# How Buffers Work

## How do they resist pH change?

# pH change when adding acid to water

1 liter of water, so V = 1 L; pH = 7

Add 1 mL 1.0 M HCl, so $V_1$ = 0.001 L, $M_1$ = 1.0 M

Use $V_1 \times M_1 = V_2 \times M_2$ to calculate $M_2$ ; $V_2$ = 1 L

0.001 L x 1.0 M = 1 L x $M_2$ ; $M_2$ = 0.001 M = $10^{-3}$ M

$[H^+] = 10^{-3}$ M; pH goes from 7 to 3

# pH change when adding base to water

1 liter of water, so V = 1 L; pH = 7

Add 1 mL 1.0 M NaOH, so $V_1$ = 0.001 L, $M_1$ = 1.0 M

Use $V_1 \times M_1 = V_2 \times M_2$ to calculate $M_2$ ; $V_2$ = 1 L

0.001 L x 1.0 M = 1 L x $M_2$ ; $M_2$ = 0.001 M = $10^{-3}$ M

$[OH^-] = 10^{-3}$ M; $[H^+] = 10^{-11}$ M; pH = 11

# How Buffers Work

Buffers are a mixture of a weak acid (HA) and its conjugate base (A-)

Examples: $CH_3COOH/NaCH_3COO$, or $H_2CO_3/NaHCO_3$

$$H^+ + A^- \rightarrow HA$$

$$OH^- + HA \rightarrow H_2O + A^-$$

# Buffer Calculations

$$HA \leftrightarrow H^+ + A^-$$

$$K_a = \frac{[H^+] \times [A^-]}{[HA]}$$

$$\frac{K_a}{[H+]} = \frac{[A-]}{[HA]}$$

"Handy Equation"

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

Henderson-Hasselbach Equation

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$\frac{K_a}{[H^+]} = \frac{[A^-]}{[HA]}$$

When $[A^-] = [HA]$

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$[A^-]/[HA] = 1$ ; $\log 1 = 0$

$[A^-]/[HA] = 1$

So, $pH = pK_a$

So, $[H^+] = K_a$

# Calculation shortcut

[ ] = concentration in moles/L

$[A^-]/[HA]$ = ($A^-$ in mol/L) / (HA in mol/L)

The value of L is the same for $A^-$ and HA, so

$[A^-]/[HA]$ = (mol of $A^-$)/(mol of HA)

# pH change when adding acid to buffer

Buffer: 0.10 M $CH_3COOH$ and 0.10 M $NaCH_3COO$

pKa of $CH_3COOH$ is 4.75 (so the buffer is pH 4.75)

1 L Buffer, pH 4.75 contains

0.10 mol $CH_3COOH$ and 0.10 mol $NaCH_3COO$

Add 1 mL 1.0 M HCl to 1 L Buffer, pH 4.75, so

0.001 mol $H^+$ is added.

The added HCl reacts with the A- present to form more HA

$$H^+ + A^- \rightarrow HA$$

Moles HA = 0.100 + 0.001 = 0.101 mol HA

Moles $A^-$ = 0.100 – 0.001 = 0.099 mol $A^-$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$pH = 4.75 + \log \frac{0.099}{0.101}$$

pH = 4.75 – 0.01 = 4.74

# Buffers resist pH change because added acid or base just change the A-/HA ratio

This video is posted on my website: chemistrysky.com