letter following the formula. (s) = solid, (l) = liquid, (g) = gas, (aq) = aqueous, and (ppt) = precipitate. A precipitate is the solid formed when two liquid compounds combine and one of the resulting compounds is insoluble in the newly formed liquid.

** EXCEPTIONS: Generally combustion reactions are direct combination reactions, but this is not always true. Also, a metal will only replace another metal if it has a higher activity than the existing metal.

Practice: Identify the type of reaction.

1.	$CO_2 \xrightarrow{\Delta} C + O_2$	1. _____
2.	$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$	2. _____
3.	$S + Cl_2 \rightarrow SCl_2$	3. _____
4.	$BaCl_2 + 2\ NaOH \rightarrow 2\ NaCl + Ba(OH)_2$	4. _____
5.	$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$	5. _____
6.	$CH_4 \xrightarrow{\Delta} C + 2\ H_2$	6. _____
7.	$PB(NO_3)_2 + Mg \rightarrow Pb + Mg(NO_3)_2$	7. _____
8.	$Mg + 2\ HCl \rightarrow MgCl_2 + H_2$	8. _____
9.	$H_2SO_4\ (aq) \rightarrow H_2 + S + 2\ O_2$	9. _____
10.	$2\ O_2 + N_2 \rightarrow N_2O_4$	10. _____

Practice: Predict the products for the following reactions, and write a balanced equation.

1. sodium + iodine gas → _____

2. calcium + oxygen gas → _____

3. hydrogen gas + chlorine gas → _____

4. nickel (II) chlorate $\xrightarrow{\Delta}$ _____

5. barium carbonate $\xrightarrow{\Delta}$ _____

6. zinc hydroxide $\xrightarrow{\Delta}$ _____

7. aluminum + sulfuric acid → _____

8. potassium iodide + chlorine (gas) → _____

9. iron (II) + copper (II) nitrate → _____

10. silver nitrate + zinc chloride → _____

11. copper (II) hydroxide + acetic acid → _____

12. iron (II) sulfate + ammonium sulfide → _____

13. cobalt (II) + oxygen gas → _____

14. potassium chloride + silver nitrate → _____

15. calcium oxide + water → _____

16. sodium hydroxide + hydrochloric acid → _____

17. hydrogen gas + nitrogen gas → _____

18. silver nitrate + nickel → _____

19. magnesium bromide + chlorine gas → _____

20. sodium chloride + sulfuric acid → _____

SPECIAL REACTIONS

1) **Combustion Reactions:**
   a) combustion of a hydrocarbon (organic compound):
   hydrocarbon burning in the presence of oxygen gas yields carbon dioxide and water
   Example: $C_xH_y + O_2 \rightarrow CO_2 + H_2O$
   b) combustion of a metal:
   burning of a metal in the presence of oxygen gas yields a metal oxide
   Example: $2Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$

2) **Precipitation Reactions:**
   a) single and double replacement reactions involving reactants that are aqueous, resulting in a product that is a solid (precipitate).
   Example: $Ag(NO_3)\ (aq) + NaCl\ (aq) \rightarrow AgCl\ (ppt) + Na(NO_3)\ (aq)$
   b) Use solubility rules to help determine which product is insoluble in water and will result in a precipitate.

3) **Ionic and Net ionic Equations:**
   a) Ionic equations write a chemical reaction by showing what ions are present on both the reactant and product sides. *Please keep in mind ions are only written if the compound is in the aqueous state.
   Example: $Ag(NO_3)\ (aq) + NaCl\ (aq) \rightarrow AgCl\ (ppt) + Na(NO_3)\ (aq)$ is written as: $Ag^{1+}\ (aq) + NO_3^{1-}\ (aq) + Na^{1+}\ (aq) + Cl^{1-}\ (aq) \rightarrow$
   $AgCl\ (s) + Na^{1+}\ (aq) + NO_3^{1-}\ (aq)$
   b) Net Ionic equations express the chemical reaction with spectator ions removed. *Spectator ions are those ions that remain in the same form before and after the reaction.
   Example: Using the equation from above the Na^{1+} and the NO_3^{1-} are spectator ions and will be removed from the equation. The resulting equation looks like:
   $Ag^{1+}\ (aq) + Cl^{1-}\ (aq) \rightarrow AgCl\ (s)$

4) **Acid – Base Reactions:**
   a) The reaction between a strong acid and a strong base will form a salt and water, also called a neutralization reaction.
   Example: $HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$
   b) The reactants and products can be divided into acid-base pairs. An acid-base pair can be identified by examining the movement of the hydrogen throughout the reaction. The compound that donates the hydrogen (proton) is considered the acid. The compound that accepts the hydrogen (proton) is considered the base. Also referred to as the Brønsted-Lowry model.

Example:

Example: $NH_3\ (aq) + H_2O\ (l) \rightarrow NH_4^{1+}\ (aq) + OH^{1-}\ (aq)$

Pair 1 — Pair 2

Pair 1 acid: NH_4^{1+} base: NH_3
Pair 2 acid: H_2O base: OH^{1-}

5) **Oxidation – Reduction Reactions:**
   a) A reaction that involves the transfer of electrons. Oxidation (LEO) occurs when electrons are lost (remember your oxidation numbers). Reduction (GER) is when an atom gains electrons.
   Example: $2\ Na\ (s) + Cl_2(s) \rightarrow 2\ NaCl\ (s)$ can be rewritten as:
   LEO: $Na \rightarrow 1\ e^- + Na^{1+}$
   GER: $Cl + 1\ e^- \rightarrow Cl^{1-}$

Practice: Identify the following types of special reactions. **Choices maybe used more than once.

___ 1. **$2\ NaOH\ (aq) + H_2SO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + 2\ H_2O\ (l)$**

___ 2. **$2\ Cu\ (s) + O_2\ (g) \rightarrow 2\ CuO\ (s)$**

___ 3. **$Mg^{2+}\ (aq) + PO_4^{3-}\ (aq) + Na^{1+}\ (aq) + CO_3^{2-}\ (aq) \rightarrow MgCO_3\ (s) + Na^{1+}\ (aq) + PO_4^{3-}\ (aq)$**

___ 4. **$2\ Ag(C_2H_3O_2)\ (aq) + CaCl_2\ (aq) \rightarrow 2\ AgCl\ (s) + Ca(C_2H_3O_2)_2\ (aq)$**

___ 5. **$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$**

a. **Oxidation - Reduction**
b. **Ionic Equation**
c. **Combustion**
d. **Acid-Base Reaction**
e. **Precipitation**

Practice: Identify the precipitate formed in the following equations.

1. $HgNO_3 + KCl \rightarrow Hg_2Cl_2 + KNO_3$ ppt: _____

2. $KMnO_4 + AlPO_4 \rightarrow K_3PO_4 + Al(MnO_4)_3$ ppt: _____

3. $Pb(ClO_3)_2 + Na_2SO_4 \rightarrow PbSO_4 + NaClO_3$ ppt: _____

Practice: Change the following equations into an ionic equation and net ionic equation (if applies).

1. $Ca(NO_3)_2$ (aq) + 2 $NaClO_3$ (aq) → $Ca(ClO_3)_2$ (aq) + 2 $NaNO_3$ (aq)

2. $BaCl_2$ (aq) + Na_2SO_4 (aq) → $BaSO_4$ (s) + 2 NaCl (aq)

3. $Pb(NO_3)_2$ (aq) + H_2SO_4 (aq) → $PbSO_4$ (s) + 2 HNO_3 (aq)

Practice: Complete redox equations for the following. Remember to label LEO and GER.

1. 2 Fe (s) + 3 S (s) → Fe_2S_3 (s)

2. 4 K (s) + C (s) → K_4C (s)

3. 2 Al (s) + Fe_2O_3 (s) → 2 Fe (s) + Al_2O_3 (s)

Name: _____ **Period:** ___ **Date:** _____

Homework: Types of Reactions

Identify the type of reactions.

1. $3\ CaBr_2 + 2Na_3P \rightarrow Ca_3P_2 + 6\ NaBr$ _____
2. $2\ KI + Br_2\ (g) \rightarrow 2\ KBr + I_2\ (g)$ _____
3. $C_6H_{12}O_6 \xrightarrow{\Delta} 6\ C + 6\ H_2O$ _____
4. $2\ NaF \xrightarrow{\Delta} 2\ Na + F_2\ (g)$ _____
5. $Si + O_2\ (g) \rightarrow SiO_2$ _____
6. $2\ NaI + Pb(NO_3)_2 \rightarrow 2\ NaNO_3 + PbI_2$ _____
7. $NaI + Cs \rightarrow CsI + Na$ _____
8. $H_2\ (g) + CO + O_2\ (g) \rightarrow H_2CO_3$ _____
9. $Li_3PO_4 \xrightarrow{\Delta} 3\ Li + P + 2\ O_2\ (g)$ _____
10. $CS_2 + 2\ F_2\ (g) \rightarrow CF_4 + 2\ S$ _____

Predict the products for the following reactions, and write a balanced equation.

1. aluminum sulfate + calcium phosphate → _____

2. magnesium chloride + silver nitrate → _____

3. sodium chlorate $\xrightarrow{\Delta}$ _____

4. hydrogen gas + oxygen gas → _____

5. zinc + copper (II) nitrate → _____

6. copper (II) hydroxide $\xrightarrow{\Delta}$ _____

7. copper (II) oxide + sulfuric acid → _____

8. nitrogen gas + hydrogen gas → _____

SKIP 9. nitrogen gas + hydrogen gas → _____

10. sodium iodide + chlorine gas → _____

11. iron + hydrochloric acid→ _____

12. aluminum + sulfuric acid → _____

13. magnesium bromide + chlorine gas → _____

14. synthesis of ammonia:

15. calcium + water → _____

16. zinc sulfate + hydrogen sulfide → _____

17. iron (II) sulfide + hydrochloric acid → _____

18. lead (II) chlorate + potassium chromate → _____

19. acetic acid + sodium hydroxide → _____

20. potassium iodide + water → _____