Online Activity 5

Determining K_{sp}

Introduction

The solubility product constant, or K_{sp} of a compound is an equilibrium constant that describes the degree to which a solid dissolves in water. The K_{sp} is calculated based on the chemical reaction that describes the equilibrium between the solid salt and the dissolved ions. By convention, the equation is written with the solid salt and water as reactants and the cations and anions produced when the solid dissolves are the products.

$$Sr(IO_3)_2\ (s) + H_2O(l) \leftrightarrow 2IO_3^-\ (aq) + Sr^{2+}\ (aq)$$

Since solids and pure liquids have a constant concentration, they are not included in the K_{sp} expression, thus the value of the dominator is 1, leaving the K_{sp} dependent purely on the concentrations of the ions produced in the reaction, rather than directly based on the amount of solid added to the water.

$$K_{sp} = [Sr^{2+}]\ [IO_3^-]^2$$

Saturated Solutions

Since the K_{sp} is an equilibrium reaction, the concentrations of the reactants must be at a level that with a slight increase of either one, the solid salt will be produced and precipitate out of the solution. Therefore, to measure the Ksp, a saturated solution must first be prepared. A saturated solution is one in which the maximum concentration of ions has been achieved in the solution. It can be done by adding a salt to water until you see some of the salt sitting on the bottom of the beaker. AT this point no more salt will be dissolved and the solution is said to be saturated. A measurement of the saturation of a solution is called the solubility and is usually measured in grams of salt/100 mL of water. For very soluble salts, such as NaCl, the solubility is approximately 38g/100 mL. For the salt used in this experiment, $Sr(IO3)_2$, the solubility is only about 0.05g/100 mL of water. Thus, there is a huge range in solubility of different salts. These solubility differences can be used to create a precipitate from two more soluble salts. This can be done by reacting two solutions prepared from soluble salts that contain ions that result in a product that is less soluble.

In this reaction, you will use strontium nitrate, $Sr(NO_3)_2$, and potassium iodate, KIO_3, to produce a relatively insoluble salt, strontium iodate, $Sr(IO_3)_2$, that will precipitate from the solution.

$$Sr(NO_3)_2\ (aq) + 2KIO_3(aq) \leftrightarrow\ Sr(IO_3)_2\ (s) + 2K^+\ (aq) + 2NO_3^-\ (aq)$$

The potassium ion, K^+ and the nitrate ions, NO_3^- do not play a role in this equilibrium as they do not react, leaving the net ionic equation as that of the precipitation. Note that the precipitation reaction is the reverse of the reaction used to calculate K_{sp}.

$$\text{Equilibrium reaction: } Sr^{2+}\ (aq) + 2IO_3^-(aq) \leftrightarrow\ Sr(IO_3)_2(s)$$

Thus, by reversing this reaction, the K_{sp} can be calculated if the concentration of either the cation or anion can be determined since their concentrations are related to each other through the equilibrium reaction.

Calculation of K_{sp}

Once you have determined the concentration of one of the ions in the saturated solution, you can use the mole ratio of the ions in the solid to find the concentration of all other ions making up the solid. In your experiment, solid $Sr(IO_3)_2$ breaks up into 2 moles of IO_3^- and 1 mole of Sr^{2+} for every mole of solid that dissolves. Thus, to find the concentration Sr^{2+}, just divide the concentration of IO_3^- by 2.

$$Sr(IO_3)_2\ (s) + H_2O(l) \leftrightarrow 2IO_3^-\ (aq) + Sr^{2+}\ (aq)$$

The solubility product constant, Ksp, is literally the product of the concentrations of all of the ions produced by the solid dissolving and can be calculated using the following equation.

$$K_{sp} = [Sr^{2+}] \times [IO_3^-] \times [IO_3^-] = [Sr^{2+}]\ [IO_3^-]^2$$

In Your Simulation…
You already calculated K_{sp} values in the last simulation, so this activity should be familiar to you. In this simulation, you will determine the solubility products, K_{sp}, of three slightly soluble salts, aluminum hydroxide, ($Al(OH)_3$), calcium phosphate ($Ca_3(PO_4)_2$), and strontium iodate ($Sr(IO_3)_2$), by measuring their concentrations in saturated solutions. You will need to write out the balanced equations for the dissolution of each material and determine their solubility product expressions in order to calculate their K_{sp} values from the solubility data.

You will determine the concentration of each material using a chemcollective.org simulation called Determining the Solubility Product. The link is http://chemcollective.org/vlab/88 (this is the same simulation that you used for Online Activity 4, so it should be familiar to you.

The simulation will give you the ion concentrations in the saturated solution. Plugging the appropriate ion concentrations into the solubility product expressions will give you values for the K_{sp} of each salt.

Online Activity 5: Procedure and Data Sheet
Include as part of your Online Activity Report

Record all measurements with the correct number of significant figures and units.

1. Go to the ChemCollective simulation Determining the Solubility Product at http://chemcollective.org/vlab/88
2. In the "Stockroom: menu on the right, select solutions, then click on the 100mL flask of distilled water and the $Al(OH)_3$ to add them to your workbench. The flask of 100mL distilled water is at the end of the list.
3. Select tools, and add the balance to your workbench.
4. Select glassware, then other, and add a plastic weigh boat to your work bench.
5. Drag the weigh boat over your balance until you see a green + sign telling you that the weigh boat is being placed on the balance.
6. Drag the aluminum hydroxide over the weigh boat until you see the green + sign. Type in 1.000 to add 1.000g aluminum hydroxide to the weigh boat.
7. Drag the weigh boat over the flask containing 100mL distilled water until you see the green + sign. Enter 1.000 to add the 1.000g aluminum hydroxide to the distilled water. A box will open on the right to show you how much of the solid has dissolved. Wait until the number stops changing, and record the concentration of aluminum and hydroxide ions in your solution.

   Concentration of aluminum ions: _____

   Concentration of hydroxide ions: _____

8. Repeat the process for the other two salts, $Ca_3(PO_4)_2$ and $Sr(IO_3)_2$

   Concentration of calcium ions: _____

   Concentration of phosphate ions: _____

   Concentration of strontium ions: _____

   Concentration of iodate ions: _____

Grading

Points

Neatness and Clarity of Data	5pts	_____pts
Significant figures and units	5pts	_____pts
All data is present	10pts	_____pts

Deductions (sliding based on TA discretion)

Lab area left unclean	20pts	_____pts
Improper waste disposal	20pts	_____pts
Disruptive behavior	20pts	_____pts
Other: _____		_____pts

Grade for Experimental Procedures and Data _____pts

Online Activity 5: Results Table
Submit as part of the Online Activity Report

Record all results with the correct number of significant figures and units

Table 1: K_{sp} Calculations

Results	**Room Temperature (25.00°C)**
Concentration of aluminum ions	
Concentration of hydroxide ions	
Solubility of $Al(OH)_3$ in g/100mL	
K_{sp} for $Al(OH)_3$	
Concentration of calcium ions	
Concentration of phosphate ions	
Solubility of $Ca(PO_4)_2$ in g/100mL	
K_{sp} for $Ca_3(PO_4)_2$	
Concentration of strontium ions	
Concentration of iodate ions	
Solubility of $Sr(IO_3)_2$ in g/100mL	
K_{sp} for $Sr(IO_3)_2$	

Grading

Points

Significant figures and units	5pts	_____pts
Table is neat and legible	5pts	_____pts
All results are present	10pts	_____pts

Deductions (sliding based on TA discretion)

Results do not make sense	20pts	_____pts
Results do not match data	20pts	_____pts
Other: _____		_____pts

Plagiarism!!! Results are identical to another student 100pts _____pts

Grade on results table _____pts

Calculations Section: Submit as part of your Online Activity Report

Concentration of Salts

Based on the concentration values obtained from the simulation, what is the concentration of the three salts in the room temperature solutions?

Concentration of aluminum hydroxide: _____

Concentration of calcium phosphate: _____

Concentration of strontium iodate: _____

Solubility of salts

Calculate the solubility of each salt in g/100mL water at room temperature.

Solubility of aluminum hydroxide: _____

Solubility of calcium phosphate: _____

Solubility of strontium iodate: _____

Dissolution Expressions for each salt

Write the balanced chemical equation for the dissolution of each salt.

Aluminum hydroxide: _____

Calcium phosphate: _____

Strontium iodate: _____

Ksp Expressions

Write the K_{sp} Expression for each salt

Aluminum hydroxide:

Calcium phosphate:

Strontium iodate:

Calculation of K_{sp}

Use the K_{sp} expressions to calculate the K_{sp} for each salt

K_{sp} Aluminum hydroxide: _____

K_{sp} Calcium phosphate : _____

K_{sp} Strontium iodate : _____

Online Activity 4 Additional Questions
Submit as part of your Online Activity Report

Place all answers on the line next to the question.
Show calculations for any numerical answers.
All answers must have correct significant figures and units

1. Write the K_c, for the following reaction: $I_2(aq) + 2S_2O_3^{2-}(aq) \leftrightarrows 2I^-(aq) + S_4O_6^{2-}(aq)$

2. Write the K_{sp} expression for the following salt: Ag_2CrO_4 (s).

3. Calculate the solubility product constant of Ag_2CrO_4 if the concentration of Ag^+, is 7.4×10^{-5} M and the concentration of chromate ion, CrO_4^{2-} is 2.0×10^{-4} M.

4. Calculate the concentration of the anion if the K_{sp} of CdS is $8x10^{-8}$ and the concentration of the cation is 0.050M.

Use the following reaction to answer the remaining questions.

$$Sr(NO_3)_2\ (aq) + 2KIO_3(aq) \rightarrow Sr(IO_3)_2\ (s) + 2K^+\ (aq) + 2NO_3^-\ (aq)$$

5. How many moles of $Sr(IO_3)_2$ (s) will be formed from 25.00mL of 0.10M KIO_3(aq)(limiting)?

6. Write the net ionic equation associated with this reaction.

7. Write the K_{sp} expression associated with the precipitate in this reaction.