

## Experiment 9 Acid-Base Equilibria

CH 204  
Spring 2008  
Dr. Brian Anderson

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### Last Week

#### Heat in chemical reactions:

heat is a measurable quantity  
produced and consumed in stoichiometric amounts

#### Heat Capacity (J/K):

how much heat is required to raise the temperature  
of something by one degree Celsius (or 1 Kelvin)

#### Specific Heat Capacities (J/gK):

Lead 0.128    Iron 0.449    Water 4.184

#### Hess's Law, Enthalpy of Formation

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### This week

Weak acid titration.

Determine  $K_a$  of acetic acid by a couple  
different methods.

Witness the awesome power of a buffer  
solution to resist changes in pH.

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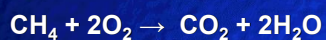
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## Non-Equilibrium Reaction

Reaction goes to completion.



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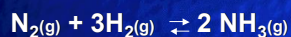
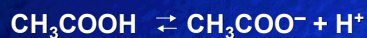
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## Equilibrium Reaction

Products react with each other to re-form the reactants.



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## Equilibrium Expression

For any equilibrium reaction,



$$K_{\text{eq}} = \frac{\text{products}}{\text{reactants}} = \frac{[\text{C}]^c[\text{D}]^d}{[\text{A}]^a[\text{B}]^b}$$

For a weak acid dissociation,



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### Strong Acids

H<sub>2</sub>SO<sub>4</sub> HNO<sub>3</sub> HCl  
HBr  
HClO<sub>3</sub> HClO<sub>4</sub> HI

### Weak Acids

*All the rest!*

CH<sub>3</sub>COOH R-COOH  
H<sub>3</sub>PO<sub>4</sub> HF NH<sub>4</sub><sup>+</sup>  
"HA"

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### Calculating [H<sup>+</sup>] and pH

If you are given the [H<sup>+</sup>]  
pH = -log[H<sup>+</sup>]

If you are given the pH  
[H<sup>+</sup>] = 10<sup>-pH</sup>

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### Four-Part Lab

#### 1) Calibrate pH meter

Make sure you're in CALIBRATION mode.

Calibrate the pH meter in the order in the lab manual: **pH 7** first, then **pH 4**, then **pH 10**.

Press ENTER or CON to confirm calibration.

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## Last Two Titrations of Your Life

### 2) Titrate 25 ml of 0.1 M acetic acid using 0.1 M NaOH

DO NOT add water! No indicator this time. Titrate in a beaker, not a flask, because you need room for the pH electrode.

Record pH after the addition of every 1.0 ml of NaOH at first, and as the pH begins to change more quickly, record smaller volume increments, down to 0.2 or 0.1 ml. Try to catch points on the vertical portion of the graph.

Switch roles with your lab partner and repeat the titration a second time.

Graph pH (y-axis) versus ml added (x-axis) in Excel.

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## At the Equivalence Point

All of the HA has been reacted away.

If the solution was initially 0.1M acetic acid, it is now 0.05 M acetate

At the half-equivalence point, half of the HA has been reacted away, and the HA and A<sup>-</sup> concentrations are equal.

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## Half-Equivalence Point

At the half-equivalence point, [HA] = [A<sup>-</sup>].

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

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

$$-\log K_a = -\log [H^+]$$

$$pH = pK_a$$

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## A Short-Cut to $K_a$

- 3) Measure the pH of 1.0 M acetic acid and two buffer solutions

Use measured  $[H^+]$  and known acetic acid and acetate concentrations to calculate  $K_a$

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

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## Dissociation of acetic acid

	$CH_3COOH$	$CH_3COO^-$	$H^+$
initial	1.0	0	0
equilibrium	$1.0 - x$	$x$	$x$

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[x][x]}{[1.0 - x]}$$

Assume  $x \ll 1.0$  M

$$K_a = x^2 / 1.0$$

$$K_a = (10^{-pH})^2 / 1.0$$

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## Buffer Solutions

	$CH_3COOH$	$CH_3COO^-$	$H^+$
initial	$[HA]$	$[A^-]$	0
equilibrium	$[HA] - x$	$[A^-] + x$	$x$

Mixing HA and  $A^-$  will dilute both of them.  
Calculate the new  $[HA]$  and  $[A^-]$  after the dilution,  
then use that value in the equilibrium expression.

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## And Finally...

- 4) Add strong acid & base to buffers and to water and compare the changes in pH.

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## pH meters need love, too

Glass bulb is very thin

Remove carefully from storage bottle – turn the bottle, not the cap

Rinse well between samples, dab dry with KimWipes

Keep the bulb wet between readings

Swish samples to get better readings



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## Post-lab 9

All or nothing again – no partial credit.

There is a hint sheet for Post-Lab 9 on the [Freebies](#) page of the course web site.

The Cheat Sheet for Experiment 9 is also online.

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## Next week

Final Class Meeting

Course/Instructor Surveys

TA Evaluations

Kinetics lab

Lab check-out

If you have missed more than one lab,  
e-mail me to discuss make-up week.

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## Next week's quiz

The terminal test, the closing quiz, the final finale!

Given  $[H^+]$  calculate pH

Given pH, calculate  $[H^+]$

Know how to recognize a buffer solution

Know how to make up a buffer solution

Given three variables in an equilibrium  
expression, calculate the fourth. (Also,  
concentration is moles per liter.)

Dilution problems.

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