

# Three Ways to Prepare a Buffer

Suppose you are asked to prepare 500 mL of a  $\text{HCO}_3^-/\text{CO}_3^{2-}$  buffer subject to the following conditions: the buffer must have a pH of 9.87 and the combined concentrations of  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$  must be 0.200 M. How might you prepare this buffer?

We begin by determining the relative amount of weak base ( $\text{CO}_3^{2-}$ ) and weak acid ( $\text{HCO}_3^-$ ) needed to give the desired pH; thus, using the Henderson-Hasselbalch equation we find that

$$\text{pH} = 9.87 = \text{p}K_a + \log \frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]} = 10.33 + \log \frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$$
$$\frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]} = 0.3467$$

We then calculate the total moles of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$  that we need to prepare the buffer

$$\text{mol HCO}_3^- + \text{mol CO}_3^{2-} = \frac{0.200 \text{ mol}}{\text{L}} \times 0.500 \text{ L} = 0.100 \text{ mol}$$

Next, we calculate the exact moles of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$  needed. Letting  $X$  be the moles of  $\text{CO}_3^{2-}$ , we know that the moles of  $\text{HCO}_3^-$  are

$$\text{mol HCO}_3^- = 0.100 \text{ mol} - X$$

Substituting back gives

$$\frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]} = \frac{X}{0.100 - X} = 0.3467$$

$$X = 0.02574 \text{ mol CO}_3^{2-}$$

$$0.100 - X = 0.07426 \text{ mol HCO}_3^-$$

Now that we know how many moles of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$  we need, we can determine the amounts of each reagent to use. We have three choices: (i) use solid  $\text{Na}_2\text{CO}_3$  and solid  $\text{NaHCO}_3$ ; (ii) use solid  $\text{NaHCO}_3$  and convert some of it to  $\text{CO}_3^{2-}$  by adding a strong base; or (iii) use solid  $\text{Na}_2\text{CO}_3$  and convert some of it to  $\text{HCO}_3^-$  by adding a strong acid.

## Using $\text{Na}_2\text{CO}_3$ and $\text{NaHCO}_3$

The moles of  $\text{Na}_2\text{CO}_3$  and  $\text{NaHCO}_3$  needed are the moles of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$  calculated above; thus

$$0.02574 \text{ mol Na}_2\text{CO}_3 \times \frac{105.989 \text{ g}}{\text{mol}} = 2.73 \text{ g Na}_2\text{CO}_3$$

$$0.07426 \text{ mol NaHCO}_3 \times \frac{84.0059 \text{ g}}{\text{mol}} = 6.24 \text{ g NaHCO}_3$$

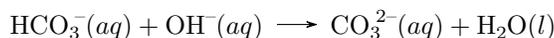
To prepare the buffer, therefore, we add these amounts of the solid reagents to a 500-mL volumetric flask and dilute to volume.

## Using NaHCO<sub>3</sub> and NaOH

In this approach we begin by weighing out an amount of NaHCO<sub>3</sub> equivalent to the total moles of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> needed; thus, we begin with 0.100 moles of NaHCO<sub>3</sub>, or

$$0.100 \text{ mol NaHCO}_3 \times \frac{84.0059 \text{ g}}{\text{mol}} = 8.40 \text{ g NaHCO}_3$$

Next, we add NaOH, converting 0.02574 moles of HCO<sub>3</sub><sup>-</sup> to CO<sub>3</sub><sup>2-</sup> as shown by the following reaction



Thus, we need 0.02574 moles of NaOH, or

$$0.02574 \text{ mol NaOH} \times \frac{1\text{L}}{6 \text{ mol}} \times \frac{1000\text{mL}}{\text{L}} = 4.29 \text{ mL NaOH}$$

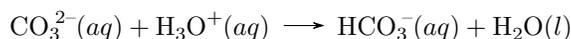
To prepare the buffer we add 8.40 g of NaHCO<sub>3</sub> to a 500-mL volumetric flask and dissolve it with some water. We then add 4.29 mL of 6 M NaOH and dilute to volume.

## Using Na<sub>2</sub>CO<sub>3</sub> and HCl

In this approach we begin by weighing out an amount of Na<sub>2</sub>CO<sub>3</sub> equivalent to the total moles of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> needed; thus we begin with 0.100 moles of Na<sub>2</sub>CO<sub>3</sub>, or

$$0.100 \text{ mol Na}_2\text{CO}_3 \times \frac{105.998 \text{ g}}{\text{mol}} = 10.60 \text{ g Na}_2\text{CO}_3$$

Next, we add HCl, converting 0.07426 moles of CO<sub>3</sub><sup>2-</sup> to HCO<sub>3</sub><sup>-</sup> as shown by the following reaction



Thus, we need 0.07426 moles of HCl, or

$$0.07426 \text{ mol HCl} \times \frac{1\text{L}}{6 \text{ mol}} \times \frac{1000 \text{ mL}}{\text{L}} = 12.38 \text{ mL HCl}$$

To prepare the buffer we add 10.60 g of Na<sub>2</sub>CO<sub>3</sub> to a 500-mL volumetric flask and dissolve it with some water. We then add 12.38 mL of 6 M HCl and dilute to volume.

## A Final Comment of Preparing Buffers

For reasons we will discuss later, a buffer prepared following one of these approaches probably will not produce a solution with a pH that matches exactly the desired pH. When we prepare a buffer in the laboratory it often is necessary to adjust the buffer's pH level to the desired value by adding small amounts of either a strong acid or a strong base while monitoring the pH with a pH electrode.