Acid-Base Equilibria

Inspired by Paul Groves

A BLUFFER'S GUIDE

1. $H_2O \rightleftharpoons H^+ + OH^-$ $K_w = [H^+][OH^-] = 10^{-14}$
$pH = -\log[H^+]$ $pH+pOH = 14$ $[H+] = 10^{-pH}$
Convert between pH, pOH, $[H^+]$, & $[OH^-]$

2. Acid Ionization Constant (K_a):

$HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$K_a = [A^-][H_3O^+]/[HA]$

Example: $HF + H_2O \rightleftharpoons H_3O^+ + F^-$

$K_a = [F^-][H_3O^+]/[HF]$

3. Typical question: Given K_a and the starting concentrations of acid, find concentrations (or pH) of $[H^+]$ at equilibrium.

Example: K_a for acetic acid = 1.8×10^{-5}.
Find the pH of 0.100M acetic acid.

4. Polyprotic Acids: H_3PO_4, H_2SO_4, $H_2C_2O_4$, etc. The 1st dissociation is strong for H_2SO_4.
When using Hess's Law with a polyprotic acid: $K_{overall} = K_{a1} \times K_{a2}$
Calculating pH, use K_{a1}

5. Bronsted-Lowry Definitions.
Acids = H+ donors; Bases = H+ acceptors
Conjugate acid-base pairs.

6. Base Ionization Constant (K_b):

$B + H_2O \rightleftharpoons BH^+ + OH^-$

$K_b = [BH^+][OH^-]/[B]$

Example: $F^- + H_2O \rightleftharpoons HF + OH^-$

$K_b = [HF][OH^-]/[F^-]$

7. Salt solns can have pH's ≠ 7 (hydrolysis)
ions from weak acids → basic solutions
$C_2H_3O_2^- + H_2O \rightleftharpoons HC_2H_3O_2 + OH^-$
ions from weak bases → acidic solutions
$NH_4^+ + H_2O \rightleftharpoons NH_4OH + H^+$

8. $K_a \times K_b = K_w = 10^{-14}$
only applies for **conjugate** acids & bases!
Example: K_a $HC_2H_3O_2 = 1.8 \times 10^{-5}$
K_b $C_2H_3O_2^- = 10^{-14} / 1.8 \times 10^{-5}$

9. Percent ionization =
$[H^+]_{eqilibrium} / [HA]_{initial} \times 100$

10. Acid Strength-know the 6 strong acids: HCl, HBr, HI, HNO_3, $HClO_4$, and H_2SO_4 (removal of first H^+ only)

(a) binary acids - acid strength increases with increasing size and electronegativity of the "other element". (NOTE: Size predominates over electronegativity in determining acid strength.)
Examples: $H_2Te > H_2O$ & $HF > NH_3$

(b) Oxoacids - Acid strength increases with increasing:
(1) electronegativity
(2) number of bonded oxygen atoms
(3) oxidation state of the "central atom".

Example: $HClO_4$ or $[O_3Cl(OH)]$
is very **acidic**
NaOH is very **basic**
Acid strength also increases with ***decreasing*** radii of the "central atom".
Example:
HOCl (bond between Cl and OH is covalent--making HOCl **acidic**)
HOI (bond between I and OH is ionic--making HOI **basic**)

11. Lewis Acids and Bases:
(This applies to coordinate covalent bonds.)
Lewis Acid--electron pair acceptor
Lewis Base--electron pair donor
"Have Pair…Will Share" – Lewis Base

In complex ion formation, metal ions are Lewis acids, and ligands are Lewis bases.
Example: $Cu^{2+} + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+}$
Cu^{2+} acts as an acid; NH_3 acts as a base.

12. Strong Bases: amide ion, NH_2^-
hydride ion, H^-, methoxide ion, CH_3O^-

Based on a handout by William Bond, Snohomish HS