CHEM 116
Buffers and Titration

Lecture 20
Prof. Sevian

Today's agenda

- Equilibrium in acid-base systems
  - Finish comparing strong vs. weak acids (and strong vs. weak bases)
- Buffers
  - When approximately equal amounts of HA and A^- are present in solution
- Titration
  - Predict what happens to pH as you add an acid to a base, or vice-versa

Announcements

- There is a graded extra credit assignment during discussion sections on Thursday Nov 20 and Tuesday Nov 25. You must attend discussion to do it.
- Next exam is Exam 3 on Tuesday, Dec 2 (first lecture after Thanksgiving break) – note date change from syllabus
- Final exam has been scheduled for Tuesday, Dec 16, 3:00pm

There are only three type of acid-base problems

1. Predict the pH: given the amount of acid, base and/or salt added to some water, predict the pH of the solution.
   - How you approach calculating the pH depends on what you added to the water, so that's the first thing you have to figure out
   - Variables are: strong or weak, acid or base
   - "Salts" in the Bronsted-Lowry scheme are actually acids or bases – their conjugates are more familiar to you
2. Equilibrium: given the measured pH of a solution, figure out how much acid, base or salt must have been added to some water to make the pH be that value.
   - These are always equilibrium problems
3. Titration: given a solution of unknown (acid or base) concentration, neutralize it with a known amount of (base or acid) to figure out the unknown concentration.
   - Involves stoichiometry since a neutralization reaction is occurring
   - If a weak acid or base is involved, it will also involve equilibrium calculations

Comparing strong and weak acids

Strong acid

0.020 M HCl solution

- Acid dissociates completely
- $[H^+]$ is equal to [HCl]
- $[H^+]$ = 0.020 M
- pH = 1.70

Weak acid

0.020 M CH_3COOH solution

- Acid does not dissociate completely
- Need to know K_a to solve
- Must use equilibrium calculation to solve
- $[H^+] \approx \sqrt{C_A \cdot K_a}$
  = 0.00060 M
- pH = 3.22

How to recognize strong vs. weak acids

Memorize the strongest acids

- All halides except fluoride: HCl, HBr, HI
- Nitric acid: HNO_3
- Sulfuric acid (only the first H^+): H_2SO_4
- Perchloric acid: $HClO_4$

Weak acids are listed in the K_a table

Acids and Bases in general: What you (will) need to be able to do

- Identify conjugate acid-base pairs and predict reactions
- Equilibrium
- Titration
- Buffers
  - Equations to use as shortcuts for solving problems

Strategies to master:

- Using the math tricks to solve problems
- Deciding on the right approach to solving a problem: recognizing acid-base equilibrium problems
- Recognizing hydrolysis reactions – "hydrolysis" is a fancy name for adding a weak acid or weak base to water (unfortunately referred to as a "salt" because it's the conjugate that happens to be more familiar)

Adding a "salt" to water

- Is the salt a conjugate of a strong acid/base or of a weak acid/base?
- If it is a salt of a strong acid or base, then nothing will happen (like adding table salt to water – no change in pH).
- If it is a conjugate of a weak acid or base, then the "salt" is itself also a weak base or acid. So it <u>hydrolyzes</u> and makes some H^+ or OH^-, which changes the pH.

Acid-base properties of salt solutions: hydrolysis

NaCl (*aq*) NH_4Cl (*aq*) NaClO (*aq*)

When you add a salt to water, if it is soluble to any extent, it breaks apart into its constituent + and – ions. These ions can be weak acids or weak bases themselves. If they are, they "hydrolyze" to form either H^+ or OH^-, which changes the pH away from neutral pH 7 of the water.

Hydrolysis of a salt: comparing weak vs. strong

Salt of a strong acid

- What is the pH of a 0.020 M solution of NaBr?
- Is Na^+ a conjugate of anything? No.
- Is Br^- a conjugate of anything? Yes. Of HBr.
- Is HBr strong or weak?
- HBr is a strong acid, so Br^- is a very weak base.

$$\mathbf{Br^- + H_2O \leftrightarrows HBr + OH^-}$$

- K_a for HBr is very large, so K_b for Br^- is very small.
- Equilibrium lies so strongly to the left that OH^- does not get produced in significant enough quantity to rival 1.0×10^{-7} M that exists in water.

Salt of a weak acid

- What is the pH of a 0.020 M solution of NaBrO?
- Is Na^+ a conjugate of anything? No.
- Is BrO^- a conjugate of anything? Yes. Of HBrO.
- Is HBrO strong or weak?
- HBrO is a weak acid, so BrO^- is a weak base, but not very weak.

$$\mathbf{BrO^- + H_2O \leftrightarrows HBrO + OH^-}$$

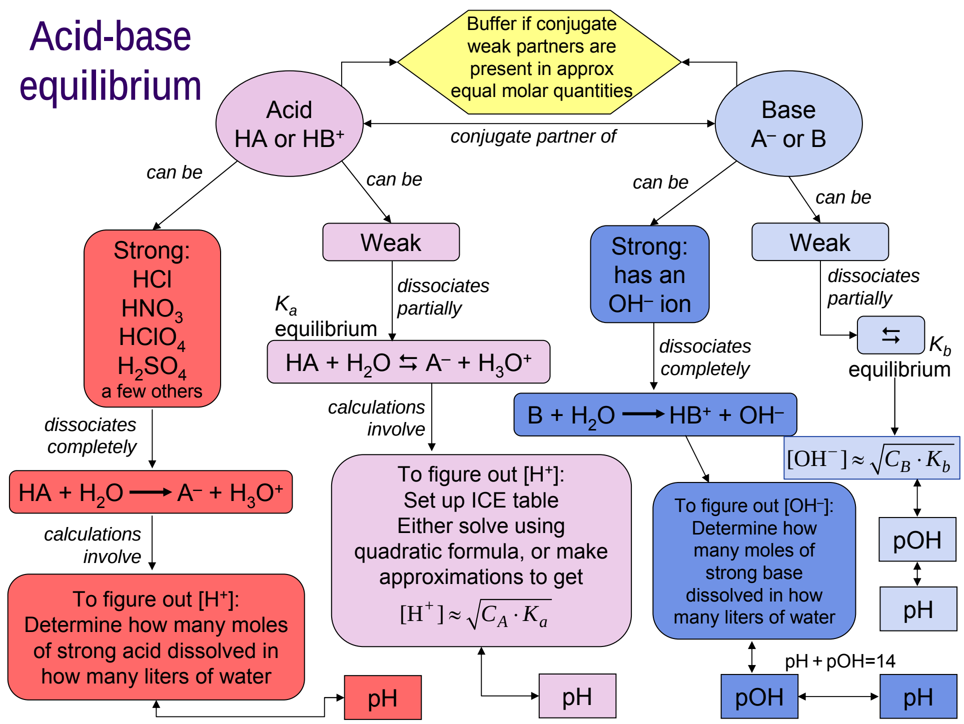
- K_a for HBrO is 2.5×10^{-9}, so K_b for BrO^- is 4.0×10^{-6}.
- Rxn occurs to enough extent that OH^- gets produced in significant enough quantity to make solution basic.

Hydrolysis example

Exercise similar to 16.17, p. 701

Which of the following salts, when added to water, would produce the most acidic solution?

a) KBr
b) NH_4NO_3
c) $AlCl_3$
d) Na_2HPO_4



Acid-base equilibrium
Buffer if conjugate weak partners are present in approx equal molar quantities
Acid HA or HB+
conjugate partner of
Base A– or B
can be
Strong: HCl HNO3 HClO4 H2SO4 a few others
dissociates completely
HA + H2O → A– + H3O+
calculations involve
To figure out [H+]: Determine how many moles of strong acid dissolved in how many liters of water
pH
can be
Weak
Ka equilibrium
dissociates partially
HA + H2O ⇆ A– + H3O+
calculations involve
To figure out [H+]: Set up ICE table Either solve using quadratic formula, or make approximations to get
[H+] ≈ √(CA · Ka)
pH
can be
Strong: has an OH– ion
dissociates completely
B + H2O → HB+ + OH–
To figure out [OH–]: Determine how many moles of strong base dissolved in how many liters of water
pOH
pH + pOH=14
pH
can be
Weak
dissociates partially
⇆
Kb equilibrium
[OH–] ≈ √(CB · Kb)
pOH
pH