NOTES #57 LEWIS ACIDS AND BASES, COMPLEX IONS, Ksp AND INCREASING SOLUBILITY

1. So far, we have just talked about the Arhennius and Brønsted definitions of acids and bases. A Brønsted acid is a substance that _____ an H^+ and a Brønsted base is a substance that _____ an H^+. ***The Brønsted definition is based on H^+.***

2. A much more GENERAL way of defining acids and bases is the LEWIS ACID/BASE definition which states: A Lewis acid is a substance that can ACCEPT A PAIR OF ELECTRONS. A Lewis base is a substance that can DONATE A PAIR OF ELECTRONS. ** ***Notice, the Lewis definition is based on acceptance/donation of _____.***

3. ALL of the Brønsted acids and bases we've seen can also be classified as Lewis acids and bases. (Is the converse true? We'll see.)

EX: $H^+ + NH_3 \rightleftharpoons NH_4^+$ EX: $H^+ + H_2O \rightleftharpoons H_3O^+$

4. The Lewis acid/base definition also covers a wealth of reactions that DO NOT involve the transfer of H^+. Label the Lewis acid and Lewis base in the following example.

a. Boron compounds and Aluminum compounds are well documented *STRONG* Lewis acids because they so often *need* an electron pair to fill their octets.

EX: $BF_3 + NH_3 \rightarrow BF_3\text{-}NH_3$ This is called an "adduct".

This is an example of a _____ bond.

** Could BF_3 also be called a Brønsted acid? Could NH_3 be a Brønsted base?

b. The formation of many of the oxyacids are also examples of Lewis acid/base process. EX: $SO_3 + H_2O \rightarrow$

c. Transition metals are also known to need electron pairs and act as Lewis acids.
For each example, label the Lewis acid and Lewis base. (see the half-sheet concerning complex ions)

EX: $Ag^+ (aq) + 2\ NH_3 (aq) \rightleftharpoons Ag(NH_3)_2^+ (aq)$ $SnCl_4 (s) + 2\ Cl^- (aq) \rightleftharpoons SnCl_6^{2-} (aq)$

EX: The hydration of metal cations is another example of a Lewis acid/base process.

$Cu^{2+} (aq) + 4\ H_2O (l) \rightleftharpoons Cu(H_2O)_4^{2+} (aq)$

COMMON ION EFFECT and SOLUBILITY

1. Consider the solubility expression for compound, AgCl. $AgCl (s) \rightleftharpoons$ Ksp = [ ] [ ]

What affect would adding some $AgNO_3$ to the solution have on Q, the ion product? What would the system have to do to re-reach equilibrium? (Hint: what is the common ion?) *Equilibrium would shift to the*_____.

2. In summary, adding a common ion to a solution _____ the solubility of the salt in solution.

EX 1: Calculate the solubility in g/L of AgBr in (a) pure water and (b) in 0.0010 M NaBr. Ksp = 7.7×10^{-13}
FIRST, make a prediction: _____

II. pH and SOLUBILITY

1. The pH of a solution can greatly affect a salt's solubility. It's all about Le Chatelier's Principle!

2. Consider the solubility expression for magnesium hydroxide. $Mg(OH)_2 (s) \rightleftharpoons$

Thinking about Le Chatelier's Principle, the addition of more OH^- would shift the equilibrium _____ which would _____ the solubility of $Mg(OH)_2$. Adding more H^+, however, would _____ and would shift the equilibrium to the _____ which would _____ the solubility of $Mg(OH)_2$.

** So, in an _____ solution, $Mg(OH)_2$ solid has a much greater solubility. This should help you understand why you can ingest some Milk of Magnesia and it dissolves enough to make acid indigestion feel better.

3. This idea also applies to other salts with other types of anions that HYDROLYZE. Consider the solubility expression for Silver Phosphate. Ag_3PO_4 (s) ⇌ Ksp = [ ] [ ]

What kind of reactivity would happen in an ACIDIC solution? ** The weak acid, _____, would be formed. So, in an ACIDIC solution, Ag_3PO_4 would demonstrate _____ solubility due to the fact that the H^+ would react with the base, PO_4^{3-}. This would cause Q to_____, shifting equilibrium to the _____.

4. SUMMARY: We have to figure out WHICH salts will be MORE soluble in an acidic medium and those salts that are not affected by pH.

HINT!!! VERY few salts become more soluble in a basic medium.

a. The general rule is that if A- is a CONJUGATE BASE of a weak acid, the salt, MA, will show _____ solubility in an acidic medium. (Why? Because the presence of H^+ will encourage the formation of the weak acid, HA...which will decrease the [A-] pushing the solubility equilibrium to the right....)

Examples of anions that are conjugate bases of weak acids: _____

b. Solubility of salts that contain ions that DO NOT hydrolyze because if they did they would produce strong acids and bases are NOT affect by pH. Examples of salts that contain anions that are NOT affected by pH, in other words, do NOT _____include: _____

EX2: Which of the following compounds would be MORE soluble in an acidic solution? EXPLAIN.
$Ca(OH)_2$ ⇌ $PbBr_2$ ⇌ CuS ⇌ Ag_2CO_3 ⇌

5. CALCULATIONS, pH, AND SOLUBILITY.

EX3: Calculate the molar solubility of silver hydroxide at a pH of 8.0 and 10.0. Ksp = 2.0×10^{-8}. Comment on these solubility differences.

EX4: Calculate whether or not a precipitate will form if 2.000 mL of 0.600 M NH_3 are added to 1.0000 L of 1.00×10^{-3} M $FeSO_4$. ↓We will ignore complex ions to study the math! (In reality complex ions always win! Huge Kf values, right?)

III. COMPLEX ION EQUILIBRIA AND SOLUBILITY

1. What ARE complex ions? An ion that contains a central _____ attracted to one or more molecules or ions. Complex ions are held together with IMFs. Their attachments are referred to as _____ .

2. Notice that complex ion formation is a LEWIS ACID/BASE process:
Ex: $Ag^+ + 2\ CN^- \leftrightarrow Ag(CN)_2^-$ Kf = 1.0×10^{21}

3.Complex ion formation is usually VERY favorable and as a result, has a _____ Kf value. Examples of complex ion formation reactions were given to you in a summary sheet. YOU SHOULD MEMORIZE THESE REACTIONS! Notice that it's easy to predict the products of complex ion formation reactions if you . . . LOOK FOR TRENDS:

Ligand/charge ratio? Kf values? Colors? Summary of charges? What types of ligands are common?

4. The formation of complex ions can _____the solubility of a substance. Calculations can be done to show this, we will just understand this process conceptually!

EX 5: Explain how the solubility of AgCl would be INCREASED in a 1 M NH_3 solution as compared to solubility in water.