

Experiment Nein! Acid-Base Equilibria

CH 204
Fall 2009
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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

This week

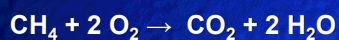
Weak acid titration.

Determine K_a of acetic acid by a couple
different methods.

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

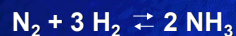
Non-Equilibrium Reaction

Reaction goes to completion.



Equilibrium Reaction

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



Equilibrium Expression

For any equilibrium reaction,



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

For a weak acid dissociation,



Strong Acids

H₂SO₄ HNO₃ HCl
HBr
HClO₃ HClO₄ HI

Weak Acids

All the rest!

CH₃COOH R-COOH
H₃PO₄ HF NH₄⁺
"HA"

Calculating [H⁺] and pH

If you are given the [H⁺]
pH = -log [H⁺]

If you are given the pH
[H⁺] = 10^{-pH}

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.

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.

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 sodium acetate

At the half-equivalence point, half of the HA has been reacted away, and the [HA] and [A⁻] concentrations are equal.

Half-Equivalence Point

At the half-equivalence point, [HA] = [A⁻].

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

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

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

$$pH = pK_a$$

A Short-Cut to K_a

- 3) Measure the pH of 1.2 M acetic acid and two buffer solutions

Use measured pH and known acetic acid and acetate concentrations to calculate K_a

$$K_a = \frac{[10^{-\text{pH}}][A^-]}{[HA]}$$

Calculating K_a from Acid Solution

	CH_3COOH	CH_3COO^-	H^+
initial	1.2	0	0
equilibrium	$1.2 - x$	x	x

$$K_a = \frac{[\text{H}^+][A^-]}{[HA]} = \frac{[x][x]}{[1.2 - x]}$$

$$x = 10^{-\text{pH}}$$

Assume $x \ll 1.2 \text{ M}$

Calculating K_a from Acid Solution

If $x \ll 1.2 \text{ M}$, then

$$K_a = \frac{[x][x]}{[1.2 - x]} = \frac{[x^2]}{[1.2]}$$

$$K_a = \frac{(10^{-\text{pH}})^2}{[1.2]}$$

Calculating K_a from Buffer Solution

Dilution problem!

25 mL 1.2 M NaA + 10 mL 1.2 M HA

$$[A^-] = 1.2 \text{ M} \times \frac{25}{35} = 0.857 \text{ M}$$

$$[HA] = 1.2 \text{ M} \times \frac{10}{35} = 0.343 \text{ M}$$

Then use these values in the equilibrium expression:

Calculating K_a from Buffer Solution

	CH_3COOH	CH_3COO^-	H^+
initial	0.343	0.857	0
equilibrium	$0.343 - x$	$0.857 + x$	x

$$x = 10^{-\text{pH}}$$

Assume $x \ll 0.343 \text{ M}$

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[10^{-\text{pH}}][0.857]}{[0.343]}$$

And Finally...

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

pH meters need love, too

Glass bulb is very thin

Remove carefully from storage bottle

Rinse well between samples, dab dry with KimWipes

Keep the bulb wet between readings

Swish samples to get better readings



Next week's quiz

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.

Next week

Final Class Meeting

Course/Instructor Survey

Last Quiz

TA Evaluations

Kinetics lab

Lab check-out

No class meeting after Experiment 10

No quiz after Experiment 10
