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19.1 Notes: THE SELF IONIZATION OF WATER & pH

The Self-ionization of Water

*Do you think pure water is made up of all H_2O molecules???



In pure water at 25°C, both H_3O^+ ions and OH^- ions are found at concentrations of $1.0 \times 10^{-7}M$.

*What is the equilibrium constant of the above reaction?

*What is the ion-product constant for water?

For all solutions at 25°C, the product of the concentration of H_3O^+ and OH^- ions is 1.0×10^{-14} .

All solutions have H_3O^+ ions and OH^- ions. Even acidic solutions have some OH^- ions and basic have some H_3O^+ ions. Why???

Diagram of acidic solutions, neutral solutions, and basic solutions.

The pH Scale

Molar concentrations of H_3O^+ and OH^- are very small in most solutions.

Your stomach has HCl of $0.01M$ therefore the molar concentration of H_3O^+ is 0.01 (or 1×10^{-2}).

Pure water $[H_3O^+] = 1 \times 10^{-7}M$
Strong base $[H_3O^+] = 1 \times 10^{-12}M$

$$pH = -\log[H_3O^+]$$

Log review

$$10,000 = 10^4 \quad \log 10^4 = 4$$

- $0.001 =$
- $1 \times 10^{-12} =$
- $1 \times 10^{-2} =$
- $10^7 =$
- $10^{-7} =$
- $6.3 \times 10^8 =$
- $3.2 \times 10^{-5} =$

Look at the chart on p 629.

How many more times acidic is coffee than pure water? Estimate coffee at 5.

How many more times basic is limewater than borax? Estimate.

Sample problems

- In one brand of vegetable juice the concentration of H_3O^+ ions is $7.3 \times 10^{-5}M$. What is the juice's pH?
- Normal rainwater has a pH near 6. In rainwater that falls close to a coal-burning power plant, the concentration of H_3O^+ ions is $6.23 \times 10^{-4}M$. What is the pH? Is this more acidic or basic than normal rainwater?
- In household bleach, the concentration of OH^- ions is $5.0 \times 10^{-2}M$. What is the pH?

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MORE pH and pOH problems

1. What is $[H_3O^+]$ in a 0.002M solution of NaOH?
2. What is $[H_3O^+]$ in a 0.002M solution of HCl?
3. If $[OH^-]$ is 7.2×10^{-11} , what's the pH?
4. If $pH=4.0$, what's $[H_3O^+]$? $[OH^-]$?
5. What is the pH of a solution with $[OH^-]$ of 9.02×10^{-7} ?
6. A solution with a pOH of 7 has a base added to it. The hydroxide concentration increases by a factor of 10,000. What's the new pOH?
7. What is the hydronium concentration of a 0.050M HCl solution? What is the hydroxide concentration?

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pH problems

1. When pH is 3.2, what is the $[H_3O^+]$ concentration?
2. Find the pOH of a solution with a pH of 6.8.
3. What is the pH of a solution with a pOH of 3.2? Is it acidic, basic, or neutral?
4. If $[H_3O^+]$ is 3.2×10^{-6} , what is the pH? pOH? Acidic, basic, or neutral?
5. If $[OH^-]$ is 1.8×10^{-13} , what is the pH?
6. If pOH = 2, what is $[OH^-]$? $[H_3O^+]$?
7. If pH = 9, what is $[OH^-]$?
8. Find a solution's pH if it's OH^- concentration is $7.84 \times 10^{-4}M$.
9. A solution with a pH of 3 has acid added to it and its $[H_3O^+]$ increases by 1000. What is the new pH?

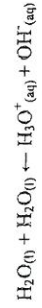
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19.2 Notes: THE SELF IONIZATION OF WATER & pH

The Self-ionization of Water

*Do you think pure water is made up of all H₂O molecules???



In pure water at 25°C, both H₃O⁺ ions and OH⁻ ions are found at concentrations of 1.0 x 10⁻⁷M.

*What is the equilibrium constant of the above reaction?

$$K_{eq} = \frac{[H_3O^+][OH^-]}{[H_2O]^2}$$

*What is the ion-product constant for water?

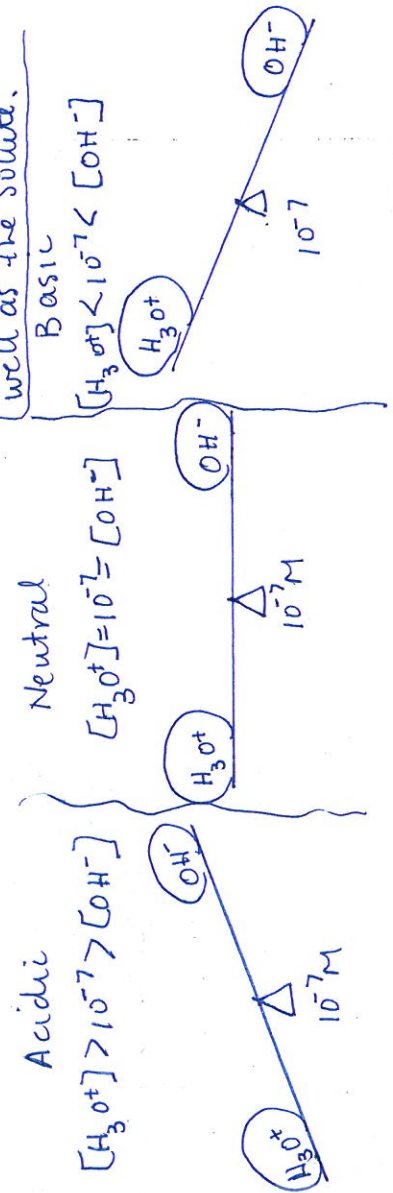
$$K_{eq} [H_2O]^2 = [H_3O^+][OH^-] \Rightarrow K_w = [H_3O^+][OH^-] = (1.0 \times 10^{-7})(1.0 \times 10^{-7}) = 1.0 \times 10^{-14}$$

For all solutions at 25°C, the product of the concentration of H₃O⁺ and OH⁻ ions is 1.0 x 10⁻¹⁴.

All solutions have H₃O⁺ ions and OH⁻ ions. Even acidic solutions have some OH⁻ ions and basic have some H₃O⁺ ions. Why???

Since the solution is in water, the water molecules still react w/ themselves as well as the solute.

Diagram of acidic solutions, neutral solutions, and basic solutions.



The pH Scale

Molar concentrations of H₃O⁺ and OH⁻ are very small in most solutions.

Your stomach has HCl of 0.1M therefore the molar concentration of H₃O⁺ is 0.1M or 1.0 x 10⁻²M

Pure water [H₃O⁺] = 1 x 10⁻⁷M
 Strong base [OH⁻] = 1 x 10⁻¹²M

pH = -log[H₃O⁺]

pOH = -log[OH⁻]
 pH + pOH = 14 since

[H₃O⁺][OH⁻] = 1.0 x 10⁻¹⁴

10,000 = 10⁴ log 10⁴ = 4

a. 0.001 ⇒ 1.0 x 10⁻³ log 1.0 x 10⁻³ = -3

b. 1 x 10⁻¹² ⇒ log 1.0 x 10⁻¹² = -12

c. 1 x 10⁻² ⇒ log 1 x 10⁻² = -2

d. 10⁷ = log 10⁷ = 7

e. 10⁷ = log 10⁷ = 7

f. 6.3 x 10⁸ ⇒ between -5 + -4

g. 3.2 x 10⁹ ⇒ between -5 + -4

Look at the chart on p 629.

How many more times acidic is coffee than pure water? Estimate coffee at 5.

pH = 5 ∴ 5 = -log[H₃O⁺] [H₃O⁺] = 10⁻⁵ = 1.0 x 10⁻⁵ + water is

How many more times basic is limewater than borax? Estimate.

pOH = 9 ∴ [OH⁻] = 1.0 x 10⁻⁹ limewater 1.0 x 10⁻¹¹ 1.0 x 10⁻⁷ ∴ 10² x more basic

∴ 100x (or 10²) more basic

ions is 7.3 x 10⁻⁵M. acidic

pH = -log(7.3 x 10⁻⁵ M) = 4.1

1. In one brand of vegetable juice the concentration of H₃O⁺ ions is 7.3 x 10⁻⁵M. What is the juice's pH?

2. Normal rainwater has a pH near 6. In rainwater that falls close to a coal-burning power plant, the concentration of H₃O⁺ ions is 6.23 x 10⁻⁴M. What is the pH? Is this more acidic or basic than normal rainwater?

pH = -log(6.23 x 10⁻⁴ M) = 3.21 ∴ 10³ or 1000x more acidic

3. In household bleach, the concentration of OH⁻ ions is 5.0 x 10⁻²M. What is the pH?

pOH = -log(5.0 x 10⁻² M) = 1.3

∴ pH = 14 - 1.3 = 12.7

pH problems

MORE pH and pOH problems

- 1. When pH is 3.2, what is the $[H_3O^+]$ concentration? $3.2 = -\log [H_3O^+]$; $[H_3O^+] = 10^{-3.2} = 6.31 \times 10^{-4} M$
- 2. Find the pOH of a solution with a pH of 6.8. $14 - 6.8 = 7.2$
- 3. What is the pH of a solution with a pOH of 3.2? Is it acidic, basic, or neutral? $14 - 3.2 = 10.8$ ∴ basic

- 1. What is $[H_3O^+]$ in a 0.002M solution of NaOH? Strong base ∴ $[OH^-] = 0.002M$
 $[OH^-][H_3O^+] = 1.0 \times 10^{-14}$
 $0.002 [H_3O^+] = 1.0 \times 10^{-14} \Rightarrow [H_3O^+] = 5.0 \times 10^{-12} M$
- 2. What is $[H_3O^+]$ in a 0.002M solution of HCl?
Strong acid ∴ $[H_3O^+] = 0.002M$

- 4. If $[H_3O^+]$ is 3.2×10^{-6} , what is the pH? pOH? Acidic, basic, or neutral?
 $pH = -\log(3.2 \times 10^{-6}) = 5.49$ ∴ soln is acidic
 $pOH = 14 - 5.49 = 8.51$
- 5. If $[OH^-]$ is 1.8×10^{13} , what is the pH?
 $pOH = -\log(1.8 \times 10^{-13}) = 13$ ∴ $pH = 14 - 13 = 1$
- 6. If pOH = 2, what is $[OH^-]$? $[H_3O^+]$?
 $2 = -\log [OH^-] \Rightarrow [OH^-] = 10^{-2} = 0.01M$ $pH = 12$
 $12 = -\log [H_3O^+] \Rightarrow [H_3O^+] = 1.0 \times 10^{-12} M$
- 7. If pH = 9, what is $[OH^-]$?
 $pOH = 14 - 9 = 5$ $[OH^-] = 1.0 \times 10^{-5} M$

- 3. If $[OH^-]$ is 7.2×10^{-11} , what's the pH?
 $pOH = -\log(7.2 \times 10^{-11}) = 10$ ∴ $pH = 14 - 10 = 4$ or 3.9
- 4. If pH=4.0, what's $[H_3O^+]$? $[OH^-]$?
 $[H_3O^+] = 1.0 \times 10^{-4} M$ ∴ $[OH^-] = 1.0 \times 10^{-10} M$
- 5. What is the pH of a solution with $[OH^-]$ of 9.02×10^{-7} ?
 $pOH = -\log(9.02 \times 10^{-7}) = 6.04$ ∴ $pH = 14 - 6.04 = 7.96$

- 8. Find a solution's pH if it's OH^- concentration is $7.84 \times 10^{-6} M$.
 $pOH = -\log(7.84 \times 10^{-6}) = 5.11$ $14 - 5.11 = 8.89 = pH$
- 9. A solution with a pH of 3 has acid added to it and its $[H_3O^+]$ increases by 1000. What is the new pH?
 $1.0 \times 10^{-3} (1.0 \times 10^3) = 1.0 \times 10^0$
 $\log [] = 0$

- 6. A solution with a pOH of 7 has a base added to it. The hydroxide concentration increases by a factor of 10,000. What's the new pOH?
 $[OH^-] = 1.0 \times 10^{-7} \times 10^4 = 1.0 \times 10^{-3}$ ∴ new $pOH = 3$
- 7. What is the hydronium concentration of a 0.050M HCl solution? What is the hydroxide concentration?
 $[H_3O^+] = ?$; $[OH^-] = ?$
HCl is a strong acid ∴ $[H_3O^+] = 0.050M$
since $[H_3O^+][OH^-] = 1.0 \times 10^{-14} M$
then $0.050 [OH^-] = 1.0 \times 10^{-14}$
 $[OH^-] = \frac{1.0 \times 10^{-14}}{0.050} = 2.0 \times 10^{-13} M$