The Concentration Of Pb21 In A Solution Saturated With Pbbr2(s) Is 2.14 3 1022 M. Calculate Ksp For Pbbr2.

The Concentration Of Pb2+ In A Solution Saturated With PbBr2(s) Is 2.14 × 10-22 M. Calculate Ksp For PbBr2.

Introduction to Solubility Product (K_{sp}) and Its Significance

Understanding Solubility Equilibrium

The concept of solubility product, denoted as Ksp, is fundamental in chemistry, especially when dealing with the dissolution of sparingly soluble salts. It quantifies the equilibrium between a solid salt and its ions in a saturated solution. For a generic salt AB2, which dissociates into A+ and 2B- ions, the solubility product is expressed as:

Ksp = [A+]m [B-]n

where m and n are the stoichiometric coefficients in the dissociation equation.

Importance of K_{sp}

- It provides a measure of the solubility of a salt in water.
- Helps predict whether a precipitate will form when solutions are mixed.
- Useful in applications like water treatment, pharmaceuticals, and understanding mineral deposits.

Chemical Nature of $PbBr_2$

Dissolution Reaction

Lead(II) bromide (PbBr2) dissolves in water according to the following equilibrium:

PbBr2(s) ⇌ Pb2+(aq) + 2 Br-(aq)

Stoichiometry and Dissociation

- For each mole of $PbBr_2$ that dissolves, one mole of Pb^{2+} and two moles of Br^- ions are produced.
- The equilibrium concentration of Pb^{2+} is given as 2.14×10^{-22} M in the saturated solution.

Calculating K_{sp} for $PbBr_2$

Given Data

- Concentration of Pb^{2+}: $[Pb^{2+}] = 2.14 \times 10^{-22}$ M
- The solution is saturated with solid $PbBr_2$, meaning the ion concentrations are at equilibrium.

Determining the Br^- Ion Concentration

Since the dissociation produces 2 moles of Br^- per mole of $PbBr_2$, the concentration of Br^- ions can be calculated as:

$[Br^-] = 2 \times [Pb^{2+}] = 2 \times 2.14 \times 10^{-22}$ M $= 4.28 \times 10^{-22}$ M

Expression for K_{sp}

Based on the dissociation reaction:

$PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\ Br^-(aq)$

The solubility product expression is:

$K_{sp} = [Pb^{2+}] \times [Br^-]^2$

Substituting the known concentrations:

$K_{sp} = (2.14 \times 10^{-22}) \times (4.28 \times 10^{-22})^2$

Step-by-Step Calculation of K_{sp}

Calculating $[Br^-]^2$

First, square the concentration of bromide ions:

$(4.28 \times 10^{-22})^2 = (4.28)^2 \times (10^{-22})^2 = 18.3 \times 10^{-44} = 1.83 \times 10^{-43}$

Multiplying with [Pb^{2+}]

Now, multiply this by [Pb2+] to find Ksp:

Ksp = 2.14 × 10-22 × 1.83 × 10-43

Ksp = (2.14 × 1.83) × 10-22 × 10-43 = 3.91 × 10-65

Final Result

Therefore, the solubility product constant for PbBr2 is approximately:

Ksp ≈ 3.91 × 10-65

Implications of the Calculated K_{sp}

Extremely Low Solubility

The very small value of Ksp indicates that PbBr2 is highly insoluble in water. Only an exceedingly tiny amount of the salt dissolves to reach equilibrium.

Precipitation and Supersaturation

- When the ion concentrations in a solution exceed the equilibrium concentrations, PbBr2 will precipitate.
- This property is useful in processes like purification, where precipitation can be used to remove lead or bromide ions from solutions.

Environmental and Industrial Relevance

- Due to its low solubility, PbBr2 can be used in applications where minimal solubility is desirable, such as in certain types of detectors or semiconductors.
- Understanding its solubility helps in environmental management, especially in controlling lead contamination.

Conclusion

The calculation of the solubility product constant, Ksp, for PbBr2 based on the provided ion concentration demonstrates the principles of solubility equilibria. With an ion concentration of 2.14 × 10-22 M for Pb2+, the resulting Ksp is approximately 3.91 × 10-65. This extremely low value reflects the poor solubility of PbBr2 in water, highlighting the importance of precise measurements in chemical calculations and their implications in real-world applications. Understanding such solubility constants is vital in various fields, including environmental chemistry, materials science, and industrial processes, where controlling solubility can be crucial to safety and functionality.

Frequently Asked Questions

What is the significance of the concentration of Pb^{2+} in a saturated $PbBr_2$ solution when calculating its solubility product constant (Ksp)?

The concentration of Pb^{2+} in a saturated solution directly reflects the solubility of $PbBr_2$ and is used to determine Ksp by relating it to the concentration of Br^- ions, assuming the dissociation equilibrium is established.

How do you set up the expression for the Ksp of $PbBr_2$ based on its dissociation in water?

The dissociation of $PbBr_2$ in water is written as $PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Br^-(aq)$. Therefore, $Ksp = [Pb^{2+}][Br^-]^2$. Knowing $[Pb^{2+}]$, you can find $[Br^-]$ and calculate Ksp.

Given the concentration of Pb^{2+} as 2.14×10^{-22} M, how do you find the concentration of Br^- ions in the solution?

Since each formula unit of $PbBr_2$ produces 2 Br^- ions upon dissolution, $[Br^-] = 2 \times [Pb^{2+}] = 2 \times 2.14 \times 10^{-22}$ M $= 4.28 \times 10^{-22}$ M.

What is the step-by-step calculation of Ksp for $PbBr_2$ using the given Pb^{2+} concentration?

First, determine $[Br^-] = 2 \times 2.14 \times 10^{-22}$ M $= 4.28 \times 10^{-22}$ M. Then, $Ksp = [Pb^{2+}] \times [Br^-]^2 = (2.14 \times 10^{-22}) \times (4.28 \times 10^{-22})^2 = 2.14 \times 10^{-22} \times (1.83 \times 10^{-43}) \approx 3.92 \times 10^{-65}$.

Why is understanding the Ksp value important in predicting the solubility of $PbBr_2$ in water?

The Ksp value indicates the extent to which $PbBr_2$ dissolves in water. A very low Ksp, like in this case, shows that $PbBr_2$ is only sparingly soluble, and this value helps predict solubility limits and potential precipitation.

Are there any assumptions made when calculating Ksp from the given concentration of Pb^{2+} in a saturated solution?

Yes, assumptions include that the solution is at equilibrium, the activity coefficients are approximately 1, and the only source of Br^- ions is the dissolution of $PbBr_2$, with no other competing equilibria or complex formations.

Additional Resources

The Concentration Of Pb^{2+} In A Solution Saturated With $PbBr_2(s)$ Is 2.14×10^{-22} M. Calculate Ksp For $PbBr_2$.

Introduction

The solubility product constant, denoted as Ksp, is a fundamental concept in chemical thermodynamics and aqueous chemistry, providing insight into the solubility of sparingly soluble salts. Understanding and calculating Ksp values are essential for predicting the behavior of ionic compounds in solution, designing separation processes, and controlling environmental pollutants. This article delves into the calculation of the Ksp for lead(II) bromide ($PbBr_2$) based on a given concentration of lead ions (Pb^{2+}) in a saturated solution.

Background and Significance

The Role of Solubility Equilibria in Chemistry

Solubility equilibria describe the dynamic balance between the dissociation of a solid salt into its constituent ions and the recombination of those ions into the solid form. For a generic salt $AB_2(s)$, which dissociates into A^{2+} and $2Br^-$ ions, the equilibrium can be written as:

$$ \text{AB}_2(s) \leftrightarrow \text{A}^{2+}(aq) + 2\text{Br}^-(aq) $$

The solubility product constant, Ksp, quantifies the maximum extent to which a salt can dissolve in water at a given temperature. It is expressed as:

$$ K_{sp} = [\text{A}^{2+}] [\text{Br}^-]^2 $$

Knowledge of Ksp allows chemists to compare the solubility of different salts, predict precipitation under various conditions, and understand phenomena such as ion competition and complex formation.

Lead(II) Bromide ($PbBr_2$): An Overview

$PbBr_2$ is a sparingly soluble salt, with applications in scintillation detectors, radiation shielding, and other electronic materials. Its solubility characteristics influence its use and handling in industrial processes. Given its low solubility, precise determination of its Ksp is vital for process control and environmental safety, especially considering lead's toxicity.

The Given Data and Problem Statement

Data Summary

- Concentration of Pb^{2+} in saturated solution: 2.14×10^{-22} M
- Substance: $PbBr_2$ (lead(II) bromide)
- Objective: Calculate the solubility product constant, Ksp, for $PbBr_2$.

Assumptions and Considerations

- The solution is saturated with $PbBr_2$, meaning the system is at equilibrium.
- The dissociation of $PbBr_2$ is represented by:

$$\text{PbBr}_2(s) \leftrightarrow \text{Pb}^{2+}(aq) + 2 \text{Br}^-(aq)$$

- The concentration of Pb^{2+} ions directly relates to the solubility of $PbBr_2$.
- The bromide ion concentration can be derived from the stoichiometry of the dissociation.

Step-by-Step Calculation of Ksp

1. Understanding the Dissociation Equation

The dissociation of $PbBr_2$ in water is:

$$\text{PbBr}_2(s) \leftrightarrow \text{Pb}^{2+}(aq) + 2 \text{Br}^-(aq)$$

At equilibrium, the molar concentrations of ions are:

- $[\text{Pb}^{2+}] = s$
- $[\text{Br}^-] = 2s$

where s is the molar solubility of $PbBr_2$.

2. Relating Given Data to Ion Concentrations

Given:

$$ [\text{Pb}^{2+}] = 2.14 \times 10^{-22} \, \text{M} $$

Since this is the molar concentration of lead ions at equilibrium, it directly corresponds to s:

$$ s = 2.14 \times 10^{-22} \, \text{M} $$

Correspondingly, the bromide ion concentration is:

$$ [\text{Br}^-] = 2s = 2 \times 2.14 \times 10^{-22} = 4.28 \times 10^{-22} \, \text{M} $$

3. Calculating Ksp

Using the general expression for Ksp:

$$ K_{sp} = [\text{Pb}^{2+}] \times [\text{Br}^-]^2 $$

Substituting the values:

$$ K_{sp} = (2.14 \times 10^{-22}) \times (4.28 \times 10^{-22})^2 $$

Calculating the square of bromide concentration:

$$ (4.28 \times 10^{-22})^2 = 4.28^2 \times 10^{-44} \approx 18.3 \times 10^{-44} = 1.83 \times 10^{-43} $$

Now, multiply:

$$ K_{sp} = 2.14 \times 10^{-22} \times 1.83 \times 10^{-43} $$

$$ K_{sp} \approx (2.14 \times 1.83) \times 10^{-22 - 43} $$

$$ K_{sp} \approx 3.91 \times 10^{-65} $$

Final Result and Interpretation

Calculated Ksp for $PbBr_2$

$$
\boxed{
K_{sp} \approx 3.91 \times 10^{-65}
}
$$

This remarkably low value confirms the extremely limited solubility of $PbBr_2$ in water, consistent with its classification as a sparingly soluble salt.

Implications and Context

- The tiny magnitude of Ksp indicates that only a negligible amount of $PbBr_2$ dissolves in water under standard conditions.
- Such low solubility has environmental implications, especially in contexts where lead contamination is a concern.
- The calculated Ksp can be used to predict the solubility of $PbBr_2$ in various conditions, inform purification strategies, and guide environmental safety assessments.

Additional Considerations

Temperature Dependence

The Ksp value is temperature-dependent; the calculation assumes standard laboratory conditions (~25°C). Variations in temperature could significantly alter solubility.

Potential Sources of Error

- The assumption of ideal behavior in dilute solutions is generally valid here.
- The given concentration is extremely low, approaching the limits of detection and measurement accuracy.
- Any impurities or complex formation could affect the actual solubility.

Environmental and Industrial Relevance

Understanding the solubility behavior of lead salts like $PbBr_2$ is crucial for:

- Managing lead pollution in water sources.
- Designing effective remediation techniques.
- Developing materials with controlled solubility for electronic or optical applications.

Conclusion

By analyzing the given concentration of Pb^{2+} ions in a saturated solution and applying fundamental principles of solubility equilibria, we have successfully calculated the Ksp for lead(II) bromide:

$$\boxed{
K_{sp} \approx 3.91 \times 10^{-65}
}$$

This value underscores the compound's low solubility and provides a basis for further studies into its behavior under various environmental and industrial conditions. Accurate knowledge of such constants is essential for chemists, environmental scientists, and engineers working with lead-based compounds, ensuring safe handling, effective purification, and environmental protection.

References

- Atkins, P., & de Paula, J. (2014). Physical Chemistry (10th ed.). Oxford University Press.
- Skoog, D. A., West, D. M., Holler, F. J., & Crouch, S. R. (2014). Fundamentals of Analytical Chemistry (9th ed.). Brooks Cole.
- Lide, D. R. (Ed.). (2004). CRC Handbook of Chemistry and Physics (85th ed.). CRC Press.
- Environmental Protection Agency (EPA). Lead in Water: Regulations and Toxicity.

The Concentration Of Pb21 In A Solution Saturated With Pbbr2 S Is 2 14 3 1022 M Calculate Ksp For Pbbr2

The Concentration Of Pb21 In A Solution Saturated With Pbbr2 S Is 2 14 3 1022 M Calculate Ksp For Pbbr2

Related Articles

- A Sonar Echo Returns To A Submarine 1.65 S After Being Emitted. What Is The Distance To The Object Creating
- The American Red Cross Uses Social Marketing Tools Such As ________ To Increase Blood Donations.a. Wikisb.
- Someone Who Lobbies On Behalf Of A Company That He Or She Works For As Part Of His Or Her Job Is ________.

Back to Home