9—Solubility of Potassium Bitartrate

Name: ______________________________

Date: ______________________________

Section: ______________________________

Objectives

- You will be able to explain how the presence of a common ion in a slightly soluble ionic compound affects the solubility and the solubility product of a slightly soluble substance.
- You will gain additional understanding of ionic equilibria in aqueous solutions

Pre-Laboratory Requirements

- Read Chapter 19.3, pp 633-643, in Silberberg
- Pre-Lab Questions (if required by your instructor)
- Laboratory Notebook—prepared before lab (if required by your instructor)

Safety Notes

- Eye protection must be worn at all times

Discussion

Slightly soluble ionic solids exist in equilibrium between two phases. We call the solid phase a precipitate when it is in equilibrium with anions and cations from the ionic solid. Limestone is a common mineral in the Shenandoah Valley, and its chemical name is calcium carbonate. Calcium carbonate is a slightly soluble ionic solid and an important mineral in many regions of the earth because of the solubility properties of slightly soluble ionic solids.

The solid form of calcium carbonate, $CaCO_3$, dissolves in neutral water forming calcium ions, Ca^{2+}, and carbonate ions, CO_3^{2-}. In the presence of water an equilibrium exists between solid calcium carbonate *molecules* and soluble calcium *ions* and carbonate *ions*. The calcium carbonate equilibrium is:

$$CaCO_3\,(s) \rightleftarrows Ca^{2+}(aq) + CO_3^{2-}(aq)$$

The solubility of calcium carbonate in neutral water is 0.013 g/L. Although 0.013 g/L is a very small number, over millions of years water is capable of dissolving huge quantities of limestone, forming large canyons (i.e., the Grand Canyon), making sinkholes, and forming beautiful geologic formations called travertine. These things happen because the ions in solution move with the water, and Le Chatelier's principal demands that more ions from the solid will go into solution to replace the ions that were transported away. Over time, millions of cubic yards of limestone can be transported by streams to the oceans. Ocean water eventually becomes supersaturated and precipitates calcium carbonate on the floor of the ocean, creating new limestone that will appear on land millions of years later.

The solubility product constant, K_{sp}, is the equilibrium expression used to mathematically describe the relationship between a solid substance and ions in solution. The equilibrium constant is defined in the same way we defined equilibrium constants when all species remained in solution. However, because the solid is a different phase than the ions in solution, the solid is dropped from the equilibrium expression. The solubility product constant for the calcium carbonate equilibrium is:

$$K_{sp} = \frac{[Ca^{2+}][CO_3^{2-}]}{[CaCO_3(s)]} = [Ca^{2+}][CO_3^{2-}]$$

Procedure

In this experiment, you will test how the solubility of potassium bitartrate ($KHC_4H_4O_6$) in water is affected by the presence of other ions in the solution. Potassium bitartrate dissociates in solution according to the following equation:

$$KHC_4H_4O_s(s) \rightarrow K^+ + HC_4H_4O_6^- \ (aq)$$

The solubility product for this reaction is:

$$K_{sp} = [K^+][HC_4H_4O_6^-]$$

We will prepare 6 solutions containing different amounts of K^+, and after giving the solutions time to equilibrate, titrate the solutions to measure the concentration of bitartrate ($HC_4H_4O_6^-$). The concentration of bitartrate in each solution can then be used with the amount of potassium to calculate the solubility product of $KHC_4H_4O_6$ for each of the 6 solutions. The neutralization reaction of sodium hydroxide with bitartrate is:

$$[HC_4H_4O_6^-] + OH^- \rightarrow [C_4H_4O_6^{2-}] + H_2O$$

The number of moles of OH^- titrated is therefore a direct measure of the number of moles of bitartrate. Note: When calculating $[K^+]$, remember to include the amount of potassium contributed by the KCl solution *and* the amount contributed by the dissolved $KHC_4H_4O_6$.

Each pair of students will be assigned one solution from the table below to prepare:

Solution Number	Vol. of 0.100 *M* KCl (mL)	Vol. of 0.100 *M* NaCl (mL)
1	50.0	0.0
2	40.0	10.0
3	30.0	20.0
4	20.0	30.0
5	10.0	40.0
6	0.0	50.0

Part I. Preparation of a Saturated $KHC_4H_4O_6$ Solution

1. Measure about 1.0 g of $KHC_4H_4O_6$ into a 100 mL beaker
2. Add the volumes of 0.100 *M* KCl and 0.100 *M* NaCl for <u>your assigned solution</u> to the beaker using a graduated cylinder for measurement
3. Stir the mixture on a stir plate using a stir bar for 20 minutes
4. After 20 minutes, gravity filter the mixture to separate any undissolved $KHC_4H_4O_6$ from the solution (***Note: save the filtrate-this is the saturated*** $KHC_4H_4O_6$ ***solution***)

Part II. Titration of the Saturated $KHC_4H_4O_6$ Solution

1. Pipet a 20.00 mL sample of the saturated $KHC_4H_4O_6$ solution into a 125 mL Erlenmeyer flask
2. Add 25 mL of water to the flask and add 1-2 drops of phenolphthalein indicator
3. Titrate the sample with NaOH to the endpoint (be sure to record the molarity of NaOH)
4. Repeat this procedure with another 20.00 mL sample of the saturated $KHC_4H_4O_6$ solution
5. Calculate the concentration of $HC_4H_4O_6^-$ in the solution (*Note: the solubility is equal to [$HC_4H_4O_6^-$]*)
6. Calculate the Ksp of $KHC_4H_4O_6$ using the equation: Ksp = [K+][$HC_4H_4O_6$]

Titration Data

Solution number: __________ Molarity of NaOH: __________________________

	Trial 1	Trial 2
Vol. saturated $KHC_4H_4O_6$ (mL)	20.00 mL	20.00 mL
Molarity of NaOH solution		
Initial buret reading (mL)		
Final buret reading (mL)		
Volume of NaOH (mL)		
Moles of NaOH		
Moles of $HC_4H_4O_6^-$		
[$HC_4H_4O_6^-$]		
Average [$HC_4H_4O_6^-$]		
Solubility (mol/L)		
$[K^+]_{KHC4H4O6}$		
$[K^+]_{KCl}$		
$[K^+]_{total}$		
K_{sp}		

Calculations:

Class Data

Solution	$[K^+]_{KCl}$	$[K^+]_{total}$	$[HC_4H_4O_6^-]$	Solubility	K_{sp}	Average K_{sp}
1						
1						
2						
2						
3						
3						
4						
4						
5						
5						
6						
6						

What trends/relationships do you see in this data? Give an explanation for these observations.

Mental Model. Draw a picture(s) showing the relationships identified above. The pictures should depict what is happening on the molecular level.