Chapter 8 Applications of Aqueous Equilibrium

- Acid/Base Review
- Buffer Solutions
- Titration Curves
- Solubility

Big Idea: Buffer systems maintain the pH value of a solution even when small amounts of acid or bases are added to the system. In order to have a buffer, a weak acid and its conjugate base or a weak base and its conjugate acid must be present.

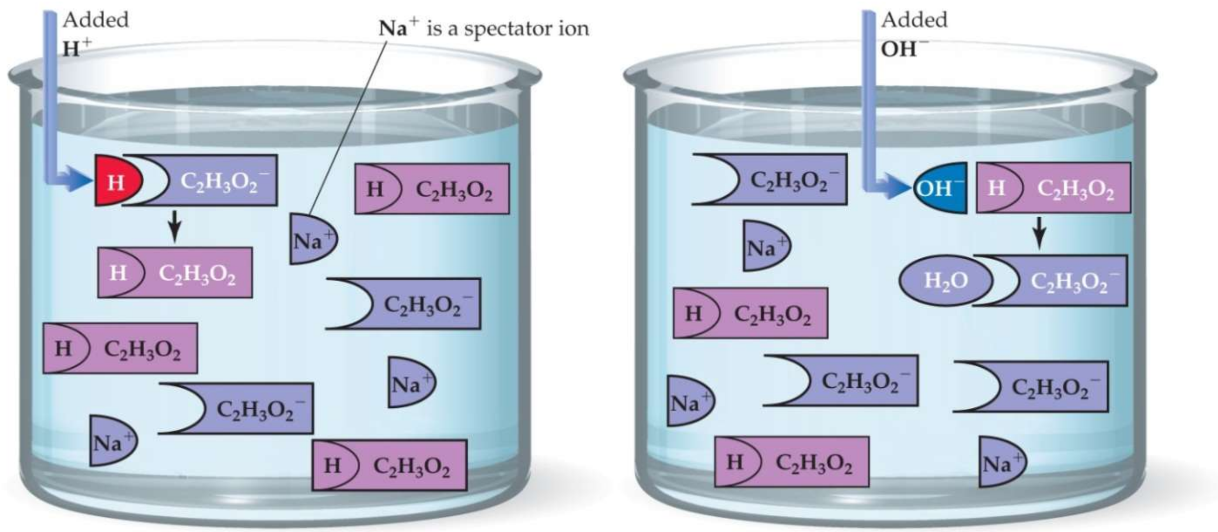
Acid/Base Review

Determine the major species in solution:

- $Ca(OH)_2$
  - Major Species:
- $HC_2H_3O_2$
  - Major Species:
- $HClO_4$
  - Major Species:
- NaCN
  - Major Species:
- CH_3NH_3Cl
  - Major Species:

Buffer Solutions

Buffer: A solution that resists any change in pH when small amounts of acid or base are added.



- Buffers Consist of:
  - Weak Acid and its Conjugate Base
    - $(HC_2H_3O_2$ / $NaC_2H_3O_2)$
  - Weak Base and its Conjugate Acid
    - $(NH_3$ / $NH_4Cl)$

Buffer Solutions

- **Step 1:** Identify major species in solution.
- **Step 2(a):** Identify IF any reaction will go to completion (this happens if you have H^+ and a weak base or OH^- and a weak acid in your major species). If no reaction goes to completion go to step 3.
- **Step 2(b):** If a reaction goes to completion, make an "IF" table to determine the major species in solution after the reaction goes to completion (products and excess reactants.) IF tables are in moles not molarity.
- **Step 3:** Examine major species to see if you have a buffer solution.

Buffer Solutions

Student Question

How many of the following can be mixed to form a buffer solution?

KOH & HF

RbOH & HBr

$NaC_2H_3O_2$ & HCl

H_3PO_4 & HBr

NH_3 & NH_4Cl

a) 1
b) 2
c) 3
d) 4
e) 5

Buffer Solutions

- **Buffer Problems**
  - Assume that [HA] is constant
  - Assume that [A^-] is constant

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$$

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

- Solve for pH=-log[H^+]

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

$$log\left(\frac{K_a}{[H^+]}\right) = log\left(\frac{[A^-]}{[HA]}\right)$$

$$log(K_a) - log([H^+]) = log\left(\frac{[A^-]}{[HA]}\right)$$

$$-log([H^+]) = -log([K_a]) + log\left(\frac{[A^-]}{[HA]}\right)$$

$$\boxed{pH = pK_a + log\left(\frac{[A^-]}{[HA]}\right)}$$

Buffer Solutions

Identify Major Species

↓

Find species after reactions goes to completion

- ONLY Strong Acid <u>or</u> Strong Base <u>or</u> Strong Acid and a Weak Acid <u>or</u> Strong Base and a Weak Base
- ONLY Weak Acid <u>or</u> Weak Base
- Weak Acid and its Conjugate Base <u>or</u> Weak Base and its Conjugate Acid

Buffer Solutions

- How to determine pH

Strong Acid <u>or</u> Strong Acid and a Weak Acid → The amount of H^+/OH^- from the weak acid/base is negligible in comparison to the strong acid/base therefore just use the strong acid/base to calculate the pH. → $pH = -log[H^+]$

Strong Base <u>or</u> Strong Base and a Weak Base → $pOH = -log[OH^-]$, $pH = 14 - pOH$

Weak Acid

Weak Base → Ice Table

Weak Acid and its Conjugate Base

Weak Base and its Conjugate Acid

$$pH = pK_a + log\left(\frac{[A^-]}{[HA]}\right)$$

Buffer Solutions

Situation #1:

Solution #1 (1L)	Add	Solution #2 (1L)
Water	1 drop HCl	0.010 M HCl
$[H^+]$=		$[H^+]$=
pH =		pH =

Buffer Solutions

Situation #2:

Solution #1 (1L)	Add	Solution #2 (1L)
0.50 M $HC_2H_3O_2$ 0.50 M $NaC_2H_3O_2$	1 drop HCl	0.010 M HCl 0.50 M $HC_2H_3O_2$ 0.50 M $NaC_2H_3O_2$
$[H^+]=1.8\times10^{-5}$ M		$[H^+]=$
pH=4.74		pH =

Buffer Solutions

Student Question

A buffer solution contains 0.0200 M acetic acid and 0.0200 M sodium acetate. What is the pH after 2.0 mmol of NaOH are added to 1.00 L of this buffer?

Helpful Information: pK_a=4.75 for acetic acid

a) 4.75
b) 4.70
c) 4.80
d) 4.84
e) None of the above

Buffer Solutions

Buffer Capacity: An indication of the amount of acid or base that can be added before a buffer loses its ability to resist the change in pH

- A buffer has the greatest buffer capacity when:
  - there are equal amounts of [HA] and [A^-]
  - there are large quantities of [HA] and [A^-]

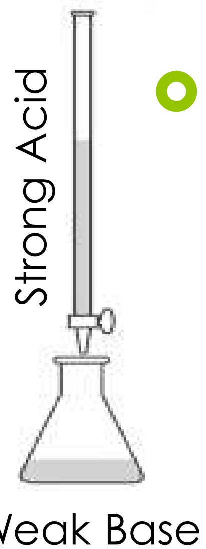
Note: When choosing a buffer, pick a buffer that has a pK_a closest to what you want the pH to be.

Titration Curves

- **Equivalence Point:** The stage of a titration when exactly the right volume of solution needed to complete the reaction has been added.

Note: The equivalence point is sometimes called the stoichiometric point.

Titration Curves



- Weak Base/ Strong Acid (NH_3/HCl)
  - Calculate the pH at the following four points of a titration curve in which 0.50 M HCl is added to 50. mL of 1.0 M NH_3 (K_b=1.8×10^{-5}).

- **Case #1:** No acid added (50. mL of 1.0 M NH_3)
- **Case #2:** 50. mL of HCl added (50. mL of 1.0 M NH_3 and 50. mL of 0.50 M HCl)
- **Case #3:** 100. mL of HCl added (50. mL of 1.0 M NH_3 and 100. mL of 0.50 M HCl)
- **Case #4:** 150. mL of HCl added (50. mL of 1.0 M NH_3 and 150. mL of 0.50 M HCl)

Titration Curves

- Mark these points on your titration curve
  a. The equivalence point
  b. The region with buffering
  c. pH = pK_a
  d. pH depends only on $[A^-]$ (weak base only present)
  e. pH depends only on [HA] (weak acid only present)
  f. The pH only depends on the amount of strong acid or base added

Buffer Solutions

Identify Major Species

↓

Find species after reactions goes to completion

- ONLY Strong Acid **or** Strong Base **or** Strong Acid and a Weak Acid **or** Strong Base and a Weak Base
- ONLY Weak Acid **or** Weak Base
- Weak Acid and its Conjugate Base **or** Weak Base and its Conjugate Acid

Buffer Solutions

- What method would you use to calculate the pH at each of the points?

Strong Acid or Strong Acid and a Weak Acid

Strong Base or Strong Base and a Weak Base

The amount of H^+/OH^- from the weak acid/base is negligible in comparison to the strong acid/base therefore just use the strong acid/base to calculate the pH.

Strong Acid or Strong Acid and a Weak Acid:

$$pH = -log[H^+]$$

Strong Base or Strong Base and a Weak Base:

$$pOH = -log[OH^-]$$
$$pH = 14 - pOH$$

Weak Acid / **Weak Base**: Ice Table

Weak Acid and its Conjugate Base / **Weak Base and its Conjugate Acid**:

$$pH = pK_a + log\left(\frac{[A^-]}{[HA]}\right)$$

Titration Curves

- Mark these points on your titration curve
  a. The equivalence point
  b. The region with buffering
  c. pH = pK_a
  d. pH depends only on $[A^-]$ (weak base only present)
  e. pH depends only on [HA] (weak acid only present)
  f. The pH only depends on the amount of strong acid or base added

Solubility

Name	Formula	K_{sp}(25°C)
Barium sulfate	$BaSO_4$	1.5×10^{-9}
Calcium carbonate	$CaCO_3$	8.7×10^{-9}
Calcium fluoride	CaF_2	4.0×10^{-11}
Calcium hydroxide	$Ca(OH)_2$	1.3×10^{-6}
Calcium sulfate	$CaSO_4$	6.1×10^{-5}
Copper(II) sulfide	CuS	8.5×10^{-45}
Iron(II) carbonate	$FeCO_3$	2.1×10^{-11}
Iron(II) hydroxide	$Fe(OH)_2$	1.8×10^{-15}
Lead(II) chloride	$PbCl_2$	1.6×10^{-5}
Lead(II) sulfate	$PbSO_4$	1.3×10^{-8}
Lead(II) sulfide	PbS	7×10^{-29}
Magnesium carbonate	$MgCO_3$	1×10^{-15}
Magnesium hydroxide	$Mg(OH)_2$	8.9×10^{-12}
Silver chloride	$AgCl$	1.6×10^{-10}
Silver chromate	Ag_2CrO_4	9.0×10^{-12}
Silver iodide	AgI	1.5×10^{-16}

Select values from table 8.5 in book

Solubility

Student Question

What is the molar solubility of CaF_2?

$K_{sp} = 4.0\times10^{-11}$

a) 2.1×10^{-4} M
b) 3.4×10^{-4} M
c) 4.3×10^{-4} M
d) 6.3×10^{-6} M
e) None of the above

Take Away From Chapter 8

Big Idea: Buffer systems maintain the pH value of a solution even when small amounts of acid or bases are added to the system. In order to have a buffer, a weak acid and its conjugate base must be present or a weak base and its conjugate acid.

- **Buffer Solution**
  - Be able to identity buffer solutions. (15,46,47)
    - Weak acid/conjugate base
    - Weak base/conjugate acid
  - Be able to calculate the pH of a buffer solution (21,22,23,27,29,35,37,39,40,42,43,44,48)
    - Henderson-Hasselbalch Equation
      - $pH = pK_a + log\left(\frac{[A^-]}{[HA]}\right)$

Numbers correspond to end of chapter questions.

Take Away From Chapter 8

- **Buffer Solution** (Continued)
  - Know when a solution has the greatest buffer capacity.(16,49)
    - When there is ample amounts of both $[A^-]$ and [HA]
    - When $[A^-]=[HA]$
- **Titration Curves**
  - Be able to calculate the pH at any point in a titration curve.(63,64,65,66)
  - Be able to draw titration curves for: (54,55,56,57,61)
    - Strong acid/strong base
    - Strong base/strong acid
    - Weak acid/strong base
    - Weak base/strong acid

Numbers correspond to end of chapter questions.

Take Away From Chapter 8

- **Solubility**
  - Be able to calculate the molar solubility of a solid given the K_{sp}. (98)
  - Be able to calculate/know the effect on the molar solubility when a common ion is present in solution.(106,107)

Numbers correspond to end of chapter questions.