SCH 4U

WEAK BASES & BUFFERS

$$B_{(aq)} + H_2O_{(l)} \rightleftharpoons HB^+_{(aq)} + OH^-_{(aq)}$$

Base dissociation constant: $K_b = \frac{[HB^+][OH^-]}{[B]}$

EXAMPLES:

1. Caffeine (cafN) is a weak base with a $K_b = 4.1 \times 10^{-4}$.
   What is the pH of a 0.70 mol/L solution?

2. Calculate the K_b of a 0.100 mol/L weak base whose pH is 10.62.

ACIDS & CONJUGATE BASES

RECALL: $\boldsymbol{K_w = 1.0 \times 10^{-14}} = [H_3O^+][OH^-]$ for all conjugate acid/base systems.

PROPERTIES OF ACIDS/BASES & THEIR CONJUGATES:

① Stronger the acid, the weaker its conjugate base.
Stronger the base, the weaker its conjugate acid.

② Conjugate of a strong acid is always a weak base.
Conjugate of a strong base is always a weak acid.

PROOF of $K_w = K_a \times K_b$

Consider the acetic acid and the acetate ion mixture – ACID & its CONJUGATE BASE mixture

- Acetic acid dissociates in water (***reaction (1)***) to forms hydronium ions and acetate ions

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

acid — conjugate base

The K_a formula follows ⟹ $K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$

- Acetate salts dissociate when dissolved and the acetate ion (which is the conjugate base of acetic acid) reacts with water (***reaction (2)***).

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

The K_b formula follows ⟹ $K_b = \frac{[CH_3COOH][OH^-]}{[CH_3COO^-]}$

Combining (1) and (2):

$$K_a \times K_b = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]} \times \frac{[CH_3COOH][OH^-]}{[CH_3COO^-]}$$

$$= [H_3O^+][OH^-]$$

$$= K_w = 1.0 \times 10^{-14}$$

Based on the above proof, we can conclude:

$$\boldsymbol{K_a \times K_b = K_w = 1.0 \times 10^{-14}}$$

We can use the above relationship to convert between the values of K_a and K_b.

SOLVING PROBLEMS USING SALTS

EXAMPLES:

① Find the K_b for CN^- ion (not found in Table E.11)

$$CN^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HCN_{(aq)} + OH^-_{(aq)}$$

Base

- Find K_a for HCN in Table E.9
- We use $K_a \times K_b = K_w$ to find K_b.

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{6.2\times10^{-10}} = 1.6 \times 10^{-5}$$

② Find K_b for methanoate ion $HCOO^-$.

③ What is the pH of a 0.100 mol/L solution of sodium cyanide (NaCN)?

- Salt dissociation equation.
- Conj. acid/base eq'n with anion
- ICE table
- K_b
- Solve for $[OH^-]$ with K_c expression
- $pOH = -log[OH^-]$
- $pH = 14 - pOH$

④ What is the pH of a 0.0500 mol/L solution of potassium lactate?

$KLac_{(aq)} \rightarrow K^+_{(aq)} + Lac^-_{(aq)}$

BUFFER SOLUTIONS

① ***ACID/CONJ BASE BUFFERS***

A solution containing a mixture of a weak acid and its conjugate base (the anion from its salt) is able to resist change in pH when strong acids or bases are added.

Eg. CH_3COOH and CH_3COO^- mixture

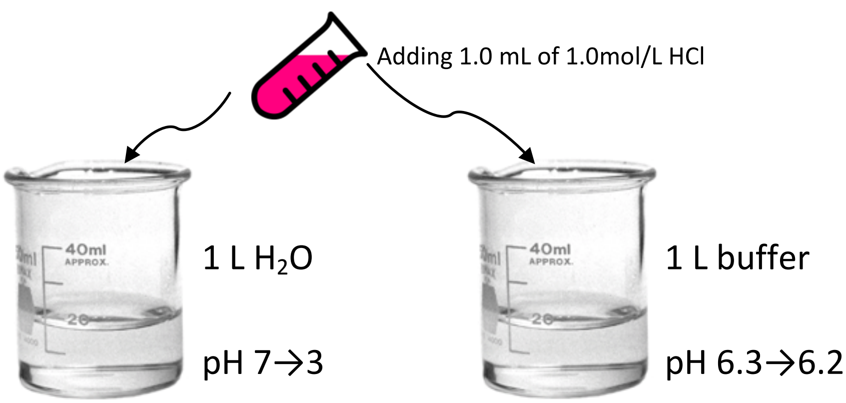
CH_3COOH ↓ acetic acid

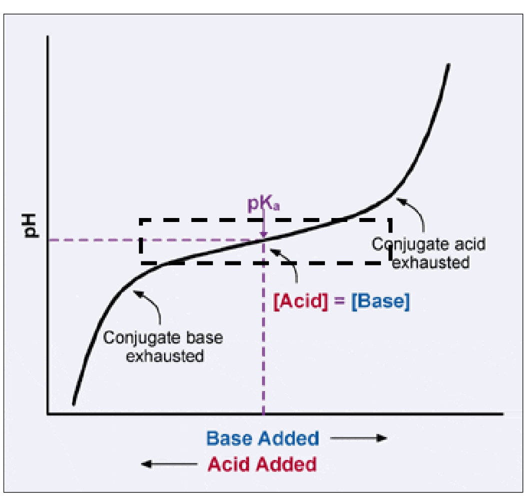
CH_3COO^- ↓ acetate ion (from $NaCH_3COO$, for instance)

Eg. C_6H_5COOH and $C_6H_5COO^-$ mixture

C_6H_5COOH ↓ benzoic acid

$C_6H_5COO^-$ ↓ benzoate ion (from KC_6H_5COO for instance)





BUFFER CAPACITY = how much acid/base can be absorbed before the pH starts to change drastically.

HOW DO ACID/CONJ BASE BUFFERS WORK?

- mixture of HA (weak acid) and NaA (its salt)

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons A^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

[HA] high	[A$^-$] high
(weak, little dissociation)	(NaA is soluble)

By adding a strong acid (H_3O^+) or base (OH^-), these new components put a stress on the equilibrium and are removed, keeping pH relatively stable.

ILLUSTRATION/EXPLANATION:

① Add strong acid (H_3O^+)

$$HA_{(aq)} + H_2O_{(l)} \leftleftharpoons A^-{}_{(aq)} + \boldsymbol{H_3O^+{}_{(aq)}}$$

Reaction shifts left to remove excess hydronium ion and keep pH constant

② Add strong base (OH^-)

OH^- reacts with H_3O^+ to produce H_2O

$$HA_{(aq)} + \boldsymbol{H_2O_{(l)}} \rightrightharpoons A^-{}_{(aq)} + \boldsymbol{H_3O^+{}_{(aq)}}$$

Reaction shifts right to replace reduced hydronium ion and keep pH constant

CHARACTERISTICS OF BUFFERS:

① More concentrated the components of buffer, more pH change it can resist.

② [Acid] = [Salt], buffer is at its maximum capacity to resist change (**buffer capacity**).

② *BASE/CONJ ACID BUFFERS*

A solution that contains a weak base/conjugate acid mixture, that is able to resist changes in pH when strong acids or bases are added.

Eg. NH_3 and NH_4^+ mixture

NH_3 → ammonia

NH_4^+ → ammonium ion (for instance NH_4Cl)

Eg. NH_2CONH_2 and $NH_2CONH_3^+$ mixture

NH_2CONH_2 → urea

$NH_2CONH_3^+$ → ureum ion (for instance NH_2CONH_3Br)

HOW DO BASE/CONJ ACID BUFFERS WORK?

Example: mixture of NH_3 (weak base) and NH_4Cl (its salt)

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

$[NH_3]$ high (weak base)

$[NH_4^+]$ high (from soluble salt)

① Add strong acid (H_3O^+)

- reacts with OH^- to make water.

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

Reaction shifts right to replace OH^-

② Add strong base (OH^-)

- increase $[OH^-]$

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

Reaction shifts left to reduce OH^-