Acid Base Equilibrium

General Acid/Base properties

Acids: taste sour (think vinegar)
React w/ active metals --> produce $H_{2(g)}$
Conduct electrical current
Turn litmus paper red
Reacts w/ base (neutralization)

Acid properties due to H^+ (H_3O^+) in solution

Bases: taste bitter (think soap)
Feels slippery
Conducts electrical current
Turns litmus blue
Reacts w/ acid (neutralization)

Basic properties due to OH^- in solution

Definitions:

Arrhenius

- Acids produce H^+ in solution (Chem 11)
- Base produce OH^-

Brønsted-Lowry

- Acid: proton (H^+) donor
- Base: proton acceptor

These can be ions (charged) OR molecules (non-charged)
Substances can also be ***amphiprotic*** → can act as an acid OR base

Amphiprotic: NH_3, H_2O, HCO_3^- etc… (Both has H, and can accept H)

Conjugate acids & bases:

Conjugate acid/base pairs differ only by the number of hydrogens, the one with 1 MORE hydrogen is the acid, the one with 1 LESS hydrogen is the base. Conjugate pairs exist on either side of an acid-base equilibrium.

Ex.

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^+{}_{(aq)}$$

Acid Base Base Acid

Ex. Identify the conjugates in the following

$$HCl_{(aq)} + OH^-{}_{(l)} \rightleftharpoons Cl^-{}_{(aq)} + H_2O_{(aq)}$$

Water is amphiprotic!

Ex.

$$HF_{(aq)} + HCO_3^-{}_{(l)} \rightleftharpoons F^-{}_{(aq)} + H_2CO_{3(aq)}$$

Ex.

$$HCN_{(aq)} + HSO_3^-{}_{(l)} \rightleftharpoons CN^-{}_{(aq)} + H_2SO_{3(aq)}$$

Hebden pg 115-118 – READ, pg 118-120 do Q's 13-19

Relative Strength of acid/bases

Concentration: # of moles (acid/base) in one liter of solution

20 M → 1×10^{-10} M

Generally:

> 5M = concentrated
< 5M = dilute

Strength: describes how readily a substance dissociates into ions.

Ex. $HCl \rightarrow H^+ + Cl^-$ 100%

$HF \rightleftharpoons H^+ + F^-$ <<100%

100% dissociation = strong, less than 100% = weak

Strong acids – dissociate into H_3O^+ 100%

Ex. $HClO_4$, HI, HBr, HCl, HNO_3, H_2SO_4

Weak acids – all other acids
Forms an equilibrium b/w un-dissociated acid and its ions.

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

Usually ← towards reactants

Strong bases – there are 3 strong bases that you need to know about:

NH_2^-, O^{2-}, OH^- (Usually **OH^-** forms in aqueous solutions)

$O^{2-} + H_2O \rightarrow 2OH^-$

Weak bases – all remaining bases (on the table) are weak they form an equilibrium.

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + NH_4^+_{(aq)}$$

Levelling effect: all strong acids and strong bases are equal

$H_2O + HCl \rightarrow H_3O^+ + Cl^-$ in water the strongest acid is **H_3O^+**

$H_2O + HNO_3 \rightarrow H_3O^+ + NO_3^-$

K_w – the Water Constant

$$2H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + H_3O^+_{(aq)}$$

$K_w = 1.0 \times 10^{-14} = [OH^-][H_3O^+]$ - **@ 25ºC**

Ex. What is the $[OH^-]$ in a 0.005M solution of HCl?

Ex. What is the $[H_3O^+]$ in a 0.0000007 M solution of NaOH?

pH – a common way to represent concentration of an acid

pH = -log $[H_3O^+]$ or -log $[H^+]$

As $[H^+]$ increases, pH decreases
Because pH is log base 10, means every pH level is 10x stronger

Ex. Is pH 2 stronger or weaker than pH 5, by how much?

Ex. What is the pH of a 5.2×10^{-5} M solution of HCl?

Reminder: SigFigs w/ pH are weird

$\underline{1.00} \times 10^{\mathbf{-3}} \rightarrow \mathbf{3}.\underline{000}$
[ ] pH

pH examples:
Ex. What's the pH of 4.20 moles of HCl in 3.15L?

Ex. What's the pH of 0.000375 moles of HNO_3 in 6235mL?

pOH – like pH but with OH

Ex. If I take 15mL of concentrated HCl (12M) and dilute it to 6L what's the pOH?

Ex. What's the pH and pOH of of a 4.23×10^{-8} M solution of $HClO_4$?

Hebden pg 134 – 143 try all questions

<u>Quantitative</u> comparison of acid strength (K_a)

Acid dissociation of weak acids usually lies to the reactant side.

Ex.

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

We can calculate how much by using $\mathbf{K_a}$

$$K_a(CH_3COOH) = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} = 1.8 \text{ x } 10^{-5}$$

A K_a of $1x10^{-2}$ is 1000 times larger than a K_a of $1x10^{-5}$

From the K_a we can calculate $[H^+]$ and pH values

Ex. What's the pH of a 0.500 M HNO_2 solution?

Reaction	$HNO_2 \rightleftharpoons$	H^+ +	NO_2^-
[**I**nitial]			
Change			
[**E**quilibirum]			

We can ASSUME X is small, when compared to [ ]

Ex. What's the pH of 0.0020 M ammonium?

Reaction	$NH_4^+ \rightleftharpoons$	H^+ +	NH_3
[**I**nitial]			
Change			
[**E**quilibirum]			

Ex. If a solution of HF has a pH of 4.2 what is its concentration?

Hebden pg. 128 #31,33 & pg 152 #74-82

Base constant (K_b)

ALWAYS Have to calculate: cannot be taken from the table

Recall: $\mathbf{K_w = K_a \times K_b}$

So… $K_b = \frac{K_w}{K_a}$

You MUST use the conjugate acid's K_a

Recall that the Brønsted-Lowry definition of a base means that it is a proton acceptor. So that the base will gain an H^+ from reactants to products.

$$F^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HF_{(aq)} + OH^-_{(aq)}$$

So $K_b = \frac{[HF][OH^-]}{[F^-]} = \frac{K_w}{K_a}$

Ex. What's the K_b of NH_3?

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

Ex. What is the pH of a 0.200M F^- solution?

Reaction	F^-	+ H_2O $\rightleftharpoons$	HF	+ OH^-
[**I**nitial]				
Change	-			
[**E**quilibirum]				

Ex. What's the $[F^-]$ in water if water has a pH of 7.62?

$$F^-_{(aq)} + H_2O_{(l)} \rightarrow HF_{(aq)} + OH^-_{(aq)}$$

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