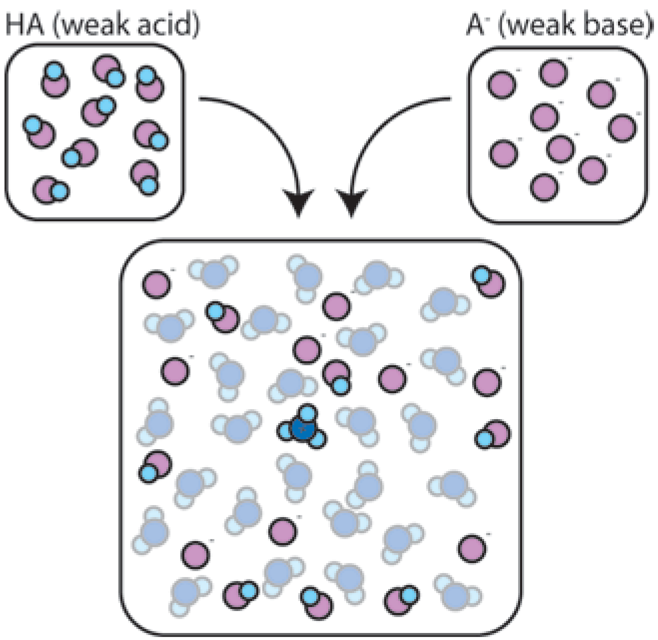
Chemistry 201

Methods for making buffers

NC State University

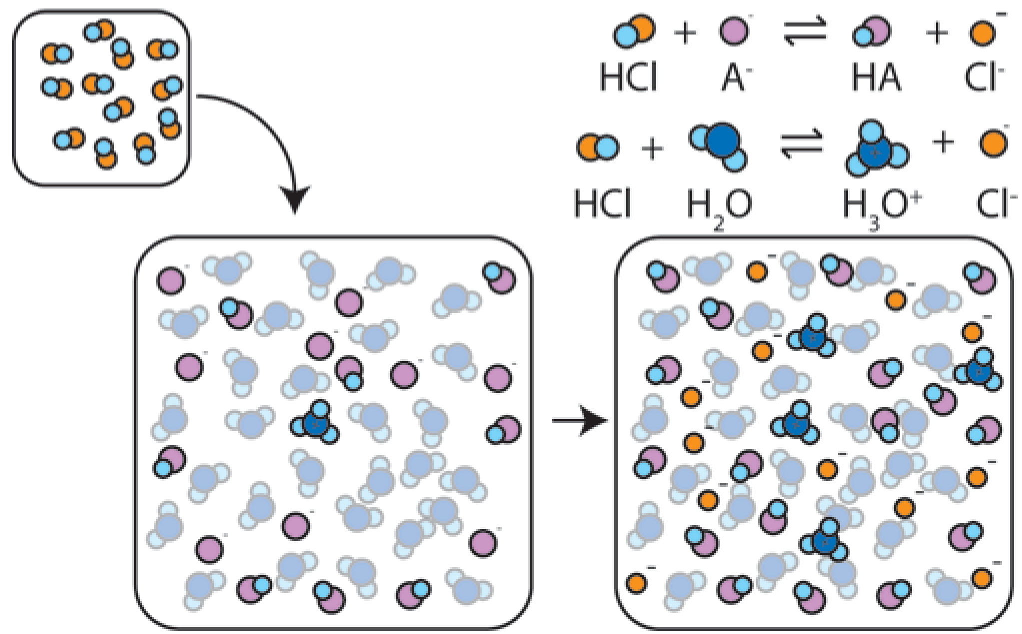
Two ways to make a buffer

Method 1



Add the acid and conjugate base to the solution in a defined proportion.

Method 2



Add a strong acid to the weak base (or vice versa) until the desired proportion $[A^-]/[HA]$ is obtained.

Buffer strength

The ratio $[A^-]/[HA]$ should be as close as possible 1:1, but the amounts may vary. To make a stronger buffer you simply need to increase the amount of each component. Let's investigate.

Suppose we add 1 mL of 1 M HCl to 1 liter of solution. The final concentration of HCl is 0.001 M.

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Suppose we add 1 mL of 1 M HCl to 1 liter of solution. The final concentration of HCl is 0.001 M. pH = 3

Suppose we add 1 mL of 1 M HCl to 1 liter of 10 mM optimal phosphate buffer solution (pKa = 7.2) solution. The final concentration of HCl is 0.001 M. $pH = pKa + \log10([A^-]/[HA])$

Buffer strength

Keeping in mind that the unbuffered solution in this example ([HCl] = 0.001 M) would be pH = 3

Suppose we add 1 mL of 1 M HCl to 1 liter of 10 mM optimal phosphate buffer solution (pKa = 7.2) solution. The final concentration of HCl is 0.001 M.

$pH = pKa + \log_{10}([A^-]/[HA])$

$[A^-] = 0.005 – 0.001 = 0.004$ $[HA] = 0.005 + 0.001 = 0.006$

pH = 7.2 + log10(0.004/0.006) = 7.02

If the target pH = 7.2 (i.e. pH = pKa) then this buffer is too weak. An error of 0.2 pH units could be significant.

Buffer strength

Keeping in mind that the unbuffered solution in this example ([HCl] = 0.001 M) would be pH = 3

Suppose we add 1 mL of 1 M HCl to 1 liter of 100 mM optimal phosphate buffer solution (pKa = 7.2) solution. The final concentration of HCl is 0.001 M.

$pH = pKa + \log_{10}([A^-]/[HA])$

$[A^-] = 0.05 – 0.001 = 0.049$ $[HA] = 0.05 + 0.001 = 0.051$

pH = 7.2 + log10(0.049/0.051) = 7.18

If the target pH = 7.2 (i.e. pH = pKa) then this buffer is reasonable. The difference is only -0.02.

Buffer strength

Keeping in mind that the unbuffered solution in this example ([HCl] = 0.001 M) would be pH = 3

Suppose we add 1 mL of 1 M HCl to 1 liter of 300 mM optimal phosphate buffer solution (pKa = 7.2) solution. The final concentration of HCl is 0.001 M.

$pH = pKa + \log_{10}([A^-]/[HA])$

$[A^-] = 0.150 – 0.001 = 0.149$ $[HA] = 0.150 + 0.001 = 0.151$

$pH = 7.2 + \log10(0.149/0.151) = 7.194$

If the target pH = 7.2 (i.e. pH = pKa) then we would say that this buffer is definitely strong enough, difference = -0.006

Titrating to make a buffer

You can create a buffer either by adding the acid and Its conjugate base to a solution or by titrating in strong base to acid (or vice versa). Remember, regardless of the method used to prepare it:

The buffering strength is maximum when [HA] = $[A^-]$

The buffering range is considered to extend from $[A^-]/[HA] = 0.1$ to $[A^-]/[HA] = 10$. This is subjective. Wertz suggests 0.01 to 100 is an acceptable range.