How to find ksp from concentration

The product constant solubility, \(K_{sp}\), is the equilibrium constant for a solid substance dissolving into an aqueous solution. Represents the level at which a solute dissolves in solution. The more soluble the substance, the higher the value \(K_{sp}\). Consider the general dissolution reaction below (in aqueous solutions): \[aA_{(s)} \rightleftharpoons cC_{(aq)} + dD_{(aq)} \tag{1} \] To resolve for \(K_{sp}\) it is necessary to take the molarities or concentrations of the products (cC and dD) and multiply them. If there are coefficients in front of any of the products, it is necessary to raise the product to this power of coefficient (and also multiply the concentration by that coefficient). This is shown below: \[K_{sp} = [C]^c [D]^d \tag{2}\] Note that the reagent, aA, is not included in equation \(K_{sp}\). Solids are not included in the calculation of equilibrium constant expressions, because their concentrations do not alter the expression; any change in their concentrations are negligible and therefore omitted. Thus, \(K_{sp}\) represents the maximum extent that a solid that can be dissolved in the solution. Learning Objectives Perform calculations by converting Ksp into solubility. The purification of water for drinking and other uses is a complicated process. Heavy metals need to be removed, a process carried out by the addition of carbonates and sulfates. Lead contamination can present major health problems, especially for younger children. Lead sulfates and carbonates are very insoluble, so they will precipitate the solution very easily. Product Constants Solubility (25°C) Composite Ksp Composite Ksp AgBr 5.0 × 10 -13 CuS 8.0 × 10 -37 AgCl 1.8 × 10 -10 Fe (OH) 2 7.9 × 10 -16 Al(OH) 3 3 3.0 × 10 -34 Mg(OH) 2 7.1 × 10 -12 BaCO 3 5.0 ×10 -9 PbCl 2 1.7 × 10 -5 BaSO 4 1.1 × 10 -10 PbCO 3 7.4 × 10 -14 CaCO 3 4.5 × 10 -9 PbI 2 7.1 × 10 -9 Ca(OH) 2 6.5 × 10 -6 PbSO 4 6.3 × 10 - 7 Ca 3 (PO 4) 2 1.2 × 10 -26 Zn(OH) 2 3.0 × 10 -16 CaSO 4 2.4 ×10 -5 ZnS 3.0 × 10 -23 The ksp known values of the Table above can be used to calculate the solubility of a given compound by following the steps listed below. Set up an ice problem (Initial, Change, Equilibrium) to use the Ksp value to calculate the concentration of each of the ions. The concentration of ions leads to the molar solubility of the compound. Use molar mass to convert from molar solubility to solubility. Calcium carbonate Ksp is 4.5 × 10 -9 . We started by assembling an ICE table showing the dissociation of CaCO 3 into calcium ions and carbonate ions. The variable will be used to represent the molar solubility of CaCO 3 . In this case, each unit of CaCO 3 formula yields a Ca 2+ ion and a CO 3 2− ion. Therefore, the equilibrium concentrations of each ion are equal to . The Ksp expression can be written in terms of and then to solve for . The concentration of each of the equilibrium ions is 6.7 × 10-5 M. We can use the molar mass to convert from molar solubility to solubility. Thus, the maximum amount of calcium carbonate that is able to dissolve in 1 liter of water at 25°C is 6.7 × 10 -3 grams. Note that in the above case, the 1:1 ratio of the ions after dissociation led the Ksp to be equal to . This is referred to as a formula of the type, where the cáation is and is the anion. Now let's consider a formula of the type, such as Fe(OH) 2 . In this case, the configuration of the ICE table would be like the following: When the Ksp expression is written in terms of, the received the following result for molar solubility. The table below shows the relationship between ksp and molar solubility based on the formula. Example of compound type Ksp Expression Anion Ksp in Terms of s AB CuS [Cu 2+][S 2−] AB 2 or A 2 B Ag 2 CrO 4 [Ag +] 2 [CrO 4 2−] AB 3 or A 3 B Al(OH) 3 [Al 3+][OH −] 3 A 2 B 3 or A 3 B 2 Ba 3 (PO 4) 2 [Ba 2+] 3 [PO 4 3−] 2 Ksp expressions in terms of s can be used to solve problems in which Ksp is used to calculate molar solubility as in the examples above. Molar solubility can then be converted into solubility. Abstract The process of determining solubility using Ksp values is described. Review What information is required to perform these calculations? What allows the calculation of molar solubility? How is solubility determined? Learning objectives Define molar solubility. Perform calculations involving molar solubility and Ksp. Baking soda bicarbonate is prepared by bubbling carbon dioxide gas through a solution of ammonia and sodium chloride. Ammonium carbonate is formed for the first time that reacts with NaCl to form baking soda and ammonium chloride. Baking soda is less soluble than other materials, so it will precipitate out of the solution. Solubility is usually expressed in g/L of saturated solution. However, solubility can also be expressed as warts per liter. Molar solubility is the number of solute mols in one liter of saturated solution. In other words, the molar solubility of a given compound represents the highest molarity solution that is possible for this compound. The molar mass of a compound is the conversion factor between solubility and molar solubility. Given that the solubility of Zn(OH) 2 is 4.2 × 10 -4 g/L, molar solubility can be calculated as shown below: Solubility data can be used to calculate Ksp for a given compound. The following steps need to be taken. Convert from solubility into molar solubility. Use the dissociation equation to determine the concentration of each of the ions in mol/L. Apply the Ksp equation. experimentally at 0.533 g/L. Calculate the Ksp for Fluoride. Step 1: List known quantities and plan the problem. Known solubility of PbF 2 = 0.533 g/L molar mass = 245.20 g/mol Unknown The dissociation equation for PbF 2 and the corresponding Ksp expression The above steps will be followed to calculate the Ksp for PbF 2 . Step 2: Solve . The dissociation equation shows that for each mol of PbF 2 dissociating, 1 mol of Pb 2+ and 2 mol of F − are produced. Therefore, in equilibrium the concentrations of the ions are: Replace in expression and resolve to the . Step 3: Think about your result. The product constant solubility is significantly less than 1 for an almost insoluble compound, such as GMP 2 . Summary molar solubility calculations are described. Ksp calculations using molar solubility are described. Read the material in ChemTeam.info and make the problems at the end. Review What are the solution requirements for determining molar solubility? Why do we need to convert mass into molarity to determine Ksp? What Ksp values would you expect for very insoluble compounds? Molar solubility: The number of solute mols in one liter of saturated solution. Constants of solubility products, Ksp Solubility product constants are used to describe saturated solutions of relatively low solubility ionic compounds. A saturated solution is in a state of dynamic equilibrium between the dissolved, dissociated, ionic compound and the unresolved solid. MxAy(s) -> x My+(aq) + y Ax-(aq) The general equilibrium constant for such processes can be written as: Kc = [My+]x[Ax-]y Since the equilibrium constant refers to the product of the concentration of ions that are present in a saturated solution of an ionic compound, it is given the constant product solubility name, and given the symbol Ksp. The product constants solubility can be calculated and used in a variety of applications. Ksp Calculation of Solubility Data To calculate the Ksp for an ionic compound you need the equation for the dissolution process so that the equilibrium expression can be written. You also need the concentrations of each ion expressed in terms of molarity, or mols per liter, or the means to obtain these values. Example: Calculate the product constant solubility for lead chloride(II) if 50.0 mL of a saturated lead chloride (II) solution was found to contain 0.2207 g of lead chloride (II) dissolved in it. First, write the equation for the dissolution of lead chloride(II) and the equilibrium expression for the dissolution process. PbCl2(s) --> Pb2+(aq) + 2 Cl-(aq) Ksp = [Pb2+][Cl-]2 Second, convert the amount of dissolved lead chloride (II) into mols per liter. (0.2207 g PbCl2) (1/50.0 mL solution) (1000 mL/1 L) (1 mol PbCl2/278.1 g PbCl2) = 0.0159 M PbCl2 Third, create an ICE table. PbCl2 (s) Pb2+(aq) Inicial All solid 0 0 0 Change in Concentration - 0.0159 M (dissolve) + + M + 0.0318 M Equilibrium Concentration Less solid 0.0159 M 0.0318 M Fourth, replace equilibrium concentrations in equilibrium expression and resolve to Ksp. Ksp = [0.0159][0.0318]2 = 1.61 x 10-5 Top Calculating the Solubility of an Ionic Compound in Pure Water from your Ksp Example: Estimate the solubility of Ag2CrO4 in pure water if the product of constant solubility for silver chromate is 1.1 x 10-12. Write the equation and the balance expression. Ag2CrO4(s) --> 2 Ag+(aq) + CrO42-(aq) Ksp = [Ag+]2[CrO42-] Let x be the number of silver chromate mols that dissolves in each liter of solution (its solubility). Ag2CrO4(s) Ag+(aq) CrO42-(aq) Initial concentration All solids 0 0 Change in concentration - x dissolves + 2 x + x Equilibrium Concentration Minus solid 2 x x replace the equilibrium amounts and ksp in the equilibrium expression and resolve to x. 1.1 x 10-12 = [2x]2[x] x = 6.50 x 10-5 M Top Calculating the Solubility of an Ionic Compound in a Solution Containing a Common Ion Solubility Decreases in Presence of a common ion. A common ion is any ion in the solution that is common to the ionic compound being dissolved. For example, chloride ion in a sodium chloride solution is common to chloride in lead chloride (II). The presence of a common ion should be taken into account when determining the solubility of an ionic compound. To do this, just use the common ion concentration as the initial concentration. Example: Estimate the solubility of the bário sulfate in a sodium sulfate solution of 0.020 M. The product constant solubility for bário sulfate is 1.1 x 10-10. Write the equation and equilibrium expression for the dissolution of the outbook sulfate. BaSO4(s) --> Ba2+(aq) + SO42-(aq) Ksp = [Ba2+][SO42-] Let x represent the outbook sulfate that dissolves in sodium sulfate solution expressed in mols per liter. BaSO4(s) Ba2+(aq) SO42-(aq) Initial concentration All solids 0.020 M (na2So4) Change in concentration - x dissolve + x + x Equilibrium Concentration Less solid x 0.020 M + x Replace in equilibrium expression and resolve to x. Let's assume that since x will be very small (solubility is reduced in the presence of a common ion), the term 0.020 + x is the same as 0.020. (You can leave x in the term and use the quadratic equation or the successive approximations method to resolve to x, but it won't improve the meaning of your response.) 1.1 x 10-10 = [x][0.020 + x] = [x][0.020] x = 5.5 x 10-9 M Upper determination whether or not a precipitate will form when two solutions are combined When two electrolytic solutions are combined, a precipitate may or may not form. To determine whether a precipitate will form or not, two factors should be examined. First, to determine the possible combinations of that could result when the two solutions are combined to see if any of them are considered insoluble basis in solubility tables (Ksp tables will also do). Second, determine whether the ion concentrations are large enough that the Q reaction quotient exceeds the Ksp value. An important factor to be remembered is that there is a dilution of all species present and should be taken into account. Example: 25.0 mL of potassium chromate of 0.0020 M is mixed with 75.0 mL of 0.000125 M lead nitrate(II). It will be a precipitate lead(II) chroma shape. Ksp lead (II) chromate is 1.8 x 10-14. First, determine the global and liquid ionic equations for the reaction that occurs when the two soltutions are mixed. K2CrO4(aq) + Pb(NO3)2(aq) --> 2 KNO3(aq) + PbCrO4(s) Pb2+(aq) + CrO42-(aq) --> PbCrO4(s) This last reaction can be written in ksp terms such as: PbCrO4(s) --> Pb2+(aq) + CrO42-(aq) Ksp = [Pb2+][CrO42-] Using the dilution equation, C1V1 = C2V2, determine the initial concentration of each species once mixed (before any reaction occurs). (0.0020 M K2CrO4) (25.0 mL) = (C2)(100.0 mL) C2 to K2CrO4 = 0.00050 M Similar calculation for lead nitrate yields(II): C2 for Pb(NO3)2 = 0.0000938 M Using initial concentrations, calculate the reaction quotient Q, and compare with the value of the equilibrium constant, Ksp. Q = (0.0000938 M Pb2+)(0.00050 M CrO42-) = 4.69 x 10-8 Q is greater than ksp as soon as a lead precipitate chromate(II) is forsa. Top Top

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