



Review Acids and Bases

Acids	Bases
Taste sour	Taste bitter
Turn blue litmus paper red	Are slippery to touch
React with metals to produce hydrogen gas	Turn red litmus paper blue
React with carbonates or bicarbonates to produce carbon dioxide gas	Turn phenolphthalein pink
React with bases	React with metal salts to produce insoluble hydroxides
	React with carbon dioxide to produce carbonates
	React with acids



Lesson Objectives

By the end of this lesson, you should be able to:

- Describe the self-ionization of **water**.
- Define pH and pOH.
- Convert between pH and hydrogen ion concentration, and between pOH and hydroxide ion concentration.
- Convert between pH and pOH, and between hydrogen ion concentration and hydroxide **ion** concentration.
- Use the pH scale to characterize the acidity and **basicity** of solutions

Science Practice: Solve scientific problems involving pH using logarithmic functions.

**Words to Know**

Write the letter of the definition next to the matching word as you work through the lesson. You may use the glossary to help you.

- | | |
|---------------------|---|
| <u>B</u> pOH | A. a measure of the hydronium ion concentration in an aqueous solution; given by $\text{pH} = -\log [\text{H}^+]$ |
| <u>C</u> acidic | B. a measure of the hydroxide ion concentration in an aqueous solution; given by $\text{pOH} = -\log [\text{OH}^-]$ |
| <u>D</u> basic | C. a word describing a substance with a pH less than 7 |
| <u>A</u> pH | D. a word describing a substance with a pH greater than 7 |
| <u>F</u> alkaline | E. a word describing a substance with a pH of exactly 7 |
| <u>H</u> acidity | F. basic |
| <u>E</u> neutral | G. the degree to which a substance is basic |
| <u>G</u> alkalinity | H. the degree to which a substance is acidic |

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pH

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Lesson Question

How can you express the concentration of hydrogen and hydronium ions in a solution?

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pH

- **pH**: a measure of the hydronium ion concentration in an aqueous

solution; $\text{pH} = -\log [\text{H}^+]$

- **Acidic**: $\text{pH} < 7$

- **Basic (alkaline)**: $\text{pH} > 7$

- **Neutral**: $\text{pH} = 7$

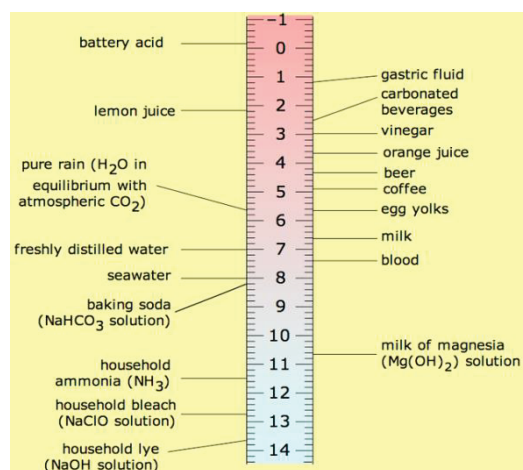
Common pH values:

- Household **bleach**: $\text{pH} \approx 13$
- Ammonia-based window cleaner: $\text{pH} \approx 11$
- Blood: $\text{pH} \approx 7.4$
- Pure water: $\text{pH} = 7$
- Soda: $\text{pH} \approx 3$
- Vinegar: $\text{pH} \approx 2$

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The pH Scale

- **Acidity**: the degree to which a substance is acidic
 - Lower pH indicates greater acidity.
- **Alkalinity**: the degree to which a substance is basic
 - **Higher** pH indicates greater alkalinity.



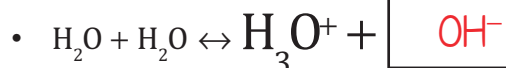
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Interactions between Water Molecules



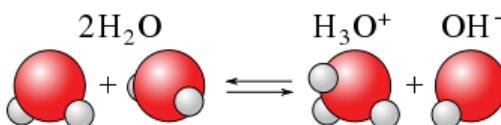
Water reacts with more water to produce hydronium and **hydroxide**.

- In aqueous solution at 25°C:

- $[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}$

- For **pure** water at 25°C:

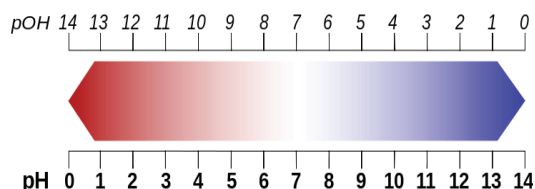
- $[\text{H}_3\text{O}^+] = [\text{OH}^-] = \boxed{10^{-7}} \text{ M}$



pH and pOH

- pOH**: a measure of the hydroxide ion concentration in an aqueous solution; $\text{pOH} = -\log[\text{OH}^-]$

For pH we also have an alternate or opposite of pH, and it's called the pOH.



- pH and pOH are **inversely** related.

- As pH increases, pOH **decreases**.

- Acids have low pH and high pOH.

- Bases have high pH and low pOH.

When water **dissociates**, it produces hydroxide **ions**.

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Review Exponents and Logarithms

Exponents

$$Z^n = (\underbrace{Z \times Z \times \dots \times Z}_n)$$

Example

$$10^3 = (10 \times 10 \times 10)$$

$$= 1,000$$

Logarithms

$$\text{Log}_z(Y) = n$$

Example

$$\text{Log}_{10}(1,000) = 3$$

The pH Equation

- $\text{pH} = -\log[\text{H}_3\text{O}^+]$

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

- $[\text{H}_3\text{O}^+] = [10^{-\text{pH}}]$

- $[\text{OH}^-] = [10^{-\text{pOH}}]$

Calculating pH and pOH

A solution of HCl has $[\text{H}^+] = 2.40 \times 10^{-4} \text{ M}$ and $[\text{OH}^-] = 4.17 \times 10^{-11} \text{ M}$.

What is the pH of this solution? What is its pOH?

- Write the appropriate equation and identify the variables.

$$\text{pH} = -\log[\text{H}^+]$$

- Substitute the given values and solve.

$$\begin{aligned} \text{pH} &= -\log[\text{H}^+] \\ &= -\log[0.00024] \\ &= -(-3.62) \\ &= 3.62 \end{aligned}$$

$$\begin{aligned} \text{pH} + \text{pOH} &= 14 \\ \text{pOH} &= 14 - \text{pH} \\ &= 14 - 3.62 \\ &= 10.38 \end{aligned}$$

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Calculating H⁺ and OH⁻

A solution of KOH has a pH of 12.75 and a pOH of 1.25. Find the concentration of H₃O⁺ and OH⁻ ions in the solution.

- Write the appropriate **equation** and identify the variables.

$$[\text{H}^+] = 10^{-\text{pH}}$$

- Substitute the given values and solve.

$$\begin{aligned} [\text{H}^+] &= 10^{-\text{pH}} \\ &= 10^{-12.75} \\ &= 1.78e^{-13} \end{aligned}$$

$$\begin{aligned} [\text{OH}^-] &= 10^{-\text{pOH}} \\ &= 10^{-1.25} \\ &= 5.6 \times 10^{-2} \end{aligned}$$

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Relate pH and pOH

- $[\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14}$
- $[\text{H}_3\text{O}^+] = \frac{1.0}{[\text{OH}^-]} \times 10^{-14}$
- $[\text{OH}^-] = \frac{1.0 \times 10^{-14}}{[\text{H}_3\text{O}^+]}$
- $\text{pH} + \text{pOH} = 14$
- $\text{pH} = 14 - \text{pOH}$
- $\text{pOH} = 14 - \text{pH}$

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Converting between Values

If $[H^+] = 3.87 \times 10^{-11} \text{ M}$, what is $[OH^-]$?

- Write the appropriate equation.

$$pH = -\log[H^+]$$

- Substitute the given values and **solve**.

$$\begin{aligned} pH &= -\log[H^+] \\ &= -\log[3.87 \times 10^{-11}] \\ &= -(-10.4) \\ &= \mathbf{10.4} \end{aligned}$$

$$\begin{aligned} pOH &= 14 - pH \\ &= 14 - 10.4 \\ &= \mathbf{3.6} \end{aligned}$$

$$\begin{aligned} [OH^-] &= 10^{-pOH} \\ &= 10^{-3.6} \\ &= \mathbf{2.51 \times 10^{-4}} \end{aligned}$$

Converting between Values

What is the pOH of a solution of HBr with a pH of 6.45?

- Write the appropriate **equation**.

$$pOH = 14 - pH$$

- Substitute the given values and solve.

$$\begin{aligned} pOH &= 14 - pH \\ &= 14 - 6.45 \\ &= \mathbf{7.55} \end{aligned}$$

Summary

pH

**Lesson Question**

How can you express the concentration of hydrogen and hydronium ions in a solution?

**Answer**

(Sample answer) pH is a measure of the acidity or alkalinity of a solution and is used to express the concentration of hydrogen and hydronium ions. Acidic solutions have pH values less than 7. Basic (alkaline) solutions have pH values greater than 7.

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pH and the pH Scale

- pH is a measure of the acidity or alkalinity of a solution.
- Acidic solutions have pH values less than 7.
- Basic (alkaline) solutions have pH values greater than 7.
- A solution with a pH of exactly 7 is said to be **neutral**.
- The pH scale is the range of pH values from **0** to 14. It can be used to compare the acidity or alkalinity of different solutions.

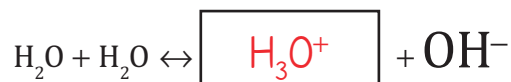
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pOH

- Water molecules can react with each other to produce an equilibrium system:



- $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ are related by the following equation:

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}$$

- Because $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ are related, we can define pOH in a similar way to pH. pOH is a measure of the alkalinity of a solution.
- $\boxed{\text{pH}}$ and pOH are inversely related.

Calculate pH and pOH

- pH is calculated using the following equation:

$$\text{pH} = -\boxed{\log} [\text{H}_3\text{O}^+]$$

- pOH is calculated using the following equation:

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

- These equations can be rearranged to calculate $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$:

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

$$[\text{OH}^-] = \boxed{10^{-\text{pOH}}}$$

- They can also be used to convert between various quantities:

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14}}{\boxed{[\text{H}_3\text{O}^+]}}$$

$$\text{pH} = 14 - \text{pOH}$$

$$[\text{H}_3\text{O}^+] = \frac{1.0 \times 10^{-14}}{[\text{OH}^-]}$$

$$\text{pOH} = \boxed{14} - \text{pH}$$

Summary

pH

Use this space to write any questions or thoughts about this lesson.