# The Ionization Constant For Water Is 2.9x10-14 At 40c. Calculate (H3O+.) (OH), PH And POH For Pure Water

**The Ionization Constant For Water Is 2.9x10-14 At 40c. Calculate (H3O+.) (OH), PH And POH For Pure Water**

Understanding the ionization constant of water is fundamental in the fields of chemistry and environmental science. The ionization constant, often denoted as Kw, describes the extent to which water dissociates into hydrogen ions (H3O+) and hydroxide ions (OH-) in aqueous solutions. At a specific temperature—here, 40°C—this value provides insight into the acidity or alkalinity of pure water. In this article, we will explore the calculation of the concentrations of hydrogen and hydroxide ions, as well as the pH and pOH of pure water at 40°C, given that Kw is 2.9×10^-14. We will also delve into the significance of these parameters and how temperature influences water ionization.

# Understanding the Ionization Constant (Kw) of Water

## What Is the Ionization Constant?

The ionization constant of water, Kw, is the equilibrium constant for the self-ionization of water:

$$\mathrm{H_2O} \leftrightarrow \mathrm{H^+} + \mathrm{OH^-}$$

or, more accurately,

$$\mathrm{H_2O} + \mathrm{H_2O} \leftrightarrow \mathrm{H_3O^+} + \mathrm{OH^-}$$

Since pure water is neutral, the concentrations of H3O+ and OH- are equal at equilibrium, and their product is constant at a given temperature—this is Kw.

## Temperature Dependence of Kw

Kw is highly temperature-dependent. At 25°C, Kw is approximately 1.0×10^-14, but as temperature increases, Kw also increases, indicating greater ionization of water. At 40°C, Kw is given as 2.9×10^-14, reflecting this increase. This change affects the pH and pOH of water, which are crucial parameters in chemistry.

# Calculating (H3O+) and (OH-) Concentrations in Pure Water at 40°C

## Step 1: Recognize the Relationship

Since water is neutral:

$$ [\mathrm{H_3O^+}] = [\mathrm{OH^-}] = x $$

and

$$ Kw = [\mathrm{H_3O^+}][\mathrm{OH^-}] = x \times x = x^2 $$

Given that $Kw = 2.9 \times 10^{-14}$,

$$ x^2 = 2.9 \times 10^{-14} $$

## Step 2: Solve for x

Taking the square root of both sides:

$$ x = \sqrt{2.9 \times 10^{-14}} $$

Using a calculator:

$$ x \approx \sqrt{2.9} \times 10^{-\frac{14}{2}} $$

$$ x \approx 1.703 \times 10^{-7} $$

Therefore,

$$ [\mathrm{H_3O^+}] = [\mathrm{OH^-}] \approx 1.70 \times 10^{-7} \, \mathrm{mol/L} $$

# Calculating pH and pOH of Pure Water at 40°C

## Understanding pH and pOH

pH and pOH are logarithmic measures of hydrogen and hydroxide ion concentrations:

$$ \mathrm{pH} = -\log [\mathrm{H_3O^+}] $$

$$ \mathrm{pOH} = -\log [\mathrm{OH^-}] $$

Since in pure water at 40°C, $[H_3O^+] = [OH^-]$, their p-values are related.

## Step 1: Calculate pH

Using the concentration found:

$$ \mathrm{pH} = -\log(1.70 \times 10^{-7}) $$

$$ \mathrm{pH} = -(\log 1.70 + \log 10^{-7}) $$

$$ \mathrm{pH} = -(\log 1.70 - 7) $$

$$ \mathrm{pH} \approx -(0.2304 - 7) = 6.7696 $$

Rounded to two decimal places:

$$ \mathrm{pH} \approx 6.77 $$

### Step 2: Calculate pOH

Since [OH-] is the same:

$$ \mathrm{pOH} = -\log(1.70 \times 10^{-7}) $$

$$ \mathrm{pOH} \approx 6.77 $$

### Step 3: Verify the Relationship

The sum of pH and pOH should be approximately 14 at 25°C, but at 40°C, due to increased Kw, this sum is slightly less:

$$ \mathrm{pH} + \mathrm{pOH} \approx 6.77 + 6.77 = 13.54 $$

This reflects the temperature dependence of water's ionization and the altered pH/pOH relationship.

## Significance of the Calculations and Practical Implications

### Understanding Water's Neutrality

While at 25°C, pure water has a pH of 7, at higher temperatures like 40°C, the pH decreases slightly because of increased ionization. This is important in processes sensitive to pH changes, such as biochemical reactions and industrial processes.

### Impact on pH Measurement

Accurate pH measurement at elevated temperatures requires considering the temperature-dependent Kw. Standard pH meters calibrated at 25°C may not provide precise readings at 40°C unless temperature compensation is applied.

## Environmental and Industrial Relevance

Knowing the precise ion concentrations and pH of water at various temperatures is crucial for environmental monitoring, water treatment, and chemical manufacturing. Slight variations can significantly influence biological systems and chemical equilibria.

# Summary

- At 40°C, the ionization constant (Kw) of water is 2.9×10^-14.
- The concentrations of H3O+ and OH- in pure water at this temperature are approximately 1.70×10^-7 mol/L.
- The pH of pure water at 40°C is about 6.77, indicating slight acidity compared to neutral pH 7 at 25°C.
- The pOH is also approximately 6.77, and their sum is around 13.54 due to temperature effects.

Understanding these calculations enhances our grasp of water chemistry and underscores the importance of temperature in chemical equilibria. Whether for laboratory experiments, environmental assessments, or industrial applications, accurate knowledge of water's ionization behavior is essential.

References:

- Atkins, P., & de Paula, J. (2014). Physical Chemistry (10th ed.). Oxford University Press.
- Lyman, J. (2004). Water Chemistry: An Introduction to the Chemistry of Natural and Engineered Water.

Note: Always consider temperature effects when working with pH and chemical equilibria, as they significantly influence reaction dynamics and measurement accuracy.

# Frequently Asked Questions

## What is the ionization constant (Kw) for pure water at 40°C?

The ionization constant (Kw) for pure water at 40°C is $2.9 \times 10^{-14}$.

## How do you calculate the concentration of $H_3O^+$ and $OH^-$ in pure water at 40°C?

Since pure water is neutral, $[H_3O^+] = [OH^-] = \sqrt{Kw} = \sqrt{(2.9 \times 10^{-14})} \approx 1.70 \times 10^{-7}$ M.

## What is the pH of pure water at 40°C?

pH = -log[$H_3O^+$] = -log($1.70 \times 10^{-7}$) ≈ 6.77.

## How do you determine the pOH of pure water at 40°C?

pOH = 14 - pH = 14 - 6.77 ≈ 7.23.

## Why does the pH of pure water decrease from 7 to approximately 6.77 at 40°C?

Because the ionization constant increases with temperature, leading to a higher concentration of $H_3O^+$ and a lower pH than at 25°C.

# Additional Resources

The Ionization Constant For Water Is 2.9x10^-14 At 40°C is a fundamental parameter in chemistry that describes the extent to which water dissociates into hydrogen ions ($H_3O^+$) and hydroxide ions ($OH^-$) at a specific temperature. Understanding this constant is crucial for various scientific and industrial applications, including pH determination, chemical reactions in aqueous solutions, and environmental chemistry. This article provides a comprehensive analysis of the calculations involved in determining the concentrations of $H_3O^+$ and $OH^-$ ions, as well as the pH and pOH of pure water at 40°C, based on the given ionization constant.

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# Understanding the Ionization Constant of Water (Kw)

The ionization constant for water, denoted as Kw, quantifies the equilibrium concentration of hydrogen ions and hydroxide ions in pure water. At 40°C, Kw is given as $2.9\times10^{-14}$. This value indicates that water, although largely neutral, slightly dissociates into ions at any temperature above 0°C.

The dissociation of water can be represented as:

$$ \mathrm{H_2O (l)} \leftrightarrow \mathrm{H^+ (aq)} + \mathrm{OH^- (aq)} $$

or equivalently:

$$ \mathrm{H_3O^+ (aq)} + \mathrm{OH^- (aq)} $$

The equilibrium expression for water dissociation is:

$$ K_w = [\mathrm{H_3O^+}] \times [\mathrm{OH^-}] $$

At 40°C, with Kw = $2.9\times10^{-14}$, the product of the molar concentrations of $H_3O^+$ and $OH^-$ in pure water is fixed at this value, assuming the system is at equilibrium and pure.

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## Calculating [$H_3O^+$] and [$OH^-$] in Pure Water at 40°C

Since pure water is neutral, the concentrations of $H_3O^+$ and $OH^-$ are equal:

$$ [\mathrm{H_3O^+}] = [\mathrm{OH^-}] $$

Let’s denote this common concentration as $x$. Therefore,

$$ Kw = x \times x = x^2 $$

$$ 2.9 \times 10^{-14} = x^2 $$

To find $x$:

$$ x = \sqrt{2.9 \times 10^{-14}} $$

Calculating:

$$ x = \sqrt{2.9} \times 10^{-7} $$

$$ \sqrt{2.9} \approx 1.704 $$

$$ x \approx 1.704 \times 10^{-7} \, \text{M} $$

Thus,

$$ [\mathrm{H_3O^+}] = [\mathrm{OH^-}] \approx 1.704 \times 10^{-7} \, \text{M} $$

This concentration indicates the molarity of the ions in pure water at this temperature.

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## Determining pH and pOH of Pure Water at 40°C

pH and pOH are logarithmic measures of the concentration of $H_3O^+$ and $OH^-$ ions, respectively.

pH Calculation:

$$ pH = -\log [\mathrm{H_3O^+}] $$

Substituting the value:

$$ pH = -\log (1.704 \times 10^{-7}) $$

Using logarithm properties:

$$ pH = -\left(\log 1.704 + \log 10^{-7}\right) $$

$$ pH = -\log 1.704 + 7 $$

$$ \log 1.704 \approx 0.231 $$

So,

$$ pH \approx -0.231 + 7 = 6.769 $$

pOH Calculation:

Similarly,

$$ pOH = -\log [\mathrm{OH^-}] $$

Since $[OH^-] = 1.704 \times 10^{-7}$:

$$ pOH \approx 6.769 $$

Note: At 40°C, the sum of pH and pOH is:

$$ pH + pOH \approx 13.538 $$

which slightly deviates from the classic 14 at 25°C, reflecting the temperature dependence of Kw.

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# Summary of Results at 40°C

| Parameter | Value | Explanation |
|---|---|---|
| $[H_3O^+]$ | approximately $1.704\times10^{-7}$ M | Concentration of hydronium ions in pure water at 40°C |
| $[OH^-]$ | approximately $1.704\times10^{-7}$ M | Concentration of hydroxide ions in pure water at 40°C |
| pH | approximately 6.77 | pH of pure water at 40°C |
| pOH | approximately 6.77 | pOH of pure water at 40°C |

Features and Considerations:

- Temperature dependence: The ionization constant Kw varies with temperature, which in turn affects pH and pOH.
- Neutrality: Despite the pH being less than 7 at 40°C, the solution remains neutral because the concentrations of $H_3O^+$ and $OH^-$ are equal.
- Practical significance: Accurate pH measurements at different temperatures are vital in industrial processes, biological systems, and environmental monitoring.

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## Features, Pros, and Cons

Features:

- Precise calculation of ion concentrations based on Kw.
- Demonstrates temperature dependence of water's ionization.
- Connects theoretical constants to practical pH and pOH values.

Pros:

- Enables accurate pH assessment in various applications.
- Essential for understanding acid-base behavior in aqueous solutions.
- Facilitates better control of chemical processes sensitive to pH.

Cons:

- Assumes ideal behavior, neglecting activity coefficients which can be significant at higher ionic strengths.
- Relies on accurate measurement of Kw, which varies with temperature and can be experimentally challenging.
- At extreme temperatures or concentrations, deviations from ideality may occur.

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## Conclusion

The ionization constant for water at 40°C, Kw = $2.9\times10^{-14}$, provides a critical insight into the behavior of water as an acid-base system at elevated temperatures. By calculating the concentrations of $H_3O^+$ and $OH^-$, and consequently the pH and pOH, chemists can better understand the subtle shifts in water's neutrality with temperature changes. As demonstrated, the pH of pure water at 40°C is approximately 6.77, slightly lower than the neutral pH of 7 at 25°C, reflecting increased ionization at higher temperatures. These calculations are fundamental in many scientific fields, emphasizing the importance of temperature considerations in chemical equilibria and solution chemistry.

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