Experiment 9
Acid-Base Equilibria

CH 204
Spring 2008
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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

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.

$HCl \rightarrow H^+ + Cl^-$

$KNO_3 \rightarrow K^+ + NO_3^-$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Equilibrium Reaction

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

$PbSO_4 \rightleftarrows Pb^{2+} + SO_4^{2-}$

$CH_3COOH \rightleftarrows CH_3COO^- + H^+$

$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2\,NH_{3(g)}$

Equilibrium Expression

For any equilibrium reaction,

$aA + bB \rightleftarrows cC + dD$

products / reactants

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

For a weak acid dissociation,

$HA \rightleftarrows H^+ + A^-$

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

Strong Acids

H_2SO_4 HNO_3 HCl
HBr
$HClO_3$ $HClO_4$ HI

Weak Acids

All the rest!

CH_3COOH R-COOH
H_3PO_4 HF NH_4^+
"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 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 1.0 M acetic acid and two buffer solutions**

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

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

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 $x << 1.0$ M

$K_a = x^2 / 1.0$

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

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.

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 dry with KimWipes
- Keep the bulb wet between readings
- Swish samples to get better readings

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.

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.

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.