

Calculating the pH of a Salt Solution: Salty and Delicious!

To calculate the pH of a salt solution, follow the thrilling three step process shown below!

- Identify the ion of the salt that is acting as a weak acid or base. (This will be the ion that came from the weak acid/base in the neutralization reaction).
 - If the ion is acting as a weak acid, write the hydrolysis reaction of the ion with water and set up a RICE table using the K_a expression.
 - The hydrolysis reaction for an acidic salt will always be the cation reacting with water to form H_3O^+ and a weak base.
 - If the ion is acting as a weak base, write the hydrolysis reaction of the ion with water and set up a RICE table using the K_b expression.
 - The hydrolysis reaction for a basic salt will always be the anion reacting with water to form OH^- and a weak acid.
- WATCH OUT:** A classic trick question is to only provide K_a values even when a K_b value is needed. Use the relationship below to convert if needed!

$$1 \times 10^{-14} = K_a \times K_b$$

- Use one of the equations below to solve for $[H_3O^+]$ or $[OH^-]$.

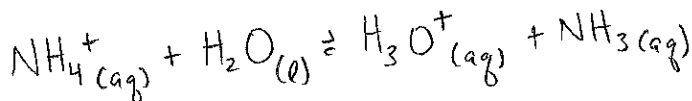
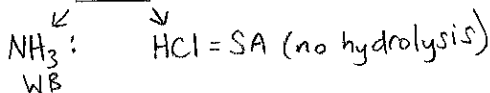
$$K_a = \frac{[x][x]}{[HA]_0} \text{ where } x = [H_3O^+] \quad \text{or} \quad K_b = \frac{[x][x]}{[B]_0} \text{ where } x = [OH^-]$$

- Once you've calculated $[H_3O^+]$ or $[OH^-]$, solve for pH or pOH.

$$pH = -\log[H_3O^+] \quad \text{or} \quad pOH = -\log[OH^-]$$

Guided Practice

- Calculate the pH of a 0.10 M NH_4Cl solution. The K_a value for NH_4^+ is 5.6×10^{-10} .



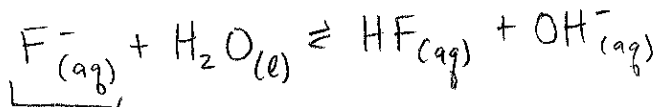
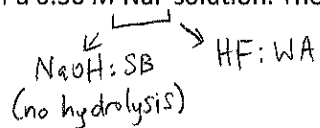
$$K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = \frac{x^2}{0.10 - x} \approx \frac{x^2}{0.10} = 5.6 \times 10^{-10}$$

$K_a \ll 1$, x negligible

$$x = [H_3O^+] = \sqrt{(0.10)(5.6 \times 10^{-10})} = 7.5 \times 10^{-6} M$$

$$pH = -\log(7.5 \times 10^{-6}) = \boxed{5.13}$$

2. Calculate the pH of a 0.30 M NaF solution. The K_a value for HF is 7.2×10^{-4} .



Acting as a weak base \Rightarrow need $K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{7.2 \times 10^{-4}} = 1.4 \times 10^{-11}$

$$K_b = \frac{[\text{HF}][\text{OH}^-]}{[\text{F}^-]} = \frac{x^2}{0.30 - x} \approx \frac{x^2}{0.30} = 1.4 \times 10^{-11}$$

$K_b \ll 1$, x negligible

$$x = [\text{OH}^-] = \sqrt{(0.30)(1.4 \times 10^{-11})} = 2.0 \times 10^{-6} \text{ M}$$

$$\text{pOH} = -\log(2.0 \times 10^{-6}) = 5.69 \Rightarrow \text{pH} = 14 - 5.69 = \boxed{8.31}$$

Multiple Choice Practice

3. What is the pH of a 1.0×10^{-2} M solution of NaCN? (For HCN, $K_a = 1.0 \times 10^{-10}$).

- a. between 0 and 3
b. between 3 and 7
c. between 7 and 10
d. between 10 and 14

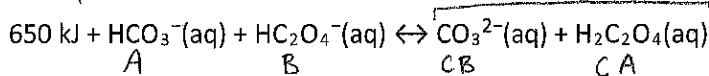
$$K_b(\text{CN}^-) = \frac{1 \times 10^{-14}}{1 \times 10^{-10}} = 1 \times 10^{-4}$$

$$K_b = \frac{x^2}{1 \times 10^{-2}} = 1 \times 10^{-4} \Rightarrow x = [\text{OH}^-] = \sqrt{(1 \times 10^{-2})(1 \times 10^{-4})} = \sqrt{1 \times 10^{-6}} = 1 \times 10^{-3}$$

$$\Rightarrow \text{pOH} = 3$$

$$\text{pH} = 14 - 3 = 11$$

favored = weaker!



4. If $K > 1$, all of the following statements are true about the reaction above EXCEPT:

- a. HC_2O_4^- is a weaker base than CO_3^{2-} .
b. HCO_3^- and $\text{H}_2\text{C}_2\text{O}_4$ are both acting as acids in the reaction.
c. The reaction lies far to the right (favors products).
d. Lowering the temperature of the solution will decrease the value of K .

5. Which of the following would form a basic solution when dissolved in water?

a. HCl
SA!

b. LiCl
 $\downarrow \quad \downarrow$
 LiOH HCl
 SB SA

\Rightarrow neutral

c. NH_4Cl
 $\downarrow \quad \downarrow$
 NH_3 HCl
 WB SA

\Rightarrow acidic

d. $\text{NaC}_2\text{H}_3\text{O}_2$
 $\downarrow \quad \downarrow$
 NaOH $\text{HC}_2\text{H}_3\text{O}_2$
 SB WA