UNIT6-DAY6-LaB1230pm

Monday, February 25, 2013
2:48 PM

Thinking Like a Chemist About
Acids and Bases

Part IV

UNIT 6 DAY 6

ke Spring 2013

What are we going to learn today?

Apply the principles of Chemical Equilibrium
to mixtures of Conjugate Acid Base Pairs

Predict the pH of such solutions
Predict the pH of such solutions after stressing the
system

Explore the concept of a Buffer solution

CH302 Vanden Bout/LaBrake Spring 2013

IMPORTANT INFORMATION

LM22 - Buffers due Th 9AM

~~LM23 - Protonation & pK_a due Th 9AM~~

Extra Practice Worksheets on Website

HW6 → Due Thurs 9am

LM21 → Due Wed 9am (maybe)

CH302 Vanden Bout/LaBrake Spring 2013

Quiz: Clicker Question 1

The pH of a solution of a soluble salt will be:

A) Neutral
B) Basic
C) Acidic
D) Any of the above, depends on the salt

CH302 Vanden Bout/LaBrake Spring 2013

Quiz: Clicker Question 2

1. Calculate the pH of the following solution, 0.15 M HF; given the Ka = 7.2×10^{-4}

A) 2.0
B) 4.0

1. Calculate the pH of the following solution, 0.15 M HF; given the Ka = 7.2×10^{-4}

A) 2.0
B) 4.0
C) 7.0
D) 9.0
E) 12.0

Quiz: Clicker Question 3

2. Calculate the pH of the following solution, 0.15 M NaF,
given the Ka of HF = Ka = 7.2×10^{-4}

A) 2.0
B) 5.9 = pOH
C) 7.0
D) 8.1 = pH
E) 12.0

Neutralization

What is in Water?

ionization

Equal molar Amts ~~ACID + BASE~~ → WATER + SALT

only this is left

ionization

ACID + BASE → SALT

weak

$K_a = [H_3O^+][A^-]/[HA]$

or strong

$[acid] = [H_3O^+]$

$K_b = [OH^-][BH^+]/[B]$

or

$[base] = [OH^-]$

$K_a = [H_3O^+][A^-]/[HA]$

or

$K_b = [OH^-][BH^+]/[B]$

or

Neutral

$K_a = [H_3O^+][A^-]/[HA]$

or

$[acid] = [H_3O^+]$

$K_b = [OH^-][BH^+]/[B]$

or

$[base] = [OH^-]$

or

$K_b = [OH^-][BH^+]/[B]$

or

Neutral

Neutralization

ionization

What is in Water?

Excess ACID + BASE → WATER + SALT

ACID + ~~BASE~~ → SALT Acid

$K_a = [H_3O^+][A^-]/[HA]$ or $[acid] = [H_3O^+]$

$K_b = [OH^-][BH^+]/[B]$ or $[base] = [OH^-]$

$K_a = [H_3O^+][A^-]/[HA]$ or $K_b = [OH^-][BH^+]/[B]$ or Neutral

Neutralization

ionization

What is in Water?

ACID + Excess BASE → WATER + SALT

~~ACID~~ + BASE → SALT + Base

$K_a = [H_3O^+][A^-]/[HA]$ or $[acid] = [H_3O^+]$

$K_b = [OH^-][BH^+]/[B]$ or $[base] = [OH^-]$

$K_a = [H_3O^+][A^-]/[HA]$ or $K_b = [OH^-][BH^+]/[B]$ or Neutral

Neutral

CH302 Vanden Bout/LaBrake Spring 2012

Poll: Clicker Question 4

pH of salt in water

Strong Acids & Strong Bases ⇒ no Ka or Kb

The pH of a 0.1 M aqueous solutions of the salts

Na^+ $NaCH_3COO$, NH_4Cl, KCl will be: Cl^-

$CH_3COO^- + H_2O \leftrightarrow CH_3COOH + OH^-$

$NH_4^+ + H_2O \leftrightarrow NH_3 + H_3O^+$

A)Neutral, Neutral, Neutral

B)Basic, Acidic, Neutral

C)Acidic, Neutral, Basic

D)Basic, Neutral, Acidic

E)Acidic, Basic, Neutral

↳ conj acid partner of common weak base

CH302 Vanden Bout/LaBrake Spring 2013

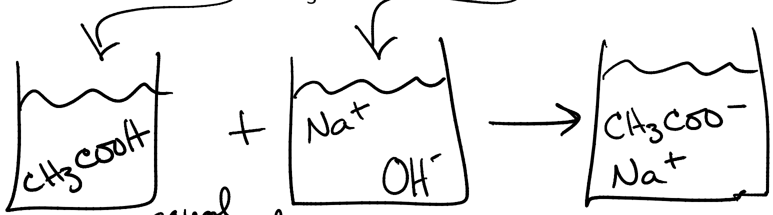
What are the components?

$CH_3COOH\ (aq) + NaOH(aq) \xrightarrow{100\%} NaCH_3COO\ (aq) + H_2O\ (l)$

weak acid strong base

What are the major species in solution as a result of mixing:

100 mL 0.1 M CH_3COOH + 100 mL 0.1 M NaOH



Major Component equal molar amts ~~CH_3COO^-~~?

weak base

CH302 Vanden Bout/LaBrake Spring 2013

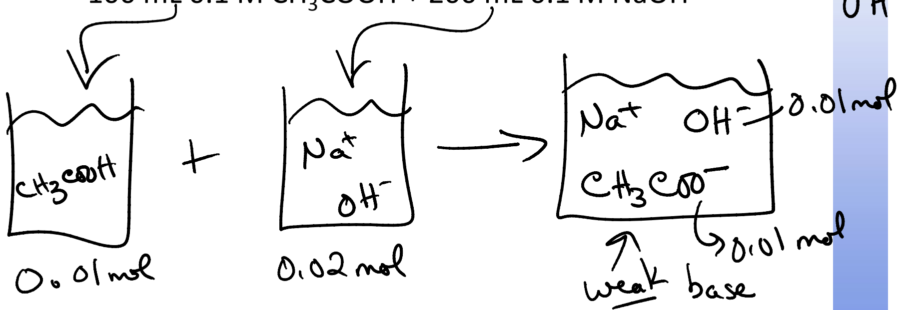
What are the components?

$CH_3COOH\ (aq) + NaOH(aq) \rightarrow NaCH_3COO\ (aq) + H_2O\ (l)$

What dominates pH?

What are the major species in solution as a result of mixing:
100 mL 0.1 M CH_3COOH + 200 mL 0.1 M NaOH

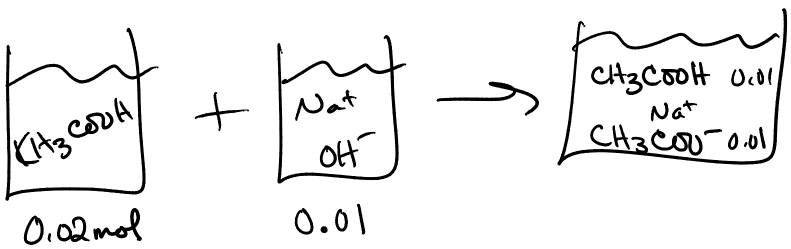
OH^-!



What are the components?

$CH_3COOH\ (aq) + NaOH(aq) \rightarrow NaCH_3COO\ (aq) + H_2O\ (l)$

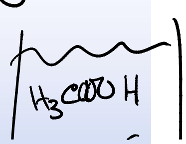
What are the major species in solution as a result of mixing:
200 mL 0.1 M CH_3COOH + 100 mL 0.1 M NaOH



How would you determine the pH?

Neutralization

	CH_3COOH +	NaOH $\rightarrow$	$NaCH_3COO + H_2O$
I	0.02 mol	0.01	$\emptyset$
C	−0.01	−0.01	+0.01



I	0.02 mol	0.01	∅	
C	−0.01	−0.01	+0.01	
E	0.01 mol	∅	0.01 mol	
	0.033 M		0.033 M	Vol = 300 mL

H_3COOH
CH_3COO^-

Ionization

$$CH_3COOH + H_2O \leftrightarrow CH_3COO^- + H_3O$$

I	0.033	0.033	∅
C	−x	+x	+x
E	0.033−x	0.033+x	+x

$$K_a = 1.8\times10^{-5} = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} = \frac{(x)(0.033+x)}{(0.033-x)}$$

What about x? Now w/ common ion
x will be VERY small

$$1.8\times10^{-5} \approx \frac{x\,\cancel{(0.033)}}{\cancel{(0.033)}}$$

$$1.8\times10^{-5} = x = [H_3O^+] = K_a$$

$$pH = -\log(1.8\times10^{-5}) = -\log(K_a) = pK_a$$
$$= 4.74$$

Common Ion Effect

$$\%\ \text{ionization} = \frac{\text{amount ionized}}{\text{amt initial}} \times 100\%$$

The % of ionization is suppressed in the presence of a common ion....Le Chatelier's Principle

? % ionization
0.1 M CH_3COOH

pH = 2.87
$[H_3O^+] = 0.00135\ M$

$$\%\ \text{ionization} = \frac{0.00135\,M}{0.1\,M}\times100\% = 1.35\%$$

mostly CH_3COOH

? % ionization
0.1 M CH_3COOH solution containing 0.1 M $NaCH_3COO$

pH = 4.74

Can ignore the "x"

$$\frac{[H_3O^+]}{C_a} = \frac{1.8\times10^{-5}}{0.1}\times100\% =$$

0.018%

Poll: Clicker Question 5

Fully describe:
Weak Base + Strong Acid
reaction with resulting salt solution

Write the chemical reaction and calculate the pH when a 200 mL 0.1 M solution of ammonia is mixed with a 100 mL 0.1 M solution of hydrochloric acid. (this is an example of what you should have mastered by now. If not, take this problem to a TA or Tutor)

Before you do the calculation you should be able to predict if the resulting solution would be:

A) Neutral
B) Basic
C) Acidic

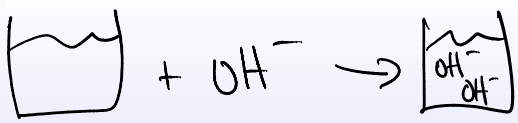
Look at a DEMO

Add a little NaOH to pure water and see what happens!

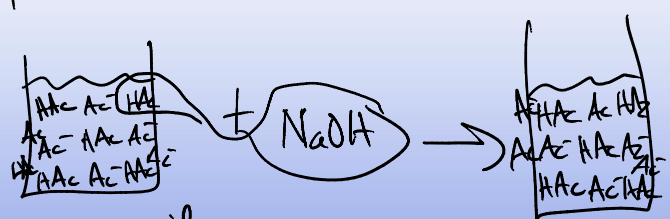
Add a little NaOH to a 1:1 mixture of acetic acid and sodium acetate and see what happens!

What is the difference?

Write down the neutralization reaction for the demo



pure H_2O



pH doesn't change much

HAc- acid
Ac⁻ anion

CH_3COOH	$+ NaOH$	$\rightarrow NaCH_3COO$	$+ H_2O$
1.5 mol	0.01	1.5 mol	
−0.01	−0.01	+0.01	
1.49 mol	∅	1.51 mol	

Because the pH changed very little it is called a buffer solution.

most buffers made w/ conj acid base pairs

Because the pH changed very little it is called a buffer solution.

conj acid base pairs

Buffer- a solution in which the pH resists change when a strong acid or base is added

Buffers can be acidic

Buffers can be basic

Depends on conj acid/base pair

CH302 Vanden Bout/LaBrake Spring 2012

Because the pH changed very little it is called a buffer solution.

What happens if we keep adding NaOH to the solution…..

eventually neutralize all the acid

excess NaOH w/ weak base

"exhaust" buffer

CH302 Vanden Bout/LaBrake Spring 2012

Calculate the pH of buffer solution

CH302 Vanden Bout/LaBrake Spring 2012

Derive a shortcut formula

$$-\log\left(K_a = \frac{[H_3O^+][A^-]}{[HA]}\right)$$

$$-\log K_a = -\log[H_3O^+] - \log\frac{[A^-]}{[HA]}$$ ← at equilibrium

Henderson Hasselbalch $pK_a = pH - \log\frac{[A^-]_0}{[HA]_0}$ = assume these are initial concentrations DUE to common ion effect

$$pH = pK_a + \log\frac{[A^-]_0}{[HA]_0}$$

CH302 Vanden Bout/LaBrake Spring 2012

Pick a formula to memorize or derive

initial conjugate base

$$pKa = pH - \log\frac{[A^-]_0}{[HA]_0}$$

initial weak acid

When the initial acid and base are similar in

$$-pKa = pH - \log \frac{[A^-]_0}{[HA]_0}$$

$$pH = pK_a + \log \frac{[A^-]_0}{[HA]_0}$$

initial weak acid

- When the initial acid and base are similar in concentration then the pH is close to the pKa

For the pH to be 1 unit different than the pKa the difference in concentrations must be at least 10 X!

$$pOH = pK_b + \log \frac{[BH^+]}{[B]}$$

CH302 Vanden Bout/LaBrake Spring 2012

Poll: Clicker Question 6

The pK_a of HF is 3.18. What is the pH of solution of 100 mL of 0.1 M HF and 100 mL of a 0.2 M NaF?

More Base

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

A. slightly less than 3.18
B. 3.18 need equal concentrations, which we don't have
C. slightly more than 3.18

CH302 Vanden Bout/LaBrake Spring 2012

Calculate the pH of a buffer system

Calculate the pH of a buffer solution that is 0.15 M HNO_2(aq) and 0.2 M $NaNO_2$.

Calculate pH using Henderson-Hasselbalch

Calculate the pH of a buffer solution that is 0.15 M HNO_2(aq) and 0.2 M $NaNO_2$.
(same as previous example)

Select buffer composition for desired pH

- Calculate the ratio of the molarities of acetate ions and acetic acid needed to buffer a solution at pH=5.25. The pK_a of CH_3COOH is 4.75.

What did we learn today?

Weak acids or bases have limited ionization in the presence of a common ion.

Substantial amounts of conjugate acid base pairs, together in solution resist change in pH.
This effect is called buffering.
When $[HA] = [A^-]$, the pKa = pH of that solution.
When $[B] = [BH^+]$, the pKb = pOH of that solution.

CH302 Vanden Bout/LaBrake Spring 2012

Learning Outcomes

Understand the concept of a buffer, buffer capacity and buffering range.

Calculate the pH of a buffer solution.
Show mastery of the Henderson-Hasselbalch equation

Calculate the pH of a buffer solution after the addition of a strong acid or strong base.