Names: _____

Workshop: Solubility Equilibria II

1. A number of factors can affect calculations of equilibria involving slightly soluble salts. Consider how the solubility of a salt is affected when it is dissolved in pure water compared to when it is dissolved in a solution that contains one of the ions found in the slightly soluble salt.

$$K_{sp} = 1.4 \times 10^{-10} \text{ for copper(II) carbonate}$$

(a) What is the solubility of copper(II) carbonate in g/100 mL of pure water? Show your calculation

(b) Use Le Chatelier's principle to predict the shift that would occur in the copper(II) carbonate equilibrium if carbonate ion were added to the system. Briefly explain:

(c) What is the solubility of copper(II) carbonate in 0.0010 M sodium carbonate? Show your calculation.

(d) How does your prediction from Part (b) correspond with the numerical results from Parts (a) and (c)?

2. The solubility of slightly soluble salts can be effected by the formation of complex ions. A complex ion is composed of a central positively charged ion and attached electron-pair donor species. In a solution containing silver and chloride ions, for example, the dichloroargentate(I) ion forms:

$$Ag^+(aq) + 2\ Cl^-(aq) \rightleftharpoons AgCl_2^-(aq) \quad K_f = 1 \times 10^6$$

Of course, the equilibrium between the slightly soluble salt and its ions occurs simultaneously in the solution:

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \quad K_{sp} = 1.8 \times 10^{-10}$$

How will the solubility of a slightly soluble salt be effected if its ions form a complex ion? To answer this question, perform the following calculations and show your work.

(a) Determine the solubility of silver chloride (g/100 mL) neglecting the effect of the complex ion formation.

(b) Add the two equations to get the net overall reaction and calculate the resulting equilibrium constant.

(c) Determine the solubility (g/100 mL) for the overall process.

(d) Compare the solubilities. What effect does complex ion formation have on the solubility of the salt?

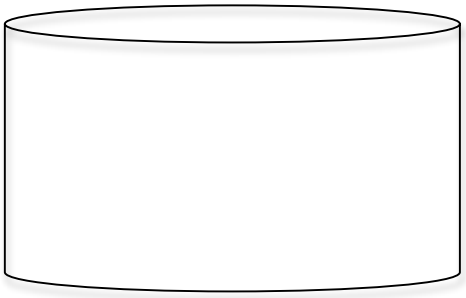
3. Consider these qualitative experimental results:

(1) Very dilute solutions of $Ba(NO_3)_2(aq)$ and $Na_2CO_3(aq)$ are poured into a large beaker half filled with pure water. A hazy cloud forms.

(2) Very dilute solutions of $Ba(NO_3)_2(aq)$ and $Na_2CO_3(aq)$ are poured into a large beaker half filled with KCl(aq) solution. The solution remains clear.

a) What causes the hazy cloud in Experiment (1)? Briefly explain.

b) Experiment (2) is an example of a phenomenon called the *salt effect*, where the solubility of a slightly soluble salt is increased by the presence of ions in the solution that are not common with the slightly soluble salt. In this case, potassium ions are attracted to the carbonate ions in the solution. Similarly, chloride ions are attracted to the barium ions. This keeps the barium and carbonate ions from combining to form a precipitate, as long as they are in low concentration relative to their solubility limit. Sketch a particulate-level diagram of this effect, and explain how your sketch illustrates the salt effect.



Explanation:

4. If we use the solubility product constant to predict the solubility of silver bromide in pure water, the result of the theoretically-based calculation matches the experimental result. On the other hand the experimentally determined solubility of silver carbonate does not match the solubility determined from a K_{sp} calculation.

a) $K_{sp} = 8.1 \times 10^{-12}$ for silver carbonate. Calculate the theoretical solubility (g/100 mL) in pure water.

b) Bromide ion is the conjugate base of a strong acid; carbonate ion is the conjugate base of a weak acid. How do these facts correlate with the theory/experiment results for silver bromide and silver carbonate? Do you expect silver carbonate to be more or less soluble than the K_{sp} calculation would predict? Explain.

c) Assume that the carbonate ion reacts to form its conjugate acid in solution:

$$CO_3^{2-}(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + OH^-(aq) \quad K = 1.8 \times 10^{10}$$

Calculate the solubility (g/100 mL) of silver carbonate that should result from the combination of the two equilibrium systems.

5. Reconsider dissolving silver bromide and silver carbonate. If your objective was to get each of these slightly soluble compounds to dissolve, and you had available concentrated solutions of hydrochloric acid and hydrobromic acid, what would be the effect on each of the salts? Qualitatively consider all four possible combinations.

	HCl	HBr
AgBr		
Ag_2CO_3		