

Experiment 9 Acid-Base Equilibria

CH 204
Spring 2007
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Last Week

Heat in chemical reactions:

heat is a measurable quantity
produced and consumed in stoichiometric amounts

Heat Capacity:

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

This week

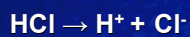
Weak acid titration.

Determine K_a of acetic acid by a couple
different methods.

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

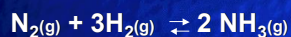
Non-Equilibrium Reaction

Reaction goes to completion.



Equilibrium Reaction

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



Equilibrium Expression

For any equilibrium reaction,

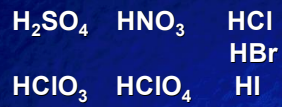


$$K_{\text{eq}} = \frac{\frac{\text{products}}{\text{reactants}}}{[\text{A}]^a[\text{B}]^b} = \frac{[\text{C}]^c[\text{D}]^d}{[\text{A}]^a[\text{B}]^b}$$

For a weak acid dissociation,

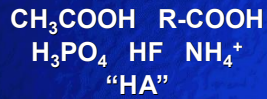


Strong Acids



Weak Acids

All the rest!



1

Review of pH

Neutral $\text{pH} = 7$
Acidic $\text{pH} < 7$
Basic (alkaline) $\text{pH} > 7$

pH is a negative log scale for acid concentrations. Increasing pH by one decreases $[\text{H}^+]$ by a factor of 10.

2

$$\text{pH} = \log_{10}[\text{H}^+]$$

| $[\text{H}^+]$ | $\log[\text{H}^+]$ | pH |
|------------------------|--------------------|-------|
| 10^{-1} | - 1 | 1 |
| 10^{-2} | - 2 | 2 |
| 10^{-3} | - 3 | 3 |
| 10^{-4} | - 4 | 4 |
| 1.78×10^{-5} | - 4.75 | 4.75 |
| 4.68×10^{-7} | - 6.33 | 6.33 |
| 8.13×10^{-12} | - 11.90 | 11.90 |

3

Calculating pH

Given the $[H^+]$, $pH = -\log[H^+]$

What is the pH of a 0.025 M HCl solution?

$$pH = -\log[.025] = -(-1.6) = 1.6$$

Given the pH, $[H^+] = 10^{-pH}$

What is the $[H^+]$ concentration in human arterial blood, which has a pH of 7.40?

$$[H^+] = 10^{-pH} = 10^{-7.40} = 3.98 \times 10^{-8} M$$

4

Review

If you are given the $[H^+]$

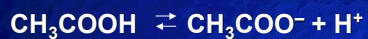
$$pH = -\log[H^+]$$

If you are given the pH

$$[H^+] = 10^{-pH}$$

pH of weak acids

What is the pH of a 0.1M solution of acetic acid?



| | CH_3COOH | CH_3COO^- | H^+ |
|-------------|------------|-------------|-------|
| initial | 0.1 | 0 | 0 |
| equilibrium | $0.1 - x$ | x | x |

Dissociation of acetic acid

| | CH ₃ COOH | CH ₃ COO ⁻ | H ⁺ |
|-------------|----------------------|----------------------------------|----------------|
| initial | 0.1 | 0 | 0 |
| equilibrium | 0.1 - x | x | x |

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[x][x]}{[0.1 - x]}$$

Assume $x \ll 0.1$ M

$$K_a = x^2 / 0.1$$

$$K_a = (10^{-pH})^2 / 0.1$$

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 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, $[HA] = [A^-]$.

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

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

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

so when $[A^-] = [HA]$, $pH = pK_a$

A Short-Cut to K_a

- 3) Measure the pH of 1.5 M acetic acid and
two buffer solutions

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

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

Deja Vu

| | CH ₃ COOH | CH ₃ COO ⁻ | H ⁺ |
|-------------|----------------------|----------------------------------|----------------|
| initial | 1.6 | 0 | 0 |
| equilibrium | 1.6 - x | x | x |

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[x][x]}{[1.6 - x]}$$

Assume $x \ll 1.5$ M

$$K_a = x^2/1.6$$

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 – turn the bottle, not the cap

Rinse well between samples

Dab, don't wipe

Swish samples to get better reading



Next week

Course Evaluations

TA Evaluations

Kinetics lab

Lab check-out

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

Next week's quiz

LAST 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.
