Calculate The Solubility Of Mgco3 In Water At 25c, Given The Ksp Is 4.0 105.

Calculate The Solubility Of Mgco3 In Water At 25c, Given The Ksp Is 4.0 105. This problem involves understanding the principles of solubility equilibria and applying the solubility product constant, Ksp, to determine how much magnesium carbonate ($MgCO_3$) dissolves in water at a given temperature. Magnesium carbonate is an important compound in various industrial applications, including antacids and dietary supplements, and understanding its solubility helps in designing processes and predicting its behavior in aqueous environments.

Understanding the Solubility Product Constant (Ksp)

What is Ksp?

The solubility product constant, Ksp, is an equilibrium constant that describes the solubility of an ionic compound in water. It is the product of the molar concentrations of the constituent ions, each raised to the power of their coefficients in the balanced dissolution equation. For a generic salt AB_2 that dissolves as:

$AB_2(s) \rightleftharpoons A^{2+}(aq) + 2\ B^-(aq)$

The Ksp expression is:

$Ksp = [A^{2+}][B^-]^2$

$MgCO_3$ Dissolution Equation

Magnesium carbonate dissolves in water according to:

$MgCO_3(s) \rightleftharpoons Mg^{2+}(aq) + CO_3^{2-}(aq)$

The solubility equilibrium involves the ions magnesium (Mg^{2+}) and carbonate (CO_3^{2-}). The Ksp expression for $MgCO_3$ is:

$Ksp = [Mg^{2+}][CO_3^{2-}]$

Given that $Ksp = 4.0 \times 10^{-5}$ at 25°C, our goal is to find the molar solubility of $MgCO_3$, which is the amount that dissolves per liter of water to produce these ion concentrations.

Setting Up the Calculation

Define the Solubility (s)

Let s be the molar solubility of $MgCO_3$ in mol/L, i.e., the amount of $MgCO_3$ that dissolves per liter of water.

From the dissolution:

- $[Mg^{2+}] = s$
- $[CO_3^{2-}] = s$

Since $MgCO_3$ dissolves into equal molar amounts of Mg^{2+} and CO_3^{2-}, their concentrations are equal at equilibrium.

Expressing Ksp in Terms of s

The Ksp expression becomes:

$Ksp = [Mg^{2+}][CO_3^{2-}] = s \times s = s^2$

Therefore:

$s^2 = 4.0 \times 10^{-5}$

Solving for s gives:

$s = \sqrt{(4.0 \times 10^{-5})}$

Calculating the square root:

$s = \sqrt{(4.0 \times 10^{-5})} = \sqrt{4.0} \times \sqrt{10^{-5}} = 2.0 \times 10^{-3}$ mol/L

Thus, the molar solubility of $MgCO_3$ at 25°C is approximately 2.0×10^{-3} mol/L.

Interpreting the Results

Solubility in Terms of Mass

To translate molar solubility into mass per liter:

- Molar mass of $MgCO_3$:

Mg: 24.305 g/mol
C: 12.011 g/mol
O_3: 3 × 16.00 g/mol = 48.00 g/mol

Total: 24.305 + 12.011 + 48.00 = 84.316 g/mol

- Mass of $MgCO_3$ dissolved per liter:

Mass = s × molar mass = 2.0×10^{-3} mol/L × 84.316 g/mol ≈ 0.169 g/L

This means approximately 0.169 grams of $MgCO_3$ dissolves in one liter of water at 25°C to reach saturation.

Factors Affecting Solubility

Common Factors Influencing Solubility

While the calculation here assumes ideal conditions, real-world solubility can be affected by:

- **Temperature:** Generally, solubility increases with temperature, but for $MgCO_3$, the given Ksp is at 25°C.
- **pH of Solution:** Acidic conditions can increase $MgCO_3$ solubility by reacting with carbonate ions.
- **Presence of Common Ions:** Ions already in solution can suppress solubility through the common ion effect.

Implications of the Calculation

Knowing the molar solubility helps in:

- Designing industrial processes involving $MgCO_3$ dissolution.
- Understanding the behavior of magnesium in natural waters.
- Predicting precipitation or scale formation in pipes and equipment.

Additional Considerations

Limitations of the Calculation

The calculation assumes:

- Pure water at 25°C.
- No additional ions or complexing agents.
- Equilibrium conditions are established.
- No kinetic effects or impurities affecting solubility.

In practice, deviations from these assumptions can alter actual solubility values.

Summary of Key Steps

To calculate solubility from Ksp:

1. Write the dissolution equilibrium.
2. Express ion concentrations in terms of molar solubility, s.
3. Set up the Ksp expression.
4. Solve for s.
5. Convert molar solubility to mass if needed.

Conclusion

Using the given Ksp of 4.0×10^{-5} for $MgCO_3$ at 25°C, the molar solubility is approximately 2.0×10^{-3} mol/L. This translates to about 0.169 grams per liter of water. Understanding these calculations enables chemists and engineers to predict the behavior of magnesium carbonate in aqueous systems, optimize processes, and manage mineral scaling and environmental impacts effectively.

Frequently Asked Questions

What is the solubility of $MgCO_3$ in water at 25°C given the Ksp is 4.0×10^{-5}?

The solubility of $MgCO_3$ in water at 25°C is approximately 1.26×10^{-3} mol/L.

How do you calculate the solubility of $MgCO_3$ using its Ksp value?

You set up the solubility expression based on its dissociation: $MgCO_3 \rightleftharpoons Mg^{2+} + CO_3^{2-}$. Since both ions have the same concentration 's,' then $K_{sp} = s^2$. Solving for 's' gives the solubility.

What is the molar solubility of $MgCO_3$ if Ksp is 4.0×10^{-5}?

The molar solubility is approximately 1.26×10^{-3} mol/L.

Why is the solubility of $MgCO_3$ in water relatively low?

Because $MgCO_3$ has a low Ksp value (4.0×10^{-5}), indicating limited dissociation and low solubility in water at 25°C.

How does temperature affect the solubility of $MgCO_3$ given its

Ksp at 25°C?

Generally, solubility can increase or decrease with temperature depending on the thermodynamics of dissolution, but specific data for $MgCO_3$ would be needed to determine the exact effect at 25°C.

Can you determine the mass of $MgCO_3$ that dissolves in 1 liter of water at 25°C based on its solubility?

Yes. First, calculate molar solubility (~1.26×10^{-3} mol/L), then multiply by the molar mass of $MgCO_3$ (84.31 g/mol) to find that approximately 0.106 g of $MgCO_3$ dissolves per liter of water at 25°C.

Additional Resources

Calculate The Solubility Of $MgCO_3$ In Water At 25°C, Given The Ksp Is 4.0×10^{-5}

Introduction

Solubility calculations are fundamental in understanding the behavior of ionic compounds in aqueous solutions. Magnesium carbonate ($MgCO_3$), a sparingly soluble salt, plays an essential role in various industrial, geological, and biological processes. When considering its solubility in water at a specific temperature, such as 25°C, the solubility product constant (Ksp) becomes a critical parameter. This review delves into the methodology for calculating the solubility of $MgCO_3$ in water at 25°C, given its Ksp value of 4.0×10^{-5}, encompassing principles of solubility equilibrium, stoichiometry, and practical implications.

Understanding Solubility and Solubility Product (Ksp)

What Is Solubility?

Solubility refers to the maximum amount of a substance that can dissolve in a solvent at a specified temperature to form a saturated solution. It is often expressed in units such as grams per liter (g/L), molarity (mol/L), or molar solubility (s).

The Concept of Ksp

The solubility product constant (Ksp) is an equilibrium expression that quantifies the solubility of a sparingly soluble ionic compound. It represents the equilibrium between the solid salt and its constituent ions in solution:

$$\text{MgCO}_3 (s) \rightleftharpoons \text{Mg}^{2+} (aq) + \text{CO}_3^{2-} (aq)$$

The Ksp expression is:

$$K_{sp} = [\text{Mg}^{2+}] \times [\text{CO}_3^{2-}]$$

Since $MgCO_3$ dissociates into one Mg^{2+} ion and one CO_3^{2-} ion, the molar concentrations of these ions at equilibrium are directly related to the solubility.

Step-by-Step Calculation of $MgCO_3$ Solubility

Step 1: Define the Solubility (s)

Let's denote the molar solubility of $MgCO_3$ as s (mol/L). When $MgCO_3$ dissolves:

- The concentration of Mg^{2+} ions in solution = s mol/L
- The concentration of CO_3^{2-} ions in solution = s mol/L

Because the dissociation occurs in a 1:1 molar ratio, both ions' concentrations are equal to s.

Step 2: Write the Expression for Ksp

Using the concentrations:

$$ K_{sp} = [\text{Mg}^{2+}] \times [\text{CO}_3^{2-}] = s \times s = s^2 $$

Given:

$$ K_{sp} = 4.0 \times 10^{-5} $$

Step 3: Solve for s

Rearranged:

$$ s^2 = 4.0 \times 10^{-5} $$

$$ s = \sqrt{4.0 \times 10^{-5}} $$

$$ s = \sqrt{4.0} \times \sqrt{10^{-5}} $$

$$ s = 2.0 \times 10^{-\frac{5}{2}} $$

$$ s = 2.0 \times 10^{-2.5} $$

Since:

$$ 10^{-2.5} = 10^{-2} \times 10^{-0.5} = 0.01 \times 0.3162 = 0.003162 $$

Therefore:

$$ s = 2.0 \times 0.003162 = 0.006324\, \text{mol/L} $$

Result: The molar solubility of $MgCO_3$ at 25°C is approximately 0.00632 mol/L.

Converting Molar Solubility to Grams per Liter

To express solubility in more practical units such as grams per liter (g/L):

1. Find the molar mass of $MgCO_3$.

$$\text{Mg} = 24.305\, \text{g/mol}$$

$$\text{C} = 12.011\, \text{g/mol}$$

$$\text{O}_3 = 3 \times 16.00 = 48.00\, \text{g/mol}$$

Total molar mass:

$$24.305 + 12.011 + 48.00 = 84.326\, \text{g/mol}$$

2. Calculate grams per liter:

$$\text{Solubility} = s \times \text{molar mass}$$

$$0.00632\, \text{mol/L} \times 84.326\, \text{g/mol} \approx 0.533\, \text{g/L}$$

Final practical solubility: Approximately 0.533 grams of $MgCO_3$ per liter of water at 25°C.

Factors Influencing $MgCO_3$ Solubility

While the calculation above provides a theoretical value based on Ksp, real-world solubility can be affected by various parameters:

- Temperature: Although calculated at 25°C, solubility varies with temperature; generally, many salts are more soluble at higher temperatures.
- pH of the solution: The solubility of carbonate salts can be affected by acidity; increased acidity can increase solubility due to carbonate ion protonation.
- Presence of common ions: The common ion effect can decrease solubility when ions like Mg^{2+} or CO_3^{2-} are already present in solution.
- Complexation: Formation of soluble complexes with other ions can enhance the apparent solubility.

Practical Implications of $MgCO_3$ Solubility

Industrial Applications

- Magnesium production: $MgCO_3$ is often used as a raw material in manufacturing magnesium metal; understanding its solubility is vital for processes like calcination.
- Water treatment: $MgCO_3$ acts as a buffering agent; knowing its solubility helps in designing appropriate dosage levels.
- Pharmaceuticals: Magnesium compounds are used as antacids; solubility influences bioavailability.

Geological and Environmental Context

- $MgCO_3$ is a common mineral in carbonate rocks; understanding its solubility helps in modeling mineral weathering and carbonate cycling.
- Its solubility influences the formation of cave systems and mineral deposits.

Comparing $MgCO_3$ with Other Carbonates

To appreciate the relative solubility of magnesium carbonate, compare it with other similar compounds:

Compound	Ksp	Molar Solubility (mol/L)	Approximate g/L
$MgCO_3$	4.0×10^{-5}	0.00632	0.533
$CaCO_3$	8.3×10^{-9}	9.11×10^{-5}	0.0077
$BaCO_3$	5.1×10^{-9}	7.14×10^{-5}	0.0060

This comparison shows $MgCO_3$ is more soluble than calcium carbonate ($CaCO_3$) and barium carbonate ($BaCO_3$), which are notably less soluble.

Limitations and Assumptions in the Calculation

While the calculation provides a useful estimate, it relies on assumptions:

- Pure water: No impurities or ions that could influence solubility.
- Ideal behavior: Solution activity coefficients are assumed to be unity; real solutions may deviate.
- Constant temperature: No temperature fluctuation affecting Ksp.
- No complex formation: Assumes Mg^{2+} and CO_3^{2-} do not form complexes with other ions.

In practical scenarios, deviations from ideality might lead to slightly different solubility values.

Advanced Considerations

Activity Coefficients and Non-Ideal Solutions

In concentrated solutions, activity coefficients become significant. The actual solubility might be better represented using activities:

$$ K_{sp} = a_{\text{Mg}^{2+}} \times a_{\text{CO}_3^{2-}} $$

where activity $a = \gamma \times [\text{ion}]$, and γ is the activity coefficient.

In dilute solutions like ours, assuming $\gamma \approx 1$ is reasonable, but for more precise calculations, especially at higher concentrations, one should account for activity coefficients.

Effect of pH and Carbonate Equilibria

In aqueous solutions, carbonate ions can undergo equilibria:

$$\text{CO}_3^{2-} + \text{H}^+ \leftrightarrow \text{HCO}_3^-$$
$$\text{HCO}_3^- + \text{H}^+ \leftrightarrow \text{H}_2\text{CO}_3$$

These equilibria can influence the solubility, especially under acidic conditions, leading to increased Mg^{2+} release due to carbonate dissolution.

Summary and Conclusion

The calculated molar solubility of magnesium carbonate ($MgCO_3$) in water at 25°C, given the K

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