Ch. 8 Notes ~ CHEMICAL REACTIONS

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics.*

I. Chemical Reactions (rxns.)

A. **chemical reaction**—an expression showing the *conversion of reactants to products, forming new substances* with new properties

1) **reactant**—*starting substance* in a rxn.
2) **product**—*ending substance* in a rxn.

REACTANTS → PRODUCTS *(reactants react to produce products)*

3) word equations do not use chemical formulas:

lead (II) nitrate + potassium iodide → lead(II) iodide + potassium nitrate

4) chemical reactions use chemical formulas and are balanced:

$Pb(NO_3)_2 + 2KI \rightarrow 2KNO_3 + PbI_2$

5) **skeleton equation**—*unbalanced* chemical equation

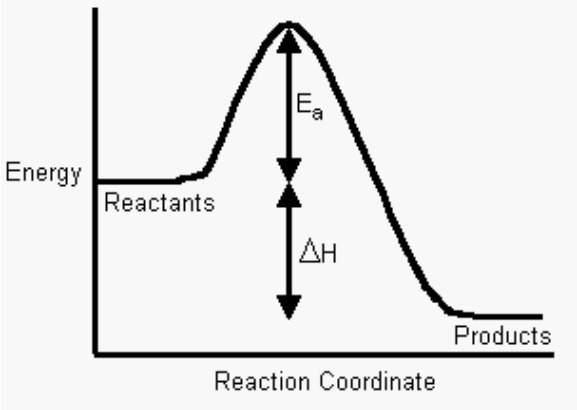
$H_2 + O_2 \rightarrow H_2O$

B. **catalyst**—a substance that *increases the reaction rate without being used up* in the reaction (symbol written above the arrow)

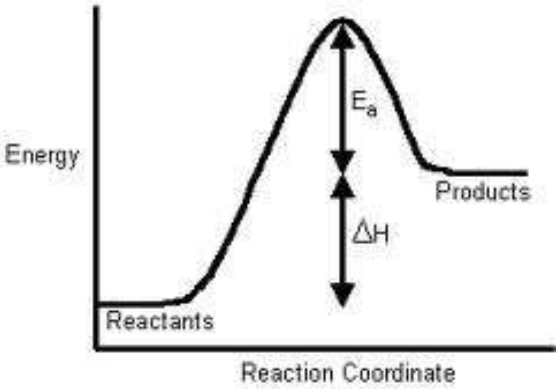
C. **** clues that a chemical reaction has taken place ****

1) *solid (precipitate) formation*
2) *gas production*
3) *odor change*
4) *cannot be reversed by physical means*
5) *temperature change , without being heated or cooled*
   a) **exothermic** – *giving off energy*
   b) **endothermic** – *absorbing energy*

EXOTHERMIC



ENDOTHERMIC



D. common reaction symbols

+	→	⇌	(s)	↓	(cr)	(l)	(aq)	(g)	↑	Δ	heat	(catalyst)

E. examples of equations

$NaI\ (aq) + AgNO_3\ (aq) \rightarrow NaNO_3\ (aq) + AgI\ (s)$

$3H_2 + N_2 \rightarrow 2NH_3$

$Zn\ (s) + 2HCl\ (aq) \rightarrow ZnCl_2(aq) + H_2\ (g)$

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

II. Balancing Chemical Equations

A. *Law of Conservation of Mass* = all atoms must be accounted for (balanced eq.)

B. **balanced equations** must have the same number of atoms on both sides

C. **coefficient**—a whole number *in front of a formula,* can be changed in order to balance the equation ($4Na_2O$ has a coefficient of 4)

D. **subscript**—a whole number telling how many atoms are in a chemical formula; *cannot be changed when balancing equations*

"Chartin' Martin Balance Method" est. 1986

1) *Write the unbalanced equation.*

Be sure all formulas are correct. Separate reactants and products with an arrow.

2) *Draw a small box around each formula.*

This will warn you not to change anything inside while you balance the equation.

3) *Put a blank line (underscore) in front of each boxed formula.*

This is where your coefficients will go as you balance.

4) *Make a chart below the reaction, with two columns, R & P.*

List all symbols shown in the reaction for both sides. If there are polyatomic ions, you may keep them together as a unit for convenience.

5) *Balance the equation.*

Use trial and error, *changing coefficients, not subscripts.* Pay attention to multiples. Change the atom totals in the chart as you balance. The equation is balanced when the numbers of atoms in the R & P columns are equal.

When you become more experienced at balancing, you may not need to use a chart. Some students do not need the chart format at all. I suggest you keep doing steps 1 & 3. Step 2 may become unnecessary in time.

E. examples

EXAMPLE 1) iron + oxygen → iron(III) oxide

$Fe + O_2 \rightarrow Fe_2O_3$

$\_4\_ Fe + \_3\_ O_2 \rightarrow \_2\_ Fe_2O_3$

	R	P
Fe	~~1~~ 4	~~2~~ 4
O	~~2~~ 6	~~3~~ 6

EXAMPLE 2) iron(III) chloride + calcium hydroxide → iron(III) hydroxide + calcium chloride

$FeCl_3 + Ca(OH)_2 \rightarrow Fe(OH)_3 + CaCl_2$

$\_2\_ FeCl_3 + \_3\_ Ca(OH)_2 \rightarrow \_2\_ Fe(OH)_3 + \_3\_ CaCl_2$

	R	P
Fe	~~1~~ 2	~~1~~ 2
Cl	~~3~~ 6	~~2~~ 6
Ca	~~1~~ 3	~~1~~ 3
(OH)	~~2~~ 6	~~3~~ 6

III. Classifying Chemical Reactions

A. **<u>synthesis (combination)</u>** **A + B → AB**

1) *two or more reactants combine to form one product*
2) energy is given off
3) examples

$SO_3 + H_2O \rightarrow H_2SO_4$ $CaO + H_2O \rightarrow Ca(OH)_2$ $Cu + S \rightarrow CuS$

B. **<u>decomposition</u>** **AB → A + B**

1) *one reactant decomposes into two or more products*
2) most decomposition rxns. require energy
3) examples

$NH_4NO_3 \xrightarrow{\Delta} N_2O + 2H_2O$ $NiCO_3 \xrightarrow{\Delta} NiO + CO_2$

C. **<u>single replacement (single displacement)</u>** **A + BC → AC + B**

1) *atoms replace other atoms* in a compound
   a) metal can replace another metal
   b) metal can replace hydrogen
   c) nonmetal can replace another nonmetal
2) How can you tell if a replacement reaction will occur?
   The *"activity series"* chart shows which will be displaced.

ACTIVITY SERIES:

HIGH → → → → decreasing activity → → → → LOW
<u>(will displace others)</u> <u>(will not displace)</u>
F_2 Cl_2 Br_2 I_2
Li Rb K Ba Ca Na Mg Al Mn Zn Fe Ni Sn Pb H Cu Hg Ag Pt Au

3) examples

EXAMPLE 3) aluminum + sulfuric acid → ?

Al > H on the activity series, so it will replace it.

$Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2$

$\underline{2}Al + \underline{3}H_2SO_4 \rightarrow Al_2(SO_4)_3 + \underline{3}H_2$

EXAMPLE 4) tin + sodium nitrate → ?

Sn < Na; Sn is not "strong" enough to displace Na.

$Sn + NaNO_3 \rightarrow$ N.R. (no rxn.)

D. **<u>double replacement (double displacement)</u>** **AB + CD → AD + CB**

1) a *swapping* of cations in a reaction
2) usually occurs in aqueous solution (aq)
3) **** characteristics of at least one of the products: solid* (**<u>precipitate</u>**), *gas, or molecular cmpd.*
4) examples

$NaOH\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$ $BaCl_2 + K_2CO_3 \rightarrow BaCO_3 + 2KCl$

E. **combustion**

1) *burning*
2) *always involves oxygen (O_2) as a reactant*
3) hydrocarbon **complete combustion** (general format):

$C_xH_y + O_2 \rightarrow CO_2 + H_2O$ **$C_xH_y + (x + y/4)O_2 \rightarrow xCO_2 + (y/2)H_2O$**

4) hydrocarbon **incomplete combustion** (general format):

$C_xH_y + O_2 \rightarrow CO + H_2O$

IV. Reactions in Aqueous Solution

A. **aqueous solution (aq)**—*homogeneous mixture of solute and solvent*

1) **solute**—*substance being dissolved*
   a) can be a solid, liquid, or gas
   b) can be molecular (polar) or ionic
2) **solvent**—*substance doing the dissolving* (in this case, water)

B. types of reactions in aqueous solutions

1) rxns that form precipitates (**precipitate**—*a solid formed from a chemical reaction)*
2) rxns. that form water $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
3) rxns. that form gases

C. net ionic equations

1) **complete ionic equation**—an equation showing dissolved (aq) ionic cmpds. (compounds) as free ions
2) **spectator ions**—*ions not directly involved* in the rxn.
3) **net ionic equation**—equation only showing particles involved in the rxn.
   a) *leave (s), (g), (l) intact*
   b) *go backwards from crisscross to "take ionic cmpds. apart"*
   c) *eliminate ions which are shown as spectator ions on both sides*
   d) *balance the net ionic equation when finished*

4) examples

EXAMPLE 5) $Pb(NO_3)_2(aq) + KI(aq) \rightarrow PbI_2(s) + KNO_3(aq)$ unbalanced

$Pb^{2+}(aq) + (NO_3)^-(aq) + K^+(aq) + I^-(aq) \rightarrow PbI_2(s) + K^+(aq) + (NO_3)^-(aq)$
$Pb^{2+}(aq) + \cancel{(NO_3)^-(aq)} + \cancel{K^+(aq)} + I^-(aq) \rightarrow PbI_2(s) + \cancel{K^+(aq)} + \cancel{(NO_3)^-(aq)}$
$Pb^{2+}(aq) + I^-(aq) \rightarrow PbI_2(s)$ unbalanced
$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$ balanced

EXAMPLE 6) $NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3(PO_4)(aq) + H_2O(l)$ unbalanced

$Na^+(aq) + (OH)^-(aq) + H^+(aq) + (PO_4)^{3-}(aq) \rightarrow Na^+(aq) + (PO_4)^{3-}(aq) + H_2O(l)$
$\cancel{Na^+(aq)} + (OH)^-(aq) + H^+(aq) + \cancel{(PO_4)^{3-}(aq)} \rightarrow \cancel{Na^+(aq)} + \cancel{(PO_4)^{3-}(aq)} + H_2O(l)$
$(OH)^-(aq) + H^+(aq) \rightarrow H_2O(l)$ balanced

V. Nature of Reactions

A. *overall equations* – reactions formed from combining a stepwise reaction mechanism

B. **reversible reactions**—reactions which can *change direction* (reversible reaction arrow is used)

1) **equilibrium**—a system in *balance* (no net change)

2) **dynamic equilibrium**— forward and backward reactions occur at the same rate

3) *LeChatelier's Principle—if a system at equilibrium is disturbed, it will correct itself to reestablish equilibrium*

A + B ⇌ C + D

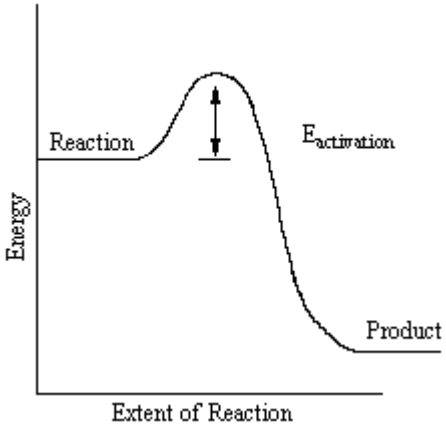
a) Changing direction

- add more A/B, or remove C/D, so more C/D will be produced
- add more C/D, or remove A/B to form more A/B

b) Adding or removing energy (heat)

C. reaction rate

1) **activation energy** (E_a) – amount of energy needed to initiate a reaction



2) **catalyst**—*substance which lowers the activation energy without acting as reactant or product (makes it easier to react)*

3) **inhibitor—**substance which retards reaction rate

4) *reaction speed*— measure production of products or disappearance of reactants

5) effects of *temperature*—more reactions go faster at higher temps.

6) *concentration*—increased concentration of reactants should increase reaction rate

7) **limiting reactant**—the parent chemical which will run out first; this controls the reaction

REACTION SUMMARY

1) **SYNTHESIS (COMBINATION)** $A + B \rightarrow AB$

2) **DECOMPOSITION** $AB \rightarrow A + B$

3) **SINGLE REPLACEMENT (SINGLE DISPLACEMENT)** $A + BC \rightarrow AC + B$

4) **DOUBLE REPLACEMENT (DOUBLE DISPLACEMENT)** $AB + CD \rightarrow AD + CB$

5) **COMBUSTION**

hydrocarbon COMPLETE COMBUSTION $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

hydrocarbon INCOMPLETE COMBUSTION $C_xH_y + O_2 \rightarrow CO + H_2O$