

Buffer Preparation

There are two principal methods for preparing buffers:

- 1) Both components of the conjugate acid-base pair are weighed out separately to obtain the desired ratio and then dissolved in water.
- 2) Both components are obtained from a prescribed amount of only one component, with the second being produced by a specified amount of strong acid or strong base to yield the desired ratio.

Here's how to do it:

Type 1: Both components weighed out separately

Example: Prepare 1 L of a 0.5 M potassium phosphate buffer at pH 7.5, assuming the availability of solid H_3PO_4 , KH_2PO_4 , K_2HPO_4 , and K_3PO_4 .

Step 1) Determine the principal components of the buffer system. This is easy for a monoprotic system. For diprotic or polyprotic systems, this can vary depending upon the desired pH. Identify the conjugate acid-base pair and write out the equilibrium.

In this case, the desired pH (7.5) is closest to the pK_a of the second ionization:
 $\text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$ $\text{pK}_a' = 7.21$

Step 2) Calculate the desired ratio of the conjugate acid-base pair using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{pK}_a' + \log \left(\frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} \right)$$
$$\frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} = 10^{\text{pH} - \text{pK}_a'}$$

In this case, $\frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} = 10^{7.5 - 7.21} = 10^{0.29} = 1.95$

We can solve it thus:

$$\begin{aligned} [\text{HPO}_4^{2-}] &= 1.95[\text{H}_2\text{PO}_4^-] \\ [\text{HPO}_4^{2-}] &= 0.5\text{M} - [\text{H}_2\text{PO}_4^-] \\ [\text{H}_2\text{PO}_4^-] &= 0.5\text{M} / 2.95 = 0.169\text{M} \\ [\text{HPO}_4^{2-}] &= 0.5\text{M} - 0.169\text{M} = 0.331\text{M} \end{aligned}$$

Step 3) Determine the most feasible means of obtaining the desired components. In this case, the obvious choice is to weigh out the desired amounts of the potassium salts (KH_2PO_4 and K_2HPO_4), which upon dissolution will completely ionize, giving both components of the acid-base pair.

Step 4) Calculate the required amount of each material. Multiplying by 1 L, we know that we need 0.169 moles of KH_2PO_4 and 0.331 moles of K_2HPO_4 . After calculating the formula weights of these, we can obtain the required masses:

$$\begin{aligned} \text{KH}_2\text{PO}_4 &: (0.169\text{ mol})(136.1\text{ g/mol}) = 23.0\text{ g KH}_2\text{PO}_4 \\ \text{K}_2\text{HPO}_4 &: (0.331\text{ mol})(174.2\text{ g/mol}) = 57.7\text{ g K}_2\text{HPO}_4 \end{aligned}$$

Step 5) Prepare the buffer. Weight out 23.0 g of KH_2PO_4 and 57.7 g of K_2HPO_4 , dissolve in about 900 mL of distilled water. Check the pH and adjust if necessary. Bring the total volume to 1 L.

Type 2: Both components originate from same source

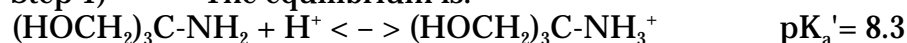
Example: Prepare 1 L of a 0.1 M Tris buffer at pH 8.3, assuming the availability of solid Tris base *, 1 M HCl, and 1 M NaOH.

* Tris = tris(hydroxymethyl)aminomethane

$(\text{HOCH}_2)_3\text{C-NH}_2$; MW = 121 g/mol

The crystalline form is the free amine (i.e. basic form).

Step 1) The equilibrium is:



Step 2) Calculate the desired ratio of the conjugate acid-base pair using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{pK}_a' + \log \left(\frac{[\text{Tris}]}{[\text{Tris}^+]}\right)$$

$$\frac{[\text{Tris}]}{[\text{Tris}^+]} = 10^{\text{pH} - \text{pK}_a}$$

In this case, $\frac{[\text{Tris}]}{[\text{Tris}^+]} = 10^{8.3-8.3} = 10^0 = 1$
(This should have been obvious.)

Thus, we will want a mix of:

0.05 M $(\text{HOCH}_2)_3\text{C-NH}_2$

0.05 M $(\text{HOCH}_2)_3\text{C-NH}_3^+$

Step 3) Both of the components will originate from crystalline Tris. You will need 0.1 moles of Tris for 1 L of 0.1 M Tris buffer. Now the problem is to determine how much strong acid will be required to give the desired ratio. In this case, you want a 50%:50% mix of Tris and Tris^+ . Therefore, you will need enough acid to convert 0.05 moles of Tris to Tris^+ . Obviously, this would be accomplished by the addition of 0.05 moles of H^+ . Coming from HCl, you will need 50 mL of the 1 M HCl solution.

Step 4) Prepare the buffer. Weight out 0.1 moles of crystalline Tris (12.1 g) and dissolve in about 900 mL of distilled water. Add 50 mL of HCl and mix well. Check the pH and adjust if necessary. Bring the total volume to 1 L.