

How Buffers Work

How do they resist pH change?

pH change when adding acid to water

1 liter of water, so $V = 1$ L; $\text{pH} = 7$

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

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

pH change when adding base to water

1 liter of water, so $V = 1$ L; $\text{pH} = 7$

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

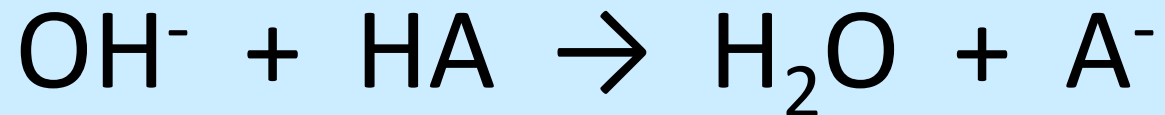
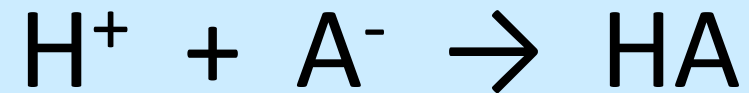
0.001 L \times 1.0 M = 1 L \times M_2 ; $M_2 = 0.001$ M = 10^{-3} M

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

How Buffers Work

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

Examples: CH₃COOH/NaCH₃COO, or H₂CO₃/NaHCO₃



Buffer Calculations



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

“Handy Equation”

$$\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

Henderson-Hasselbach Equation

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

When $[\text{A}^-] = [\text{HA}]$

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

$$\text{So, pH} = \text{pK}_a$$

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

When $[\text{A}^-] = [\text{HA}]$

$$[\text{A}^-]/[\text{HA}] = 1$$

$$\text{So, } [\text{H}^+] = K_a$$

Calculation shortcut

[] = concentration in moles/L

$$[A^-]/[HA] = (A^- \text{ in mol/L}) / (HA \text{ in mol/L})$$

The value of L is the same for A⁻ and HA, so

$$[A^-]/[HA] = (\text{mol of } A^-) / (\text{mol of HA})$$

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)

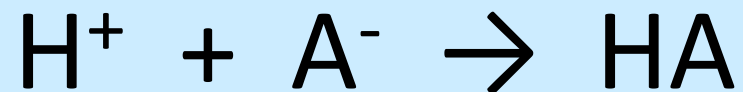
1 L Buffer, pH 4.75 contains

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



$$\text{Moles HA} = 0.100 + 0.001 = 0.101 \text{ mol HA}$$

$$\text{Moles A}^- = 0.100 - 0.001 = 0.099 \text{ mol A}^-$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

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

$$\text{pH} = 4.75 - 0.01 = 4.74$$

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

This video is posted on my website: chemistrysky.com