

What Is The Selenide Ion Concentration [Se²⁻] For A 0.300 M H₂Se Solution That Has The Stepwise Dissociation

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Understanding the selenide ion concentration [Se²⁻] in a 0.300 M H₂Se solution that undergoes stepwise dissociation is fundamental in chemistry, especially within the context of acid-base reactions and equilibrium calculations. This article explores the process involved in determining the selenide ion concentration, including the stepwise dissociation of hydrogen selenide (H₂Se), the relevant equilibrium expressions, and the methods used to calculate [Se²⁻] in such solutions. Whether you're a student, educator, or researcher, grasping these concepts provides a solid foundation for analyzing weak acid dissociation and the behavior of selenide ions in aqueous environments.

Understanding Hydrogen Selenide (H₂Se) and Its Dissociation in Water

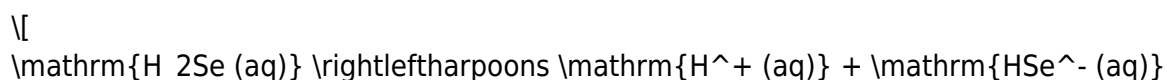
The Nature of H₂Se as a Weak Acid

Hydrogen selenide (H₂Se) is a gaseous, colorless, and highly toxic compound that exhibits weak acidity in aqueous solutions. When dissolved in water, H₂Se partially dissociates, releasing hydrogen ions (H⁺) and selenide ions (Se²⁻). Its weak acid properties mean that the dissociation does not go to completion; instead, it reaches an equilibrium state characterized by specific dissociation constants.

Stepwise Dissociation of H₂Se

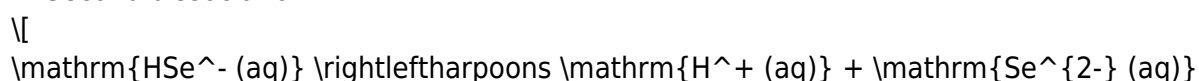
Unlike strong acids, weak acids like H₂Se undergo stepwise dissociation. The process involves two primary steps:

1. First dissociation:



with an associated acid dissociation constant (K_{a1}) .

2. Second dissociation:



with a smaller dissociation constant (K_{a2}) .

Understanding these steps is crucial because the concentration of Se²⁻ depends on the extent to

which H_2Se dissociates through both steps.

Equilibrium Constants and Stepwise Dissociation

Acid Dissociation Constants (K_{a1}) and (K_{a2})

The dissociation of H_2Se is characterized by two equilibrium constants:

- (K_{a1}) : The first dissociation constant, representing the equilibrium between H_2Se and HSe^- .
- (K_{a2}) : The second dissociation constant, representing the equilibrium between HSe^- and Se^{2-} .

Typical values are:

$$K_{a1} \approx 1.3 \times 10^{-4}$$

$$K_{a2} \approx 2.0 \times 10^{-7}$$

(Note: Values are approximate and can vary based on temperature and source.)

Since (K_{a2}) is significantly smaller than (K_{a1}) , the second dissociation is less extensive, meaning that the majority of the Se^{2-} ions originate from the second dissociation, which is less favored.

Implications for Selenide Ion Concentration

Given the small value of (K_{a2}) , the concentration of Se^{2-} in a 0.300 M H_2Se solution will be relatively low compared to the initial concentration. To accurately determine $[\text{Se}^{2-}]$, it is necessary to perform a stepwise equilibrium calculation, considering both dissociation steps and the relevant equilibrium constants.

Calculating Selenide Ion Concentration $[\text{Se}^{2-}]$

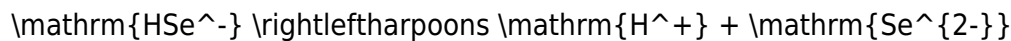
Step 1: Establishing Initial Conditions

Assuming a 0.300 M solution of H_2Se and applying the dissociation steps, the initial concentration of H_2Se is 0.300 M. As dissociation proceeds, some of it converts into HSe^- and Se^{2-} ions. The goal is to find the equilibrium concentration of Se^{2-} .

Step 2: Setting Up Equilibrium Expressions

For the second dissociation:

$$\text{HSe}^- \rightleftharpoons \text{Se}^{2-} + \text{H}^+$$



\]

the equilibrium expression is:

\[

$$K_{a2} = \frac{[\mathrm{H}^{+}][\mathrm{Se}^{2-}]}{[\mathrm{HSe}^{-}]}$$

\]

Similarly, for the first dissociation:

\[

$$K_{a1} = \frac{[\mathrm{H}^{+}][\mathrm{HSe}^{-}]}{[\mathrm{H}_2\mathrm{Se}]}$$

\]

Because these are weak acids, their dissociation is limited, and the concentrations at equilibrium can be approximated using algebraic methods or iterative calculations.

Step 3: Approximate Calculation Method

Given the small value of (K_{a2}) , the concentration of Se^{2-} is expected to be very low. To estimate $[\mathrm{Se}^{2-}]$, the following assumptions are made:

- The initial dissociation of $\mathrm{H}_2\mathrm{Se}$ to HSe^{-} is significant, while the second dissociation contributes less.
- The concentration of HSe^{-} at equilibrium is approximately equal to the amount dissociated from $\mathrm{H}_2\mathrm{Se}$ minus the amount dissociated into Se^{2-} .

The approximate steps involve:

1. Calculating the amount of $\mathrm{H}_2\mathrm{Se}$ dissociated into HSe^{-} using (K_{a1}) .
2. Using the concentration of HSe^{-} to determine the amount of Se^{2-} produced via (K_{a2}) .

This iterative process yields an estimated $[\mathrm{Se}^{2-}]$ value.

Practical Example: Stepwise Calculation of $[\mathrm{Se}^{2-}]$

Estimating the First Dissociation

Assuming that the initial dissociation of $\mathrm{H}_2\mathrm{Se}$ produces a concentration (x) of HSe^{-} :

\[

$$K_{a1} \approx \frac{[\mathrm{H}^{+}][\mathrm{HSe}^{-}]}{[\mathrm{H}_2\mathrm{Se}]} \approx \frac{x \times x}{0.300 - x}$$

\]

Since (K_{a1}) is small, (x) is small relative to 0.300 M, allowing the approximation:

\[

$$K_{a1} \approx \frac{x^2}{0.300}$$

\]

\]

$$x^2 = K_{a1} \times 0.300$$

\]

\[

$$x^2 = 1.3 \times 10^{-4} \times 0.300 \approx 3.9 \times 10^{-5}$$

\]

\[

$$x \approx \sqrt{3.9 \times 10^{-5}} \approx 6.24 \times 10^{-3} \text{ M}$$

\]

Thus, approximately 6.24 mM of HSe^- is formed.

Estimating the Second Dissociation into Se^{2-}

Using the concentration of HSe^- :

\[

$$K_{a2} \approx \frac{[\text{H}^+][\text{Se}^{2-}]}{[\text{HSe}^-]}$$

\]

Assuming the contribution of additional H^+ from the second dissociation is negligible compared to the first, and that $[\text{H}^+]$ remains approximately from the first dissociation:

\[

$$K_{a2} = \frac{[\text{H}^+][\text{Se}^{2-}]}{[\text{HSe}^-]}$$

\]

Rearranged:

\[

$$[\text{Se}^{2-}] = \frac{K_{a2} \times [\text{HSe}^-]}{[\text{H}^+]}$$

\]

Given the small (K_{a2}) , and assuming the pH is not drastically affected, $[\text{H}^+]$ can be approximated from the first dissociation:

\[

$$[\text{H}^+] \approx x = 6.24 \times 10^{-3} \text{ M}$$

\]

Plugging in the values:

\[

$$[\text{Se}^{2-}] = \frac{2.0 \times 10^{-7} \times 6.24 \times 10^{-3}}{6.24 \times 10^{-3}} \approx 2.0 \times 10^{-7} \text{ M}$$

\]

Therefore, the concentration of Se^{2-} in the solution is approximately $2.0 \times 10^{-7} \text{ M}$.

Factors Affecting Selenide Ion Concentration

pH Dependence

The concentration of Se^{2-} is highly sensitive to the pH of the solution. Since the dissociation of H_2Se is pH-dependent, more basic solutions favor the formation of Se^{2-} due to the shift in equilibrium toward dissociation of HSe^- .

Temperature Effects

Temperature influences the equilibrium constants (K_{a1}) and (K_{a2}) . An increase in temperature typically decreases the dissociation constants for weak acids, leading to lower concentrations of ions like Se^{2-} .