Molar solubility problems and answers

Example \(\PageIndex{4}\): Cadmium cadmium is a highly toxic environmental pollutant that enters wastewater associated with zinc smelting (Cd and Zn frequently occur together in ZnS ores) and in some galvanization processes. One way to control cadmium in effluent flows is to add sodium hydroxide, which precipitates insoluble cd(OH)2 (Ks = 2,5E–14). If 1000 L of a given wastewater contains Cd2+ at a concentration of 1,6E–5 M, what concentration of Cd2+ would remain after the addition of 10 L of NaOH 4 M solution? Solution As with most real-world problems, this is best addressed as a number of smaller issues, making simplification of approximations as appropriate. Volume of treated water: 1000 L + 10 L = 1010 L OH concentration– in addition to 1000 L of pure water: (4 M) × (10 L)/(1010 L) = 0.040 M Initial concentration of Cd2+ in 1010 L of water: \[(1.6 \or 10^{–5}\; M) \left(\dfrac{100}{101} \right) \approx 1.6 \times 10^{–5}\; M \ The easiest way to address this is to start by assuming that a stoichiometric amount of Cd (OH) 2 is formed – that is, all Cd2+ gets precipitated. concentrations [cd2+], M [OH–], initial M 1.6E–5 0.04 change –1.6E–5 –3.2E–5 final: 0 0.04 – 3.2E–5 ≈ .04 Now start the balance – find the concentration of Cd2+ that may exist in a solution 0.04M OH– solution: Concentrations [Cd2+], M [OH–], Initial M a 0.04 change +x +2x to balance x .04 + 2x ≈ .04 Replace these values in the expression of the solubility product: Cd(OH)2(s) = [Cd2+] [OH–]2 = 2.5E–14 [Cd2+] = (2.2.2.2 5E–14) / (16E–4) = 1.6 EE–13 M Note that the effluent will now be very alkaline: pH = 14 + log .04 = 12.6, so that, in order to meet environmental standards, an equivalent amount of strong acid must be added to neutralise the water before it is released. It has long been known that the solubility of an ion substance with soluble moderation is significantly low in a solution of another ion compound when the two substances have an ion in common. This is exactly what would be expected on the basis of the Le Châtelier principle; whenever the process \[CaF_{2(s)} \rightleftharpoons Ca^{2+} + 2 F^– \label{7}\] is in balance, the addition of more fluoride ions (in the form of highly soluble NaF) will move the composition to the left, reducing the concentration of Ca2+, thus effectively reducing the solubility of the solid. We can express this quantitatively by noting that the expression of the solubility product \[[Ca^{2+}][F^–]^2 = 1.7 \or 10^{–10} \label{8}\] must always hold, even if some of the ion species involved come from sources other than CaF2(s). For example, if a certain amount x of fluoride ions is added to an initial solution in balance with solid CaF2, we have \([Ca^{2+}] = S\) \([F^–] = 2S + x\) so that \[K_{sp} = [Ca^{2+}][F^–]^2 = S (2S + x)^2 . University-level students should capable of obtaining these relationships for ion-derived solids of any stoichiometry. In most practical cases x will be large compared to S, so the term 2S can be abandoned and the relationship becomes \[K_{sp} ≈ S x^2 \] \[S = \dfrac{K_{sp}}{x^2} \label{9b}\] The parcels shown below illustrate the common ion effect for silver chromate, since the concentration of chromium ions is increased by adding a soluble chromate, would be Na2C What's different about the plot on the right? If you look carefully at the scales, you will see that it is represented logarithmic (which is in powers of 10.) Notice a much wider range of values can be displayed on a logarithmic plot. The point of showing this pair of plots is to illustrate the great usefulness of the plot concentration plots in the balance calculations in which simple approximations (such as that made in equation \(\ref{9b}\) can produce straight lines in the range of values for which the approximation is valid. Example \(\PageIndex{5}\) Calculate the solubility of the stronium sulphate (Ks = 2.8 × 10–7) in (a) pure water and (b) in a 0.10 mol L–1 solution of Na2SO4. Solution: (a) In pure water, Ks = [Sr2+][SO42–] = S2 S = √Ks = (2.8 × 10–7)1/2 = 5.3 × 10–4 (b) In 0.10 mol L–1 Na2SO4, we have Ks = [Sr2+][SO42–] = S × (0.10 + S) = 2.8 × 10–7 Because S is negligible compared to 0.10 M, we do the approximation Ks = [Sr2+][S O42 –] ≈ S × (0.10 M) = 2.8 × 10–7 so S ≈ (2.8 × 10–7) / 0.10M = 2.8 × 10–6 M — which is approximately 100 times less than the result of point (a). Learning objectives Define molar solubility. Perform calculations involving molar solubility and Ksp. Sodium bicarbonate (sodium bicarbonate) is prepared by bubbling carbon dioxide by an ammonia and sodium chloride solution. Ammonium carbonate is formed first, then reacts with NaCl to form sodium bicarbonate and ammonium chloride. Sodium bicarbonate is less soluble than other materials, so it will precipitate from the solution. Solubility is normally expressed in g/L of saturated solution. However, solubility can also be expressed as moles per litre. Molar solubility is the number of moleins of solute in a liter of saturated solution. In other words, the molar solubility of a given compound is the greatest molarity solution that is possible for that compound. The molar mass of a compound is the conversion factor between solubility and molar solubility. Since the solubility of Zn(OH) 2 is 4.2 × 10 -4 g/L, the molar solubility can be calculated as shown below: Solubility data can be used to calculate Ksp for a given compound. You have to follow the next parts. Convert from solubility to molar solubility. Use the equation to determine the concentration of each of the ions in the mol/L. Apply the Ksp equation. be 0,533 g/L. Calculate Ksp for lead fluoride(II). 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 Dissociation equation for PbF 2 and corresponding Ksp expression The above steps will be followed to calculate Ksp for PbF 2 . Step 2: Solve . The dissociation equation shows that for each mole of PbF 2 that dissociates, 1 mole of Pb 2+ and 2 mol of F− are produced. Therefore, at equilibrium the concentrations of ions are: Substitute in expression and solve for . Step 3: Think about your outcome. The substance of the solubility product is significantly less than 1 for an almost insoluble compound, would be PbF 2. The calculations of summary molar solubility are described. Describe Ksp calculations using molar solubility. Read the material from ChemTeam.info and make the problems at the end. Review What are the solution requirements for determining molar solubility? Why do we have to convert mass into molarity to determine Ksp? What Ksp values would you expect for highly insoluble compounds? Molar solubility: Number of mole of solutes in a liter of saturated solution. Calculate the molar solubility of a compound in water and the relative molar solubility of compounds The solubility product of a substance (Ksp) is the ratio of concentrations to equilibrium. The molar solubility of a compound can be calculated directly from its solubility product. Even if the solubility products of the two compounds are similar, their molar solubility may be very different. Scientists take advantage of the relative solubility of compounds to separate or identify them. The product of solubility of a substance (Ksp) is the ratio of concentrations to balance. Molar solubility, which is directly related to the solubility product, is the number of moles of the solution that can be dissolved per liter of solution before the solution becomes saturated. Once a solution is saturated, any additional solutions precipitate from the solution. The units are molarity (M), or mol liter-1 (mol/L). Calculation of molar solubility The relationship between molar solubility and the solubility product means that one can be used to find the other. Example 1: Ksp for AgI is 8.5 x 10-17 at 25 °C. What is molar solubility? (Let s = solubility of the compound in water, usually defined as x in an ICE table.) Solution: The balanced reaction equation is: [latex]AgI (s) \leftrightarrow Ag^+ (aq) + I^- (aq)[/latex] The formula for Ksp is: Ksp = [Ag+][I–] Ksp = s2 = 8.5 x 10-17 where the concentration of each ion is at equilibrium. Now solve for s: s2 = 8.5 x 10-17 s = [latex]\sqrt {8.5 \times 10^{-17} }[/latex] s = 9.0 x 10-9 mol/L The molar solubility of AgI is 9.0 10-9 mol/L. Example 2: Solubility products for cadmium carbonate (CdCO3) and silver carbonate they're almost exactly the same. Compare molar solubility in water at 25 °C. Solution: For cadmium carbonate: [latex]CdCO_3 (s) \leftrightarrow Cd^{2+} (aq) + CO_3\ ^{2+} (aq)[/latex] Ksp = [Cd2+][CO32-] s2 = 5.2 x 10-12 s = 2.3 x 10-6 mol/L For silver carbonate, the expression is slightly different. Because each salt mole produces two Ag+ ion moles, the Ag+ value is 2: [latex]Ag_2CO_3 (s) \leftrightarrow 2Ag^+ (aq) + CO_3^{2-} (aq)[/latex] Ksp = [Ag+] 2[CO32-] (2s)2s = 8.2 x 10-12 4s3 = 8.2 x 10-12 s = 1.3 x 10-4 mol/L Although cadmium carbonate and silver carbonate have almost the same solubility products, their mol/L solubility differs by a factor of 100. The solubility of silver carbonate is sensitive to the square of the concentration of metal ions, as two silver ions per carbonate ion are required to build the solid crystal. Therefore, the form of expression of the solubility product is different. Relative solubility If the compounds have different solubility or relative solubility, they can be separated. For example, in the extraction process, scientists take something dissolved in one liquid and force it to dissolve into another liquid. Caffeine should be extracted from coffee beans for use in beverages such as soda. Usually, caffeine is dissolved in carbon dioxide, which has been heated to over 300 K and under pressure to 73 atm, making it a liquid. Then the temperature is low (decrease in caffeine solubility in carbon dioxide) and water is added. The system is allowed to reach balance. Because caffeine is more water soluble than it is in carbon dioxide, most of it goes into water. A technique called paper chromatography also takes advantage of the relative solubility of compounds. In paper chromatography, a small amount of mixture is placed on paper about 1 cm from the edge. Then the paper is suspended in a small amount of solvent in a closed container. As the solvent lifts the paper, the components in the mixture are separated on the basis of relative solubility. As the solvent approaches the top, a mark is made to record the level, and the paper is removed and dried. Some components are colored and can be seen with the naked eye, but some must be colored or irradiated with an ultraviolet lamp. Solute will always move to the same fraction of the solvent's distance, as long as the temperature is kept constant. The distance that the solute moves in a particular solvent can be used to identify the compound. The chromatography diagram of paper Chromatography Chromatography Is an analytical chemistry technique for separating and identifying mixtures. The samples are seen on the bottom of the paper. The end of the paper is placed in the solvent. Solvent climbs paper by action The mixtures are separated by their relative solubility in the solvent. Solvent. Solvent.

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