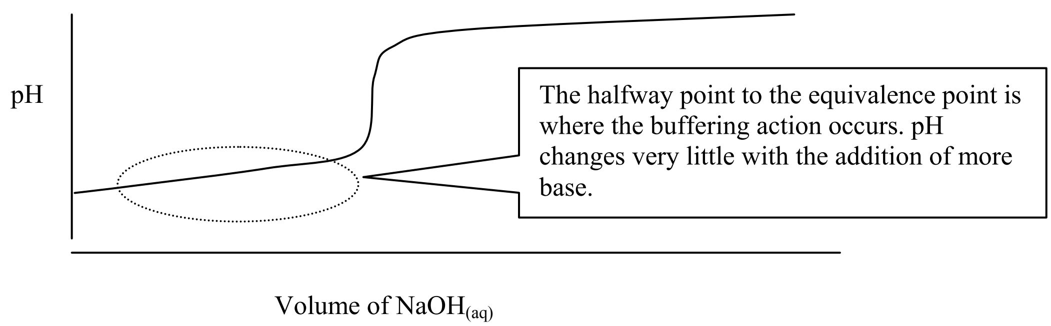
8.5 Buffers

- All pH curves involving a weak acid or weak base have at least one region where a buffering action occurs (a region on the curve where the pH changes very little despite the addition of an appreciable amount of acid or base.
- Buffer: a mixture of a conjugate acid-base pair that maintains a nearly constant pH when diluted or when a strong acid or base is added; an equal mixture of a weak acid and its conjugate base. (CA-B pairs)



- An example of a common buffer is equal amounts of $C_2H_3O_2^-{}_{(aq)}$ and $HC_2H_3O_2{}_{(aq)}$. In this buffer the pH will remain relatively constant as strong acid or base is added.
- In the above example, when H^+ is added the $C_2H_3O_2^-{}_{(aq)}$ forms $HC_2H_3O_2{}_{(aq)}$. When OH^- is added the $HC_2H_3O_2{}_{(aq)}$ is converted to $C_2H_3O_2^-{}_{(aq)}$ and water. This change will result in a small pH change. In effect, acetic acid removes OH^- from solution and acetate removes H^+ from solution and only a small pH change is observed.

The Capacity of a Buffer

- Buffering capacity is limited and with continued addition of acid or base, the buffer would eventually be used up and pH will jump dramatically.
- See figure 2 on page 616 for examples.

Buffers in Action

- Human blood has a pH of 7.4 and it must remain stable since many biological reactions occur at this pH. Some enzymes only work at specific pHs. In cells we find a buffer system comprised of $H_2PO_4^-{}_{(aq)}$ and $HPO_4^{2-}{}_{(aq)}$. In blood the buffer system is comprised of $H_2CO_{3(aq)}$ and $HCO_3^-{}_{(aq)}$.
- Interesting bit of trivia…if our blood was not buffered a glass of orange juice (citric acid) would be fatal.

Calculating pH in a Buffer

- A 1.0 L buffer is prepared that contains 0.20 mol/L acetic acid and 0.20 mol/L acetate at equilibrium.
  (a) Calculate the pH of the buffer
  (b) If 0.10 mol of $H^+{}_{(aq)}$ is added to the buffer without changing its volume, calculate the pH.
  (c) Calculate and compare the change in pH expected if the same amount of $H^+{}_{(aq)}$ is added to water.

(a) $HC_2H_3O_{2\,(aq)} \leftrightarrow H^+{}_{(aq)} + C_2H_3O_2^-{}_{(aq)}$ $K_a = 1.8 \times 10^{-5}$

$$K_a = \frac{[H^+_{(aq)}][C_2H_3O^-_{2(aq)}]}{[HC_2H_3O_{2(aq)}]}$$

$$K_a = \frac{[H^+]\,0.2}{0.2}$$

rearrange

$$[H^+_{(aq)}] = \frac{K_a[HC_2H_3O_{2(aq)}]}{[C_2H_3O^-_{2(aq)}]}$$

$$[H^+_{(aq)}] = 1.8 \times 10^{-5}\ mol/L$$

$$K_a = [H^+]$$

$$pH = -\log[H^+_{(aq)}] = -\log(1.8 \times 10^{-5}\ mol/L) = 4.74$$

(b) The $H^+{}_{(aq)}$ will react with the acetate ions in this buffer.

$H^+{}_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2\,(aq)}$

In 1 L, $C_2H_3O_2^-{}_{(aq)}$ = 0.2 mol and $HC_2H_3O_{2\,(aq)}$ = 0.2 mol

By adding 0.1 mol of $H^+_{(aq)}$, 0.1 mol of $C_2H_3O_2^-{}_{(aq)}$ will be consumed and an additional 0.1 mol of $HC_2H_3O_{2(aq)}$ will be formed to make a total of 0.3 mol.

Therefore since there was not a volume change then we would have 0.1 mol/L of $C_2H_3O_2^-{}_{(aq)}$ and 0.3 mol/L of $HC_2H_3O_{2(aq)}$.

$$K_a = \frac{[H^+_{(aq)}][C_2H_3O^-_{2(aq)}]}{[HC_2H_3O_{2(aq)}]} = 1.8 \times 10^{-5}$$

$$[H^+_{(aq)}] = \frac{K_a[HC_2H_3O_{2(aq)}]}{[C_2H_3O^-_{2(aq)}]}$$

$$[H^+_{(aq)}] = \frac{(1.8 \times 10^{-5})(0.1)}{0.3} = 5.4 \times 10^{-5}\, mo/L$$

$$pH = -\log[H^+_{(aq)}] = -\log(5.4 \times 10^{-5}\, mol/L) = 4.27$$

a pH difference of 0.47

(c) In water there presence of 0.1 mol of $H^+_{(aq)}$ in 1 L of water will dramatically affect the pH.

$$pH = -\log[H^+_{(aq)}] = -\log(0.1 mol/L) = 1.0$$

Pure water with a pH of 7.0 would drop to a pH of 1.0.

Homework

- Practice 1,2,3
- Questions 1,2,3,4,5,6,7,8,9

8.5 Buffers

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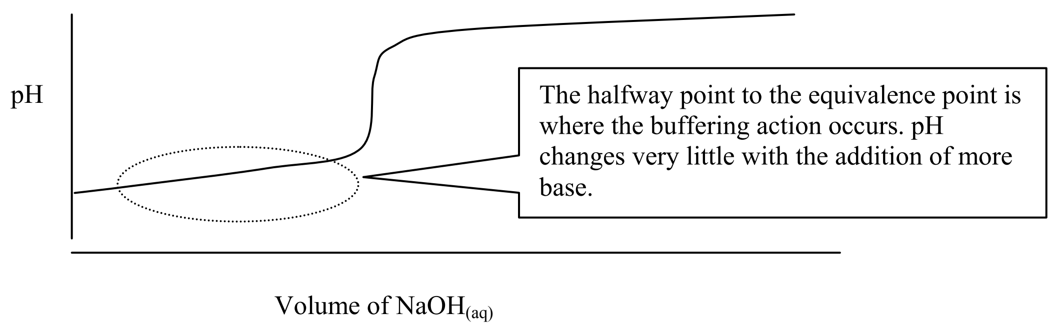

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  (f) Calculate and compare the change in pH expected if the same amount of $H^+{}_{(aq)}$ is added to water.

(a) $HC_2H_3O_{2\ (aq)} \leftrightarrow H^+{}_{(aq)} + C_2H_3O_2^-{}_{(aq)}$ $K_a = 1.8 \times 10^{-5}$

(d) The $H^+{}_{(aq)}$ will react with the acetate ions in this buffer.

$H^+{}_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2\ (aq)}$

In 1 L, $C_2H_3O_2^-{}_{(aq)}$ = 0.2 mol and $HC_2H_3O_{2\ (aq)}$ = 0.2 mol

Therefore since there was not a volume change then we would have 0.1 mol/L of $C_2H_3O_2^-{}_{(aq)}$ and 0.3 mol/L of $HC_2H_3O_{2\,(aq)}$.

(e) In water there presence of 0.1 mol of $H^+_{(aq)}$ in 1 L of water will dramatically affect the pH.

$$pH = -\log\left[H^+_{(aq)}\right] = -\log(0.1 mol/L) = 1.0$$

Pure water with a pH of 7.0 would drop to a pH of 1.0.

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