What Is The Molar Solubility Of BaF2 In 0.30 M Naf? (ksp Of Baf2 = 1.0 X 10^6)

What Is The Molar Solubility Of BaF2 In 0.30 M Naf? (ksp Of Baf2 = 1.0 X 10^6)

Understanding the molar solubility of barium fluoride (BaF_2) in a solution containing sodium fluoride (NaF) involves analyzing the equilibrium between the solid salt and its ions in solution, especially when other sources of fluoride ions are present. The problem is further complicated by the common ion effect introduced by NaF, which influences BaF_2's solubility. With the given solubility product constant (Ksp) of BaF_2 as $1.0 \times 10^{\wedge}6$, the task is to determine the molar solubility of BaF_2 in a 0.30 M NaF solution.

Understanding the Basics of Solubility and Equilibrium

What Is Solubility and Molar Solubility?

Solubility refers to the maximum amount of a substance that can dissolve in a solvent at a specific temperature to form a saturated solution. Molar solubility is expressed in moles per liter (mol/L), indicating how many moles of a compound dissolve in a liter of solution.

BaF_2 Dissolution and Its Equilibrium

The dissolution of barium fluoride in water can be represented as:

BaF_2 (s) $\rightleftharpoons$ Ba^{2+} (aq) + 2 F^- (aq)

The equilibrium constant for this process (Ksp) is expressed as:

$Ksp = [Ba^{2+}][F^-]^2$

Given that BaF_2 has a high Ksp value of $1.0 \times 10^{\wedge}6$, it suggests an extremely high solubility, which is unusual because typical Ksp values are much lower (less than 1). This indicates a potential typographical error or an unconventional problem statement. For the purpose of this discussion, assume it is a typographical mistake and that the actual Ksp is $1.0 \times 10^{\wedge}{-6}$, which is typical for BaF_2. We will clarify this in the following sections.

Effect of Common Ions on Solubility

The Common Ion Effect

The presence of common ions in a solution suppresses the solubility of salts due to Le Chatelier's principle. In this case, NaF provides additional fluoride ions (F^-), which affects the dissolution equilibrium of BaF_2.

Role of NaF in the Solution

NaF is a strong electrolyte that dissociates completely:

$NaF \rightarrow Na^+ + F^-$

In a 0.30 M NaF solution, the fluoride ion concentration contributed by NaF is 0.30 M. This common ion (F^-) impacts the solubility of BaF_2 by shifting the equilibrium to favor the undissolved form.

Calculating the Molar Solubility of BaF_2 in 0.30 M NaF

Step 1: Establish the Equilibrium Concentrations

Let the molar solubility of BaF_2 in the presence of 0.30 M NaF be 's' mol/L. Since BaF_2 dissociates into one Ba^{2+} ion and two F^- ions per mole of solid:

- $[Ba^{2+}] = s$
- $[F^-] = 2s + [\text{initial } F^-] = 2s + 0.30$ M

Because the solution already contains 0.30 M F^- from NaF, the total fluoride ion concentration at equilibrium is:

$[F^-] = 0.30 + 2s$

Step 2: Write the Expression for Ksp

Using the equilibrium concentrations:

$Ksp = [Ba^{2+}][F^-]^2$

Substituting the known values:

$Ksp = s (0.30 + 2s)^2$

Given the assumption that $Ksp = 1.0 \times 10^{-6}$ (assuming the standard low solubility for BaF_2):

$1.0 \times 10^{-6} = s (0.30 + 2s)^2$

Step 3: Solve the Equation for 's'

The resulting cubic equation:

$s (0.30 + 2s)^2 = 1.0 \times 10^{-6}$

Expand the square:

$s (0.09 + 1.2s + 4s^2) = 1.0 \times 10^{-6}$

Multiply out:

$0.09s + 1.2s^2 + 4s^3 = 1.0 \times 10^{-6}$

Because the solubility 's' is expected to be very small, the term $4s^3$ can be neglected in the initial approximation:

$0.09s + 1.2s^2 \approx 1.0 \times 10^{-6}$

Now, this is a quadratic in 's':

$1.2s^2 + 0.09s - 1.0 \times 10^{-6} \approx 0$

Solving the Quadratic Equation

Quadratic Formula

For an equation of the form:

$ax^2 + bx + c = 0$

the solutions are:

$s = [-b \pm \sqrt{(b^2 - 4ac)}] / 2a$

Applying the coefficients:

$a = 1.2$

$b = 0.09$

$c = –1.0 \times 10^{–6}$

Calculate discriminant:

$\Delta = (0.09)^2 – 4\ 1.2\ (–1.0 \times 10^{–6})$
$= 0.0081 + 4.8 \times 10^{–6}$
≈ 0.0081048

Calculate $\sqrt{\Delta}$:

$\sqrt{0.0081048} \approx 0.0901$

Calculate the positive root:

$s = [–0.09 + 0.0901] / (2\ 1.2)$
$= (0.0001) / 2.4$
$\approx 4.17 \times 10^{–5}$ M

The negative root is physically meaningless (negative solubility), so we discard it.

Final Calculation and Interpretation

Resulting Molar Solubility

The molar solubility of BaF_2 in 0.30 M NaF is approximately:

$s \approx 4.17 \times 10^{–5}$ mol/L

This indicates that in the presence of 0.30 M NaF, BaF_2's solubility is significantly reduced compared to its solubility in pure water.

Implications of the Result

- The common ion effect from fluoride ions suppresses the solubility of BaF_2.
- The high initial fluoride concentration (from NaF) shifts the equilibrium to favor the undissolved salt.
- The molar solubility of BaF_2 in pure water (without common ions) would be higher, but in this case, it's reduced due to the added fluoride ions.

Summary and Conclusions

- The molar solubility of BaF_2 in 0.30 M NaF is approximately 4.17 × 10^–5 mol/L, assuming a Ksp of 1.0 × 10^–6.
- The common ion effect caused by fluoride ions from NaF plays a crucial role in decreasing BaF_2's solubility.
- The calculation involves setting up an equilibrium expression, considering initial fluoride ion concentration, and solving the resulting quadratic equation.
- Understanding these principles can be applied to other sparingly soluble salts affected by common ions.

Note: The initial provided Ksp value of 1.0 × 10^6 is likely a typo or misinterpretation, as typical Ksp values for BaF_2 are around 1.0 × 10^–6. Adjustments in calculations are based on this more realistic assumption.

Frequently Asked Questions

What is the definition of molar solubility for BaF_2 in a solution containing NaF?

Molar solubility refers to the number of moles of BaF_2 that dissolve per liter of solution to reach equilibrium, considering the common ion effect from NaF present in the solution.

How does the presence of 0.30 M NaF affect the solubility of BaF_2?

The NaF provides fluoride ions (F^-), which suppress the dissolution of BaF_2 due to the common ion effect, thereby decreasing its molar solubility compared to pure water.

Given Ksp of BaF_2 as 1.0 x 10^{-6}, how can we set up an expression to calculate its molar solubility in 0.30 M NaF?

We can express the solubility as s, where BaF_2 dissociates into Ba^{2+} and $2F^-$ ions. Since NaF supplies F^- ions, the total F^- concentration is (2s + 0.30). The Ksp expression is Ksp = $[Ba^{2+}][F^-]^2 = s(2s + 0.30)^2$.

What is the step-by-step method to calculate the molar solubility of BaF_2 in 0.30 M NaF?

First, write the Ksp expression: $Ksp = s(2s + 0.30)^2$. Then, substitute $Ksp = 1.0 \times 10^{-6}$ and solve for s using algebraic or quadratic methods, considering that s is much smaller than 0.30 M, simplifying the calculation.

What approximate value can we expect for the molar solubility of BaF_2 in 0.30 M NaF?

Given the common ion effect, the molar solubility will be significantly lower than in pure water. Approximate calculations suggest it will be on the order of a few times 10^{-5} M, but precise calculation is needed for an exact value.

Why is understanding the molar solubility of BaF_2 in NaF relevant in practical chemistry applications?

It helps in predicting the solubility behavior of barium fluoride in fluoride-rich environments, which is important for water treatment, chemical manufacturing, and understanding precipitation reactions involving barium salts.

Additional Resources

What Is The Molar Solubility Of BaF_2 In 0.30 M NaF? (Ksp Of $BaF_2 = 1.0 \times 10^{-6}$)

Understanding the solubility behavior of salts in aqueous solutions is fundamental to the fields of chemistry and environmental science. One intriguing case is the solubility of barium fluoride (BaF_2) in a solution already containing sodium fluoride (NaF). Specifically, determining the molar solubility of BaF_2 in a 0.30 M NaF solution involves analyzing how the common ion effect influences its dissolution. With the solubility product constant (Ksp) of BaF_2 given as 1.0×10^{-6}, this scenario offers a compelling exploration into equilibrium calculations, ionic interactions, and the principles guiding solubility in complex solutions.

Background: The Chemistry of BaF_2 and NaF

Before diving into calculations, it’s essential to understand the chemical nature of the substances involved.

BaF_2: An Overview

Barium fluoride is an insoluble ionic compound composed of barium (Ba^{2+}) and fluoride ions (F^-). Its solubility is governed by its dissolution equilibrium:

$BaF_2(s) \rightleftharpoons Ba^{2+}(aq) + 2\ F^-(aq)$

The solubility product constant (Ksp) quantifies the maximum product of ion concentrations at equilibrium for this dissolution:

$Ksp = [Ba^{2+}][F^-]^2$

Given that $Ksp = 1.0 \times 10^{-6}$, BaF_2 is relatively insoluble under standard conditions.

NaF: A Source of Fluoride Ions

Sodium fluoride is a soluble salt, providing a source of fluoride ions in solution:

$NaF(s) \rightarrow Na^+(aq) + F^-(aq)$

Because NaF is highly soluble, a 0.30 M NaF solution will contain 0.30 mol of F^- per liter, which significantly influences the solubility of BaF_2 through the common ion effect.

The Common Ion Effect and Its Impact on Solubility

The presence of an existing fluoride ion concentration (from NaF) affects the dissolution equilibrium of BaF_2. This phenomenon is called the common ion effect, and it leads to decreased solubility of sparingly soluble salts.

Principle of the Common Ion Effect

When a solution already contains an ion that appears in the solubility equilibrium, the equilibrium shifts to reduce the ion's concentration, thereby decreasing the salt's solubility. In this case, the F^- ions from NaF are common to the dissolution of BaF_2.

Mathematically, the equilibrium shifts to produce fewer Ba^{2+} ions, resulting in a lower molar solubility compared to pure water.

Implications for BaF_2 in 0.30 M NaF

The initial fluoride concentration from NaF is 0.30 M, which will be added to the fluoride from BaF_2's dissolution. The total fluoride ion concentration at equilibrium becomes:

$[F^-] = 0.30\ M + 2s$

where s is the molar solubility of BaF_2 (the amount of BaF_2 that dissolves per liter).

Since the initial fluoride from NaF is significantly higher than the fluoride released from BaF_2 dissolution (which is small), it is often acceptable to approximate:

$[F^-] \approx 0.30\ M$

for the purposes of calculation, simplifying the analysis.

Calculating the Molar Solubility of BaF_2 in 0.30 M NaF

The goal is to find s, the molar solubility of BaF_2 under these conditions. The key steps involve setting up the equilibrium expression, accounting for the common ion effect, and solving for s.

Step 1: Write the Solubility Equilibrium Expression

The dissolution of BaF_2 can be summarized as:

$BaF_2(s) \rightleftharpoons Ba^{2+}(aq) + 2\ F^-(aq)$

The solubility product expression is:

$Ksp = [Ba^{2+}][F^-]^2$

Given $Ksp = 1.0 \times 10^{-6}$

Step 2: Express the Ion Concentrations in Terms of s

Let's define:

- $[Ba^{2+}] = s$ (since each mole of BaF_2 dissolves to produce 1 mol of Ba^{2+})
- $[F^-] = 0.30\ M + 2s \approx 0.30\ M$ (since 2s is small compared to 0.30 M)

This approximation is valid because s is expected to be very small, given the low Ksp.

Step 3: Set Up the Ksp Equation

Substituting into the equilibrium expression:

$Ksp = s\ (0.30)^2$

$\rightarrow 1.0 \times 10^{-6} = s\ (0.09)$

Step 4: Solve for s

Rearranged:

$s = (1.0 \times 10^{-6}) / 0.09 \approx 1.11 \times 10^{-5}\ M$

This value represents the molar solubility of BaF_2 in a 0.30 M NaF solution, considering the common ion effect.

Interpreting the Results and Significance

The calculated molar solubility, approximately 1.11×10^{-5} M, indicates a significant decrease compared to the solubility in pure water. For context, if we calculate the solubility in pure water:

s (pure water) = $\sqrt{(Ksp / [F^-])}$

but since in pure water $[F^-]$ is negligible, the solubility would be:

$s = \sqrt{Ksp} = \sqrt{(1.0 \times 10^{-6})} = 1.0 \times 10^{-3}$ M

which is roughly 100 times higher than in the 0.30 M NaF solution.

This stark contrast underscores the influence of the common ion effect: introducing a pre-existing fluoride concentration drastically reduces the solubility of BaF_2. Such insights are vital in areas like water treatment, mineral solubility predictions, and designing precipitation processes.

Additional Considerations and Complexities

While the above calculation provides a solid approximation, several factors could refine the result:

- Activity Coefficients: In real solutions, ions do not behave ideally; activity coefficients could slightly alter the concentrations.
- Temperature Effects: The solubility and Ksp are temperature-dependent; this calculation assumes a constant temperature.
- Ion Pairing: At higher ionic strengths, ion pairing might influence the effective concentrations.

For precise applications, these factors can be incorporated using more advanced models and experimental data.

Conclusion: The Key Takeaways

- The molar solubility of BaF_2 in a 0.30 M NaF solution is approximately 1.11×10^{-5} M.
- The common ion effect plays a critical role in decreasing solubility when fluoride ions are already present.
- Understanding such interactions aids in predicting solubility behaviors in complex systems, with implications spanning environmental science, industrial processes, and

materials chemistry.

In essence, this calculation exemplifies how fundamental principles of chemical equilibria and solubility can be applied to real-world scenarios, providing valuable insights into the delicate balance of ionic compounds in solution.

What Is The Molar Solubility Of Baf2 In 0 30 M Naf Ksp Of Baf2 1 0 X 10 6

What Is The Molar Solubility Of Baf2 In 0 30 M Naf Ksp Of Baf2 1 0 X 10 6

Related Articles

- What Is The Median Of The Set Of Data Given Below? 30, 16, 24, 28, 20, 20, 26
- What Is The Current Through The 20 Resistor In (figure 1) If The V = 300 V ?
- Name At Least One Important Building In Tenochtitln, And Describe Its Purpose.

Back to Home