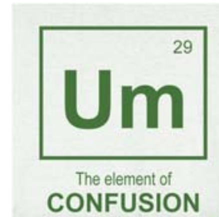
Acid-Base Properties of Salts

Section 8.6

Not all salt solutions are neutral!!

Some salts have weak acidic or weak basic properties.

Alter the pH of their aqueous solutions.



Scenario 1:

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

HCl: strong acid

NaOH: strong base

NaCl → $Na^+_{(aq)}$ + $Cl^-_{(aq)}$

$Na^+_{(aq)}$: conjugate acid of a strong base = **a very weak acid**

$Cl^-_{(aq)}$: conjugate base of a strong acid = **a very weak base**

Neither of these ions can act as a significant acid or base.

Therefore, the aqueous solution of NaCl IS neutral. (pH = 7)

In general,

A solution is **neutral** if it contains:

the cation of a strong base — Group 1 or 2 elements

\+

the anion of a strong acid — Cl^-, NO_3^-, etc.

Scenario 2:

$HC_2H_3O_{2\,(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaC_2H_3O_{2\,(aq)}$

$HC_2H_3O_2$: weak acid

NaOH: strong base

$NaC_2H_3O_2$ → $Na^+_{(aq)}$ + $C_2H_3O_2^-{}_{(aq)}$

$C_2H_3O_2^-{}_{(aq)}$: conjugate base of a weak acid = **a weak base**

The acetate ion is a weak base. It reacts with water to produce OH^-.

$C_2H_3O_2^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HC_2H_3O_{2\,(aq)} + OH^-_{(aq)}$

Therefore, the aqueous solution of $NaC_2H_3O_2$ is slightly basic (pH > 7).

In general,

A solution is **slightly basic** if it contains:

the cation of a strong base — Group 1 or 2 elements

\+

the **anion of a weak acid**

Scenario 3:

$HCl_{(aq)}$ + $NH_{3(aq)}$ → $NH_4Cl_{(aq)}$

strong acid — weak base

$NH_4^+{}_{(aq)}$ — conjugate acid of a weak base = **a weak acid**

$Cl^-{}_{(aq)}$

The ammonium ion is a weak acid. It ionizes:

$$NH_4^+{}_{(aq)} \rightleftharpoons NH_{3(aq)}{}_{(aq)} + H^+{}_{(aq)}$$

Therefore, the aqueous solution of NH_4Cl is slightly acidic (pH < 7).

In general,

A solution is **slightly acidic** if it contains:

the **cation of a weak base**

+

the anion of a strong acid Cl^-, NO_3^-, etc.

Example 1a. Predict whether a 0.10 mol/L solution of $NaNO_{2\ (aq)}$ will be acidic, basic, or neutral.

1. Write the dissociation equation for the salt.

   $$NaNO_{2\ (aq)} \rightarrow Na^+{}_{(aq)} + NO_2^-{}_{(aq)}$$

2. Examine the cation and anion - are either of them weak acids or bases?

   - **Na^+** - CA of NaOH ∴ No effect on pH
   - **NO_2^-** - CB of $HNO_{2\ (aq)}$. Since $HNO_{2\ (aq)}$ is only a weak acid, NO_2^- will act as a weak base.

   Therefore, the solution of $NaNO_2$ will be basic.

Example 1b. Find the pH of a 0.10 mol/L solution of $NaNO_{2\ (aq)}$.

1. Write the equation for the reaction between the weak base, and water.

   $$NO_2^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HNO_{2\ (aq)} + OH^-{}_{(aq)}$$

2. Set up an ICE table and K_b expression.

	NO_2^-	H_2O	HNO_2	OH^-
I	0.10	-	0	0
C	- x	-	+ x	+ x
E	0.10 – x	-	x	x

$[NO_2^-]_0 = [NaNO_2]$ because ALL SALTS are highly soluble.

$$K_b = \frac{[HNO_2][OH^-]}{[NO_2^-]}$$

But wait…we need a value for K_b, since it wasn't provided!

CHECK APPENDIX B5, p. 726

No K_b value for NO_2^-, but K_a for HNO_2 (its conjugate acid) IS provided… how can we use it?

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3. Use K_a of conjugate acid to find K_b.

   K_a of $HNO_2 = 4.6 \times 10^{-4}$

   $$K_a K_b = K_W$$

   $$K_b = \frac{K_W}{K_a} = \frac{1.0 \times 10^{-14}}{4.6 \times 10^{-4}}$$

   $$\mathbf{K_b = 2.2 \times 10^{-11}}$$

4. Sub in values and solve for $[OH^-]$

   $$K_b = \frac{[HNO_2][OH^-]}{[NO_2^-]}$$

   $$2.2 \times 10^{-11} = \frac{(x^2)}{(0.10 - x)} \cong \frac{(x^2)}{(0.10)}$$

   $\frac{0.10}{K_b} >> 100$

   $$\mathbf{x \cong 1.5 \times 10^{-6}\ mol/L}$$

   $\frac{x}{0.10} < 5\%$ Assumption was valid!

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5. Use $[OH^-]$ to find pOH

   $pOH = -\log[OH^-]$

   $pOH = -\log(1.5 \times 10^{-6}\ mol/L) = \mathbf{5.82}$

6. Use pOH to find pH

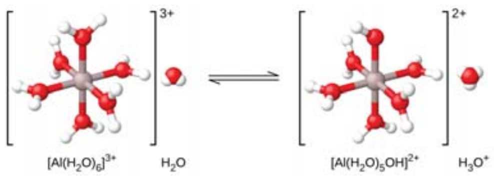
   $pH = 14.00 - pOH$

   $= 14.00 - 5.82$

   pH = 8.17

Other salts that affect pH

- Salts containing highly-charged metal ions → Acidic solutions
  - Water molecules form a “shell” of hydration around cation
  - If cation has a large + charge, it can weaken the OH bond in surrounding H_2O → H_2O more readily gives up protons to solution
  - Examples: Al^{3+} and Fe^{2+}



- **Metallic oxides** – React with water → Basic solutions
  - $CaO_{(s)} + H_2O_{(l)} \rightleftharpoons Ca(OH)_{2\,(aq)}$

- **Non-metallic oxides** – React with water → Acidic solutions
  - $CO_{2\,(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3\,(aq)}$

Summary

- In aqueous solution, some salts dissolve to produce weakly acidic or basic solutions.

- K_a and/or K_b values can be used to predict the pH of such solutions.

Homework

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