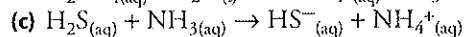
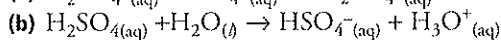
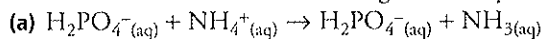


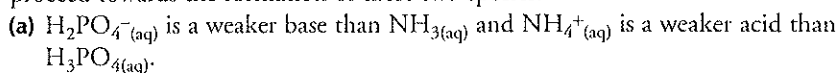
11. Problem

In which direction will the following reactions proceed? Explain why in each case.

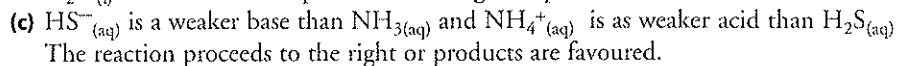
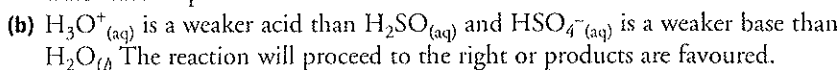


Solution

Using Figure 14.12, identify the weaker acid and the weaker base. The reaction will proceed towards the formation of these two species.



This reaction proceeds to the left or reactants are favoured..

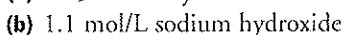
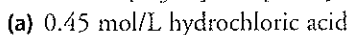


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12. Problem

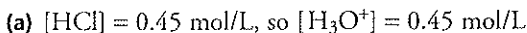
Determine $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in each solution.



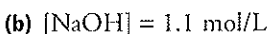
Solution

You know that hydrochloric acid is a strong acid and sodium hydroxide is a strong base. Since both dissociate completely in aqueous solutions, you can use their molar concentrations to determine $[\text{H}_3\text{O}^+]$ or $[\text{OH}^-]$. You can find the concentration of the other ion using K_w as shown below:

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



$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{0.45} \\ &= 2.2 \times 10^{-14} \text{ mol/L} \end{aligned}$$



Therefore, $[\text{OH}^-] = 1.1 \text{ mol/L}$

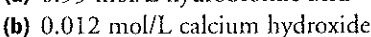
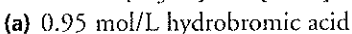
$$\begin{aligned} [\text{H}_3\text{O}^+] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{1.1} \\ &= 9.1 \times 10^{-15} \text{ mol/L} \end{aligned}$$

Check Your Solution

Solution (a) is a strong acid. Therefore, $[\text{H}_3\text{O}^+]$ should be greater than 1.0×10^{-7} , and $[\text{OH}^-]$ should be less than 1.0×10^{-7} . For a solution of a strong base, as in (b), $[\text{OH}^-]$ should be greater than 1.0×10^{-7} , and $[\text{H}_3\text{O}^+]$ should be less than 1.0×10^{-7} .

13. Problem

Determine $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ in each solution.



Solution

You know that hydrobromic acid is a strong acid and calcium hydroxide is a strong base. Since both dissociate completely in aqueous solutions, you can use their molar concentrations to determine $[\text{H}_3\text{O}^+]$ or $[\text{OH}^-]$. You can find the concentration of the other ion using K_w , as shown below:

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

(a) $[\text{HBr}] = 0.95 \text{ mol/L}$, so $[\text{H}_3\text{O}^+] = 0.95 \text{ mol/L}$

$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{0.95} \\ &= 1.1 \times 10^{-14} \text{ mol/L} \end{aligned}$$

(b) $[\text{Ca}(\text{OH})_2] = 0.12 \text{ mol/L}$

Each mole of $\text{Ca}(\text{OH})_2$ in solution forms two moles of OH^- ions.

Therefore, $[\text{OH}^-] = 2 \times 0.12 \text{ mol/L} = 0.24 \text{ mol/L}$

$$\begin{aligned} [\text{H}_3\text{O}^+] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{0.24} \\ &= 4.2 \times 10^{-13} \text{ mol/L} \end{aligned}$$

Check Your Solution

Solution (a) is a strong acid. Therefore, $[\text{H}_3\text{O}^+]$ should be greater than 1.0×10^{-7} , and $[\text{OH}^-]$ should be less than 1.0×10^{-7} . For a solution of a strong base, as in (b), $[\text{OH}^-]$ should be greater than 1.0×10^{-7} , and $[\text{H}_3\text{O}^+]$ should be less than 1.0×10^{-7} .

14. Problem

$[\text{OH}^-]$ is $5.6 \times 10^{-14} \text{ mol/L}$ in a solution of hydrochloric acid. What is the molar concentration of the $\text{HCl}_{(\text{aq})}$?

Solution

You know $[\text{OH}^-] = 5.6 \times 10^{-14} \text{ mol/L}$. You can find $[\text{H}_3\text{O}^+]$ using K_w as shown below:

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

Hydrochloric acid is a strong acid. Therefore, $[\text{H}_3\text{O}^+] = [\text{HCl}]$

$$\begin{aligned} [\text{H}_3\text{O}^+] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{5.6 \times 10^{-14}} \\ &= 0.18 \text{ mol/L} \end{aligned}$$

Therefore, $[\text{HCl}] = 0.18 \text{ mol/L}$

Check Your Solution

For a solution with $[\text{OH}^-]$ less than 1.0×10^{-7} , the $[\text{H}_3\text{O}^+]$ must be greater than 1.0×10^{-7} .

15. Problem

$[\text{H}_3\text{O}^+]$ is 1.7×10^{-14} in a solution of calcium hydroxide. What is the molar concentration of the $\text{Ca}(\text{OH})_{2(\text{aq})}$?

Solution

You know $[\text{H}_3\text{O}^+] = 1.7 \times 10^{-14} \text{ mol/L}$. You can find $[\text{OH}^-]$ using K_w as shown below:

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

Calcium hydroxide is a strong base. Each mole of $\text{Ca}(\text{OH})_2$ forms two moles of OH^- ions. Therefore, $[\text{Ca}(\text{OH})_2] = \frac{1}{2} \times [\text{OH}^-]$

$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{1.7 \times 10^{-14}} \\ &= 0.588 \text{ mol/L} \end{aligned}$$

Therefore, $[\text{Ca}(\text{OH})_2] = \frac{1}{2} \times 0.588 \text{ mol/L} = 0.29 \text{ mol/L}$

Check Your Solution

For a solution with $[\text{H}_3\text{O}^+]$ less than 1.0×10^{-7} , the $[\text{OH}^-]$ must be greater than 1.0×10^{-7} .

Solutions for Practice Problems

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16. Problem

Calculate the pH of each solution, given the hydronium ion concentration.

- (a) $[\text{H}_3\text{O}^+] = 0.0027 \text{ mol/L}$
- (b) $[\text{H}_3\text{O}^+] = 7.28 \times 10^{-8} \text{ mol/L}$
- (c) $[\text{H}_3\text{O}^+] = 9.7 \times 10^{-5} \text{ mol/L}$
- (d) $[\text{H}_3\text{O}^+] = 8.27 \times 10^{-12} \text{ mol/L}$

What Is Required?

You need to calculate the solution pH for the hydronium ion concentrations listed.

What Is Given?

The $[\text{H}_3\text{O}^+]$ is given for each solution.

Plan Your Strategy

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

Act on Your Strategy

- (a) $\text{pH} = -\log 0.0027 = 2.57$
- (b) $\text{pH} = -\log 7.28 \times 10^{-8} = 7.14$
- (c) $\text{pH} = -\log 9.75 \times 10^{-5} = 4.01$
- (d) $\text{pH} = -\log 8.27 \times 10^{-12} = 11.08$

Check Your Solution

- (a) $[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be less than 7 and the solution should be acidic, which it is at 2.57.
- (b) $[\text{H}_3\text{O}^+]$ is slightly lower than $1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH of the solution should be just above neutral, which it is at 7.14.
- (c) $[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be less than 7 and the solution should be acidic, which it is at 4.01.
- (d) $[\text{H}_3\text{O}^+] < 1.0 \times 10^{-7} \text{ mol/L}$, therefore pH should be more than 7 and the solution should be basic, which it is at 11.08.

17. Problem

$[\text{H}_3\text{O}^+]$ in a cola drink is about $5.0 \times 10^{-3} \text{ mol/L}$. Calculate the pH of the drink. State whether the drink is acidic or basic.

What Is Required?

You have to calculate the pH of a cola drink.

What Is Given?

$[\text{H}_3\text{O}^+] = 5.0 \times 10^{-3} \text{ mol/L}$

Plan Your Strategy

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

Act on Your Strategy

$\text{pH} = -\log 5.0 \times 10^{-3} = 2.30$. Therefore, the cola drink is acidic.

Check Your Solution

$[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be less than 7 and the cola drink should be acidic, which it is at 2.3.

18. Problem

A glass of orange juice has $[\text{H}_3\text{O}^+]$ of $2.9 \times 10^{-4} \text{ mol/L}$. Calculate the pH of the juice. State whether the result is acidic or basic.

What Is Required?

You have to calculate the pH of a sample of orange juice.

What Is Given?

$[\text{H}_3\text{O}^+] = 2.9 \times 10^{-4} \text{ mol/L}$

Plan Your Strategy

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

Act on Your Strategy

$\text{pH} = -\log 2.9 \times 10^{-4} = 3.54$. Therefore, the orange juice is acidic.

Check on Your Solution

$[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be less than 7 and the juice should be acidic, which it is at 3.54.

19. Problem

(a) $[\text{H}_3\text{O}^+]$ in a dilute solution of nitric acid, HNO_3 , is $6.3 \times 10^{-3} \text{ mol/L}$. Calculate the pH of the solution.

(b) $[\text{H}_3\text{O}^+]$ of a solution of sodium hydroxide is $6.59 \times 10^{-10} \text{ mol/L}$. Calculate the pH of the solution.

What Is Required?

You have to calculate the pH of the nitric acid and sodium hydroxide solutions.

What Is Given?

$[\text{H}_3\text{O}^+] = 6.3 \times 10^{-3} \text{ mol/L}$ for HNO_3

$[\text{H}_3\text{O}^+] = 6.59 \times 10^{-10} \text{ mol/L}$ for NaOH

Plan Your Strategy

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

Act on Your Strategy

(a) $\text{pH} = -\log 6.3 \times 10^{-3} = 2.2$, therefore, the solution is acidic.

(b) $\text{pH} = -\log 6.59 \times 10^{-10} = 9.18$, therefore, the solution is basic.

Check Your Solution

(a) $[\text{H}_3\text{O}^+] > 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be less than 7 and the solution should be acidic, as would be expected for nitric acid.

(b) $[\text{H}_3\text{O}^+] < 1.0 \times 10^{-7} \text{ mol/L}$, therefore the pH should be more than 7 and the solution should be basic, as would be expected for NaOH .

Solutions for Practice Problems

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20. Problem

$[\text{H}_3\text{O}^+]$ of a sample of milk is found to be $3.98 \times 10^{-7} \text{ mol/L}$. Is the milk acidic, neutral, or basic? Calculate the pH and $[\text{OH}^-]$ of the sample.

Solution

Compare $[\text{H}_3\text{O}^+]$ in the milk with $[\text{H}_3\text{O}^+]$ in neutral water.

$[\text{H}_3\text{O}^+] = 3.98 \times 10^{-7} \text{ mol/L}$, which is greater than $1.0 \times 10^{-7} \text{ mol/L}$.

Therefore, the milk is acidic.

Use the equation $\text{pH} = -\log[\text{H}_3\text{O}^+]$ to find the pH.

$$\text{pH} = -\log 3.98 \times 10^{-7}$$

$$= 6.400$$

Use the following equation to find the hydroxide ion concentration:

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

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ mol/L}}{3.98 \times 10^{-7}}$$

$$= 2.51 \times 10^{-8} \text{ mol/L}$$

Check Your Solution

The ion product is

$$[\text{H}_3\text{O}^+] \times [\text{OH}^-] = 3.98 \times 10^{-7} \times 2.51 \times 10^{-8} = 9.99 \times 10^{-15}$$

This is equal to the value of K_w , 1.0×10^{-14} , within the error introduced by mathematical rounding.

21. Problem

A sample of household ammonia has a pH of 11.9. What is the pOH and $[\text{OH}^-]$ of the sample?

Solution

Use the following equation to find the pOH:

$$\text{pH} + \text{pOH} = 14.0$$

Then calculate $[\text{OH}^-]$ using the following equation:

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

$$\text{pOH} = 14.0 - 11.9$$

$$= 2.1$$

$$[\text{OH}^-] = 10^{-2.1}$$

$$= 8 \times 10^{-3} \text{ mol/L}$$

Check Your Solution

The ammonia solution has pH greater than 7, and is therefore basic. The $[\text{OH}^-]$ is greater than $1 \times 10^{-7} \text{ mol/L}$.

22. Problem

Phenol, $\text{C}_6\text{H}_5\text{OH}$, is used as a disinfectant. An aqueous solution of phenol was found to have a pH of 4.72. Is phenol acidic, neutral, or basic? Calculate $[\text{H}_3\text{O}^+]$, $[\text{OH}^-]$, and pOH of the solution.

Solution

Compare the pH of the solution with the pH of neutral water, $\text{pH} = 7$, which is less than 7. Therefore, the solution is acidic.

Use the following equation to find the $[\text{H}_3\text{O}^+]$:

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

$$[\text{H}_3\text{O}^+] = 10^{-4.72}$$

$$= 1.9 \times 10^{-5} \text{ mol/L}$$

Use the following equation to find the hydroxide ion concentration:

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

$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{1.9 \times 10^{-5}} \\ &= 5.3 \times 10^{-10} \text{ mol/L} \end{aligned}$$

Calculate pOH using the following equation:

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

$$\begin{aligned} \text{pOH} &= -\log 5.3 \times 10^{-10} \\ &= 9.28 \end{aligned}$$

Check Your Solution

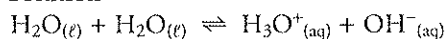
$$\text{pH} + \text{pOH} = 4.72 + 9.28 = 14.00$$

23. Problem

At normal body temperature, 37°C, the value of K_w for water is 2.5×10^{-14} .

Calculate $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ at this temperature. Is pure water at 37°C acidic, neutral, or basic?

Solution



Therefore, $[\text{H}_3\text{O}^+] = [\text{OH}^-]$

Let x represent $[\text{H}_3\text{O}^+]$.

Find the hydronium ion concentration using:

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

$$2.5 \times 10^{-14} = x^2$$

$$x = \pm 1.6 \times 10^{-7}$$

The negative root is not physically possible.

Therefore, $[\text{H}_3\text{O}^+] = [\text{OH}^-] = 1.6 \times 10^{-7} \text{ mol/L}$

Water is neutral at 37°C since $[\text{H}_3\text{O}^+] = [\text{OH}^-]$

Check Your Solution

K_w is an equilibrium constant. Every equilibrium constant depends on temperature. Since the water is pure, it must be neutral.

24. Problem

A sample of baking soda was dissolved in water and the pOH of the solution was found to be 5.81 at 25°C. Is the solution acidic, basic or neutral? Calculate the pH, $[\text{H}_3\text{O}^+]$, and $[\text{OH}^-]$ of the solution.

Solution

Compare the pOH of the solution with the pOH of neutral water at 25°C. The pOH is 5.81, which is less than 7. Therefore, the solution is basic.

Use the following equation to find the pH:

$$\text{pH} + \text{pOH} = 14.00$$

$$\begin{aligned} \text{pH} &= 14.00 - 5.81 \\ &= 8.19 \end{aligned}$$

$$\begin{aligned} [\text{H}_3\text{O}^+] &= 10^{-\text{pH}} \\ &= 10^{-8.19} \\ &= 6.5 \times 10^{-9} \text{ mol/L} \end{aligned}$$

Use the following equation to find the hydroxide ion concentration:

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

$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{6.5 \times 10^{-9}} \\ &= 1.5 \times 10^{-6} \text{ mol/L} \end{aligned}$$

Check Your Solution

$$\begin{aligned} [\text{H}_3\text{O}^+][\text{OH}^-] &= (6.5 \times 10^{-9}) \times (1.5 \times 10^{-6}) \\ &= 9.8 \times 10^{-15} \end{aligned}$$

This is equal to the value of K_w , 1.0×10^{-14} , within the error introduced by mathematical rounding.

25. Problem

A chemist dissolved some AspirinTM in water. The chemist then measured the pH of the solution and found it to be 2.73 at 25°C. What are the $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ of the solution?

Solution

Find the hydronium ion concentration using the following equation:

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

$$[\text{H}_3\text{O}^+] = 10^{-2.73} = 1.9 \times 10^{-3} \text{ mol/L}$$

Use the following equation to find the hydroxide ion concentration:

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

$$\begin{aligned} [\text{OH}^-] &= \frac{1.0 \times 10^{-14} \text{ mol/L}}{1.9 \times 10^{-3}} \\ &= 5.3 \times 10^{-12} \text{ mol/L} \end{aligned}$$

Check Your Solution

$$\begin{aligned} [\text{H}_3\text{O}^+][\text{OH}^-] &= (1.9 \times 10^{-3}) \times (5.3 \times 10^{-12}) \\ &= 1.0 \times 10^{-14} \end{aligned}$$

This is equal to the value of K_w at 25°C.

Solutions for Practice Problems

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26. Problem

Calculate the pH of a $\text{HNO}_{3(\text{aq})}$ solution which is formed by diluting 45 mL of 0.0115 mol/L $\text{HNO}_{3(\text{aq})}$ to a final volume of 2.00 L.

What is Required?

You must determine the final pH of a solution after a dilution was carried out.

What is Given?

Initial: $V_i = 45 \text{ mL}$, $c_i = 0.0115 \text{ mol/L}$, $V_f = 2.00 \text{ L}$

Plan Your Strategy

Step 1 Calculate c_f using the equation $c_i V_i = c_f V_f$

Step 2 Since $\text{HNO}_{3(\text{aq})}$ is a strong acid containing one H^+ ion per mol of $\text{HNO}_{3(\text{aq})}$, c_f for the $\text{HNO}_{3(\text{aq})} = c_f$ for $\text{H}_3\text{O}^+_{(\text{aq})}$ and $\text{pH} = -\log[\text{H}_3\text{O}^+_{(\text{aq})}]$