

**Nuggets:** *Balance Reactions; Electrolytes; Types of Reactions; Molecular, Complete Ionic, and Net Ionic reactions; Redox Reactions, Assign Oxidation Numbers, Oxidized, Reduced, Oxidizing Agent, Reducing Agent*

## CHAPTER 2

**IONIC INTERACTIONS** – held together by electrostatic forces (+ and – charged species)

$$\text{Force}_{\text{between ions}} = \frac{k(n^+e)(n^-e)}{d^2}$$

Comparing Forces of Different Ionic Compounds:

**Ionic Charges or Ionic Radii  $\uparrow \Rightarrow$  Force  $\uparrow$  and Force  $\uparrow \Rightarrow$  mp  $\uparrow$**

**Properties of Ionic Compounds:** Contains ions; hard; brittle; high bp and mp; often soluble in water and if it does then solution conducts electricity; molten solid conducts electricity

## CHAPTER 3

**ELECTROLYTES:** A chemical that produces ions; more ions means more electrical current can flow through solution

Strong-Electrolyte: Produces large numbers of ions (soluble ionic compounds; strong acids/bases)

Weak-Electrolyte: Produces only a small quantity of ions (weak acids/bases)

Nonelectrolyte: Produces no ions, e.g., sugar (insoluble ionic compounds; molecular compounds)

**Ionic Compounds:** Metal + nonmetal; **Molecular Compounds:** 2 nonmetals

Acids: Produce  $H^+$  in solution (e.g.,  $HCl \rightarrow H^+ + Cl^-$ );

Acids can be recognized when a H is at the beginning of a formula (exceptions:  $H_2O$  and  $H_2O_2$ )

Strong acids are acids that *completely* break up (dissociate) into  $H^+$ ; these are strong electrolytes

Strong Acids: HCl, HBr, HI,  $HNO_3$ ,  $H_2SO_4$ ,  $HClO_4$ ,  $HClO_3$  (helpful to memorize these)

Weak acid: an acid that isn't a strong acid; dissociates a little;

$HC_2H_3O_2$  (acetic acid) =  $CH_3COOH$  =  $CH_3CO_2H$ ,

Bases: Produce  $OH^-$  in solution (e.g.,  $NaOH \rightarrow Na^+ + OH^-$ )

Strong bases are bases that completely break up into  $OH^-$ ; these are strong electrolytes

Strong Bases: Group IA hydroxides (LiOH, NaOH, KOH, RbOH, CsOH);

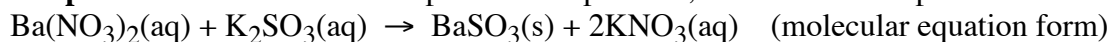
Group IIA hydroxides (only  $Sr(OH)_2$ ,  $Ba(OH)_2$ ) (helpful to memorize these)

Weak bases: any base that is not a strong base; produce a little  $OH^-$ ; weak electrolytes;

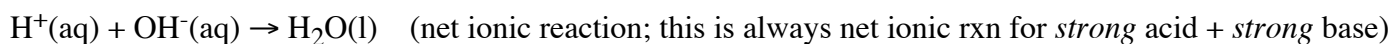
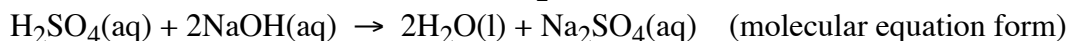
$NH_3$  (ammonia); better to write it as  $NH_4OH$

## TYPES OF REACTIONS

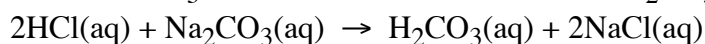
**1. Precipitation:** 2 soluble ionic compd "switch" partners; 1 new ionic compound is insoluble and precipitates



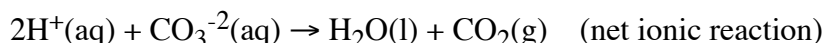
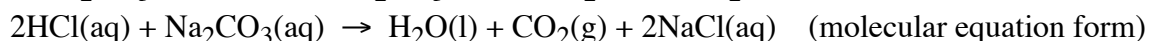
**2. Acid/Base Reactions:** Acid + Base  $\rightarrow$  H<sub>2</sub>O + salt (salt = ionic compound)



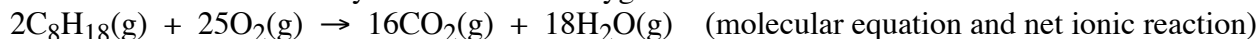
**3. Gas-Forming:** Reaction produces a gas; common example is acid + hydrogen carbonate (HCO<sub>3</sub><sup>-</sup>) or carbonate CO<sub>3</sub><sup>-2</sup>; either of these reactions form H<sub>2</sub>CO<sub>3</sub>(aq)  $\rightarrow$  H<sub>2</sub>O(l) and CO<sub>2</sub>(g).



the H<sub>2</sub>CO<sub>3</sub>(aq) breaks up: H<sub>2</sub>CO<sub>3</sub>(aq)  $\rightarrow$  H<sub>2</sub>O(l) + CO<sub>2</sub>(g) to yield an overall reaction:



**4. Combustion:** Reaction of hydrocarbon with oxygen to form water and carbon dioxide



**5. Redox:** Oxidation numbers change

**SOLUBILITY RULES (some) - Figure 3.10 for precipitation reactions (be familiar with/memorize)**

Soluble: Na<sup>+</sup>, K<sup>+</sup>, NH<sub>4</sub><sup>+</sup> (not: NH<sub>4</sub>OH), NO<sub>3</sub><sup>-</sup>, C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup> (not: HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>), ClO<sub>3</sub><sup>-</sup>, ClO<sub>4</sub><sup>-</sup>,

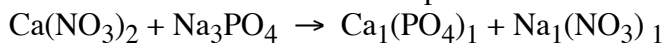
SO<sub>4</sub><sup>-2</sup> (not: Ca<sup>+2</sup>, Sr<sup>+2</sup>, Ba<sup>+2</sup>, Pb<sup>+2</sup>), Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup> (not: Ag<sup>+</sup>, Hg<sub>2</sub><sup>+2</sup>, Pb<sup>+2</sup>)

## WRITING REACTIONS

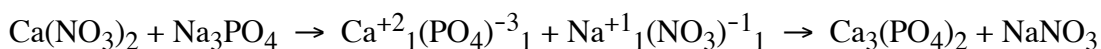
**1. Molecular Reaction:** All compounds are written in molecular form; no ions.

Example: Write the molecular, complete ionic, and net ionic reaction when 3Ca(NO<sub>3</sub>)<sub>2</sub> and Na<sub>3</sub>PO<sub>4</sub> are mixed.

1. Switch reactant parts (switch partners) in ionic or acid/base reactions; write CO<sub>2</sub> and H<sub>2</sub>O if combustion. At this time all subscripts should be one.



2. Balance the product formulas so charges total zero.



3. Balance the overall reaction.

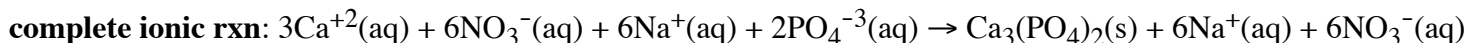


**2. Complete Ionic Reaction:** All soluble ionic compounds are written as ions with (aq)

Determine what type of chemical each reactant and product is and break up into ions when appropriate.

Break up into ions: ionic + soluble compounds; strong acids; and strong bases

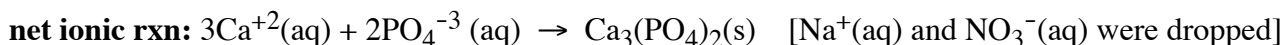
Exception: H<sub>2</sub>CO<sub>3</sub>(aq)  $\rightarrow$  H<sub>2</sub>O(l) + CO<sub>2</sub>(g)



**3. Net Ionic Reaction:** Ions that "react" are included; other ions (Spectator Ions) are not included

1. Cancel out ions from Complete Ionic Reaction where possible.

If everything cancels out  $\rightarrow$  No reaction! Watch out for H<sub>2</sub>CO<sub>3</sub>.



**Oxides of nonmetals + H<sub>2</sub>O(l)  $\rightarrow$  Acids** Example: SO<sub>2</sub>(g) + H<sub>2</sub>O(l)  $\rightarrow$  H<sub>2</sub>SO<sub>3</sub>(aq)

**Oxides of metals + H<sub>2</sub>O(l)  $\rightarrow$  Bases** Example: MgO(s) + H<sub>2</sub>O(l)  $\rightarrow$  Mg(OH)<sub>2</sub>(aq)

**EQUILIBRIUM** – many reactions don't proceed to completion (100% to products); instead, both products *and* reactants exist *simultaneously*; reactions go in the *forward direction* (to the right) and *reverse direction* (to the left) and this backwards and forwards process is called **dynamic equilibrium**

**Product favored reaction** – mainly products are formed

**Reactant favored reaction** – reactants stay as reactants and little product is formed

*Reactions often (not always!) will be driven away from strong acids, strong bases (they favor the side the strong acids and bases are not on); they often will go towards solids (precipitates) and gases*

**REDOX** - oxidation - loss of electrons; reduction - gain of electrons

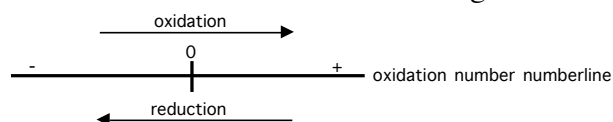
Oxidation reaction **cannot** occur without reduction reactions, and vice-versa

**LEO the lion goes GER** (LEO - Lose electrons is oxidation; GER - Gain electrons is reduction)

Reducing agent - that which causes something else to be reduced; the reducing agent is oxidized

Oxidizing agent - that which causes something else to be oxidized; the oxidizing agent is reduced

Redox reactions occur when there is a change in oxidation number



**ASSIGNING OXIDATION NUMBERS** - Bookkeeping of electrons

1. Elements in elemental form      0

2. In a compound.

a. Group 1A (Li, Na, ...)      +1

b. Group 2A (Be, Mg, ...)      +2

c. F      -1

d. H      +1 (usually)

e. O      -2 (usually)

3. Sum Rule: Sum of all the oxidation numbers = total charge on compound

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1. Which of the following ionic solids will have the highest melting point? Keep in mind that as you go down a column on the periodic table, the ions get larger.

a. NaCl                      b. LiF                      c. MgS                      d. BeO                      e. all have the same mp

2. 25.0 grams of metal chloride,  $MCl_2$ , is electrolyzed to produce 13.18 grams of  $Cl_2$ . The metal, M, is

3. A metal oxide,  $M_3O_2$ , is 86.73% by mass metal, M. Calculate the atomic mass of the metal.

4. Balance the following equations.

a.  $Mg + SiO_2 \rightarrow MgO + Si$

b.  $Ca(s) + N_2(g) \rightarrow Ca_3N_2(s)$

c.  $CH_3OH + O_2 \rightarrow CO_2 + H_2O$

d.  $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + NaCl$

e.  $P_4O_{10} + H_2O \rightarrow H_3PO_4$

f.  $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

g.  $C_3H_6 + O_2 \rightarrow CO_2 + H_2O$

5. Which of the following are soluble in water?

a. NaCl      b.  $Na_2S$       c. FeS      d. sucrose (sugar)      e. AgCl      f. HF      g. KOH

h.  $Fe(OH)_3$       i.  $FeCl_3$       j.  $CrPO_4$       k.  $(NH_4)_2CO_3$

6. a. When hydrochloric acid dissolves in water the reaction occurs:  $\text{HCl(aq)} \rightleftharpoons \text{H}^+ + \text{Cl}^-$  Is this reaction product-favored or reactant-favored?

b. When silver(I) nitrate is mixed with sodium chloride, a solid silver(I) chloride is formed. Is the reaction product-favored or reactant-favored?

7. Write balanced molecular reactions for each of the following (recall that combustion refers to the reaction of a hydrocarbon with oxygen gas,  $\text{O}_2$ , to produce water,  $\text{H}_2\text{O}$ , and carbon dioxide,  $\text{CO}_2$ ). Include phases [(aq), (s), (l), (g)].

a. gaseous pentane ( $\text{C}_5\text{H}_{12}$ ) is combusted

b. gaseous ethylene ( $\text{C}_2\text{H}_4$ ) is combusted

c. aqueous  $\text{HCl}$  and  $\text{Ba(OH)}_2$  react

d. aqueous  $\text{AgNO}_3$  and  $\text{NaBr}$  reacting

8. Identify the following chemicals when they are dissolved into water as a strong, weak, or nonelectrolytes. (Recall: strong acid/strong base/soluble ionic: strong electrolyte; weak acid/weak base: weak electrolyte; insoluble ionic/molecular: nonelectrolyte)

a.  $\text{NaCl}$

b.  $\text{HCl}$

c.  $\text{HC}_2\text{H}_3\text{O}_2$

d. sugar

e.  $\text{BaSO}_4$

f.  $\text{NH}_3$

g.  $\text{H}_2\text{SO}_4$

h.  $\text{NaOH}$

i.  $\text{HF}$

9. Which of the following compounds will form a solution that is a poor conductor of electricity? If they all do, select "e."

a.  $\text{NaCl}$

b.  $\text{KOH}$

c.  $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$

d.  $\text{HClO}_4$

e. None form a poor conductor

10. a. Write the molecular reaction of sodium oxide with water.

b. Write the molecular reaction of  $\text{P}_4\text{O}_{10}$  with water.

11. a. What are the seven common strong acids and seven strong bases (give name and chemical formula)? b. Identify (name and chemical formula) one common weak acid and one common weak base.

12. For each reaction identify whether the reaction would be product-favored or reactant-favored.

a.  $\text{HCl} + \text{H}_2\text{O} \rightarrow \text{Cl}^- + \text{H}_3\text{O}^+$

b.  $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$

c.  $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$

d.  $\text{NaF} \rightarrow \text{Na}^+ + \text{F}^-$

13. Write the balanced molecular and net ionic reaction for each of the following. If no reaction occurs, write no reaction. (Hint: Start by writing a molecular reaction, then a complete ionic, and then a net ionic.) Include phases [(aq), (s), (l), (g)].

a. An aqueous solution of  $\text{KCl}$  is combined with an aqueous solution of  $\text{AgNO}_3$  to yield a precipitate.

b. Aqueous  $\text{Pb(NO}_3)_2$  and aqueous  $\text{NaI}$  are combined.

c. A solution of  $\text{HCl}$  and a solution of  $\text{KOH}$  are combined.

d. A solution of sodium hydrogen carbonate is mixed with nitric acid.

e. A balloon containing oxygen gas and hydrogen gas is combusted.

f. Aqueous  $\text{BaCl}_2$  and aqueous  $\text{K}_2\text{SO}_4$  are mixed together to yield an insoluble precipitate.

g. The addition of aqueous  $\text{Mn(NO}_3)_2$  to an aqueous solution of  $\text{Na}_3\text{PO}_4$ .

14. Identify the type of reaction [gas-forming, acid-base, or precipitation] that is occurring below. (Note: use only one label for each reaction.)

a.  $2\text{KI(aq)} + \text{Pb(NO}_3)_2\text{(aq)} \rightarrow 2\text{KNO}_3\text{(aq)} + \text{PbI}_2\text{(s)}$

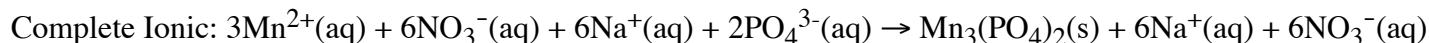
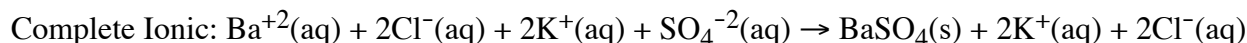
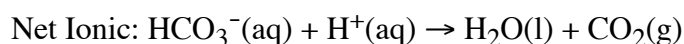
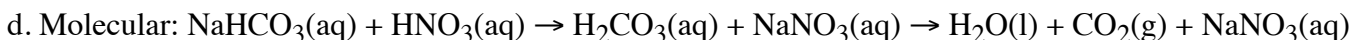
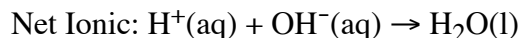
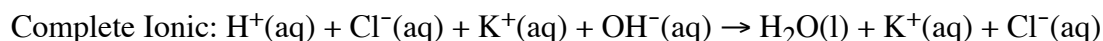
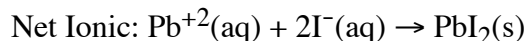
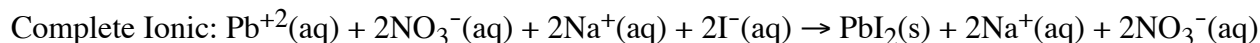
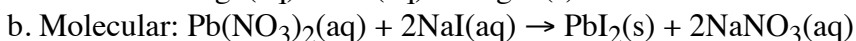
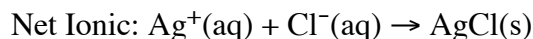
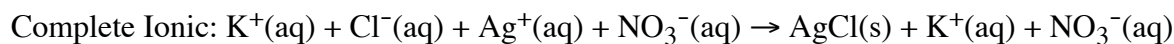
b.  $\text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{H}_2\text{O(l)} + \text{NaCl(aq)}$

c.  $\text{AgNO}_3\text{(aq)} + \text{NaCl(aq)} \rightarrow \text{AgCl(s)} + \text{NaNO}_3\text{(aq)}$

d.  $\text{Cd(NO}_3)_2\text{(aq)} + \text{H}_2\text{S(g)} \rightarrow \text{CdS(s)} + \text{HNO}_3\text{(aq)}$

e.  $\text{FeCO}_3\text{(aq)} + \text{HC}_2\text{H}_3\text{O}_2\text{(aq)} \rightarrow \text{Fe(C}_2\text{H}_3\text{O}_2)_2\text{(aq)} + \text{CO}_2\text{(g)} + \text{H}_2\text{O(l)}$





14. a. precipitation b. acid/base c. precipitation d. precipitation e. gas-forming

15. a. Na = 0 b. Fe = 0 c. Cl = 0 d. Li = +1 e. Br = -1 f. N = +2, O = -2 g. N = +4, O = -2

h. Na = +1, Cl = -1 i. Na = +1, N = +5, O = -2 j. N = +5, O = -2 k. P = +5, O = -2 l. H = +1, O = -2

m. H = +1, S = +6, O = -2 n. Ca = +2, N = +5, O = -2 o. S = +2, O = -2 p. C = +4, O = -2

q. Mn = +2, S = +6, O = -2 r. Cr = +2, P = +5, O = -2 s. Cu = +1, N = 5, O = -2

t. N = -3 (of  $\text{NH}_4$ ), H = +1, N = +5 (of  $\text{NO}_3$ ), O = -2

16. a.  $\text{S}^{2-}$  is oxidized,  $\text{NO}_3^-$  is reduced,  $\text{NO}_3^-$  is the oxidizing agent,  $\text{S}^{2-}$  is the reducing agent

b. Cu is oxidized,  $\text{NO}_3^-$  is reduced,  $\text{NO}_3^-$  is the oxidizing agent, Cu is the reducing agent

c.  $\text{SO}_2$  is oxidized,  $\text{MnO}_4^-$  is reduced,  $\text{MnO}_4^-$  is the oxidizing agent,  $\text{SO}_2$  is the reducing agent

d.  $\text{H}_2\text{S}$  is oxidized,  $\text{Hg}_2^{2+}$  is reduced,  $\text{Hg}_2^{2+}$  is the oxidizing agent,  $\text{H}_2\text{S}$  is the reducing agent