Chapter 16: Acid Base Equilibrium

1) Please fill in the missing information in the following table.

$[H_3O^+]$	pH	$[OH^-]$	pOH	Acidic, Basic, or Neutral?
1.0×10^{-7} M	7	1.0×10^{-7}	7	neutral
4.9×10^{-10}	9.31	2.0×10^{-5}	4.69	basic
1.9×10^{-6}	5.73	5.4×10^{-9} M	8.27	acidic
3×10^{-13}	12.6	4×10^{-2}	1.4	basic

2) True or False?

a) __T__ The K_a for carbonic acid refers to the reaction: $H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$.

b) __F__ The K_b for bicarbonate ion refers to the reaction: $HCO_3^- + H_3O^+ \rightleftharpoons H_2CO3 + H_2O$.

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$$

c) __T__ A solution of sodium bicarbonate in water will be basic.

no effect $NaHCO_3$ $Ka: 4.8 \times 10^{-11}$
$kb: 2.4 \times 10^{-8}$
so HCO_3^- is more basic than acidic

d) __T__ Given $CH_3(CH_2)_2CO_2H$ has $K_a = 1.51 \times 10^{-5}$, $CH_3(CH_2)_2CO_2^-$ has $K_b = 6.61 \times 10^{-10}$.

(close enough, ha ha)

e) __T__ Smaller pK_a, larger K_a, and more acidic are all synonymous.

f) __T__ A Lewis base is an electron pair donor.
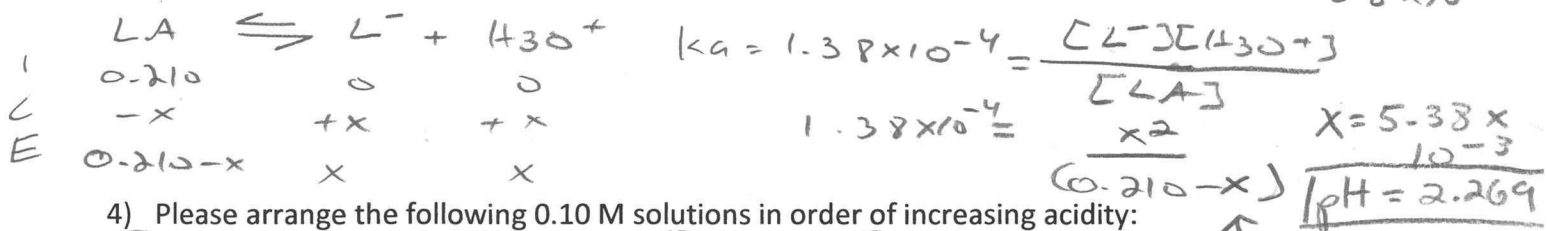
3) Lactate, $CH_3CH(OH)CO_2^-$, is constantly produced from pyruvate during normal metabolism. When the citric acid cycle backs up due to insufficient oxygen supply, lactate builds up in your exercising muscles and you feel that painful burning sensation.

Lactate has $K_b = 7.24 \times 10^{-11}$ at 25 ºC.

a) Please write the equation described by this K_b.

$$CH_3CH(OH)CO_2^-(aq) + H_2O(l) \rightleftharpoons CH_3CH(OH)COOH(aq) + OH^-(aq)$$
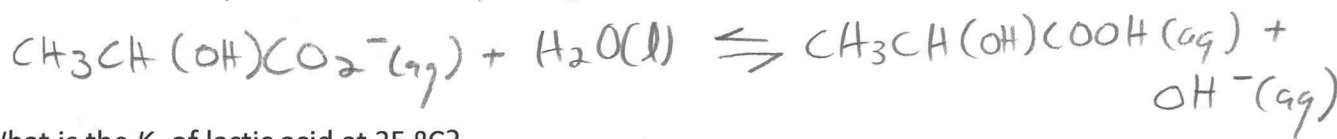
b) What is the K_a of lactic acid at 25 ºC?

$$K_a = \frac{K_w}{K_b} = \frac{10^{-14}}{(7.24 \times 10^{-11})} = 1.38 \times 10^{-4}$$

starting with acidic form, so:

lactic acid + $H_2O \rightleftharpoons$ lactate + H_3O^+

$k_a: 1.38 \times 10^{-4}$

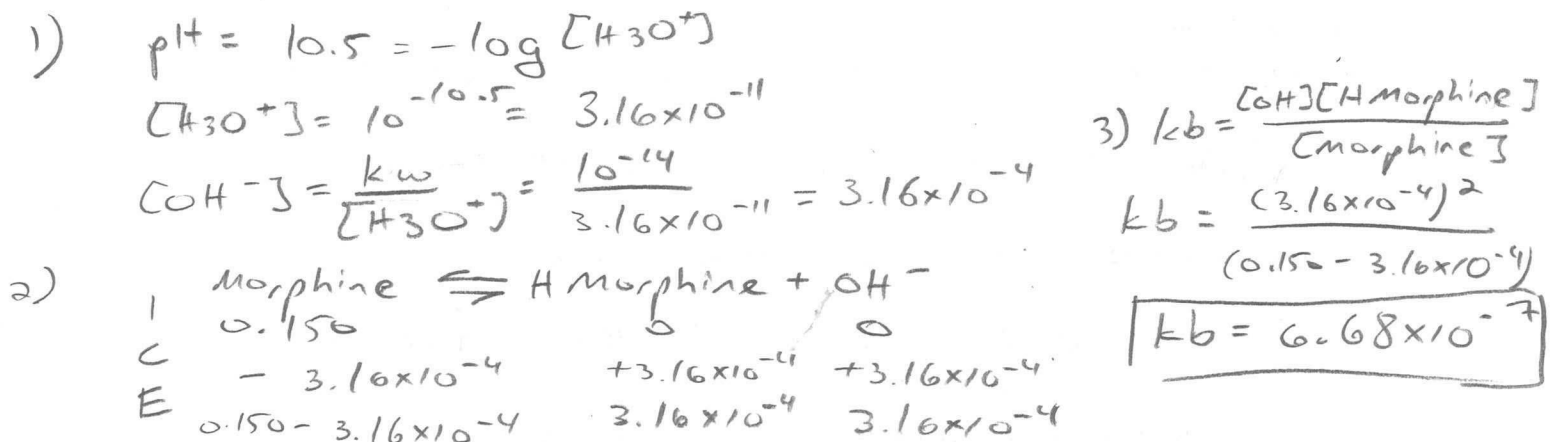c) If a solution is initially 0.210 M lactic acid, what is the pH at 25 ºC?

$$LA \rightleftharpoons L^- + H_3O^+$$

I	0.210	0	0
C	$-x$	$+x$	$+x$
E	$0.210-x$	x	x

$k_a = 1.38 \times 10^{-4} = \dfrac{[L^-][H_3O^+]}{[LA]}$

$1.38 \times 10^{-4} = \dfrac{x^2}{(0.210-x)}$

$X = 5.38 \times 10^{-3}$

$pH = 2.269$

can ignore ← (0.210-x)

4) Please arrange the following 0.10 M solutions in order of increasing acidity:

⑤ BaCl₂, ⑦ NH₄Cl, ④ NaHCO₃, ② K₃PO₄, ⑥ NH₄NO₂, ① NaNH₂, ③ LiCN

neutral

ka NH4:
5.6×10^{-10}
acidic

kb HCO3⁻:
2.4×10^{-8}
ka HCO3⁻:
4.8×10^{-11}, overall basic

kb PO4³⁻:
2.8×10^{-2}
basic

ka NH4:
5.6×10^{-10}
kb NO2:
2.2×10^{-11}
so acidic

kb NH2:
"large"
basic

kb CN⁻:
2.5×10^{-5}
basic

5) A 0.150 M solution of morphine (C₁₇H₁₉NO₃) has a pH of 10.5.
   a) What is morphine's K_b?

1) $pH = 10.5 = -\log[H_3O^+]$

$[H_3O^+] = 10^{-10.5} = 3.16 \times 10^{-11}$

$[OH^-] = \dfrac{k_w}{[H_3O^+]} = \dfrac{10^{-14}}{3.16 \times 10^{-11}} = 3.16 \times 10^{-4}$

3) $k_b = \dfrac{[OH^-][H\,Morphine]}{[morphine]}$

$k_b = \dfrac{(3.16 \times 10^{-4})^2}{(0.150 - 3.16 \times 10^{-4})}$

$k_b = 6.68 \times 10^{-7}$

2) $Morphine \rightleftharpoons H\,Morphine + OH^-$

I	0.150	0	0
C	-3.16×10^{-4}	$+3.16 \times 10^{-4}$	$+3.16 \times 10^{-4}$
E	$0.150 - 3.16 \times 10^{-4}$	3.16×10^{-4}	3.16×10^{-4}

   b) Morphine is a (circle one): Strong Acid   Weak Acid   **(Weak Base)**   Strong Base

6) The reaction: $2\,NH_3\,(g) \rightleftharpoons N_2\,(g) + 3\,H_2\,(g)$ has $K_p = 1.89 \times 10^{-6}$ at 25 ºC.

(Challenge – hint, this is not an acid/base problem) When a certain partial pressure of NH₃ (g) is put into an otherwise empty rigid vessel at 25 ºC, equilibrium is reached when 50.0% of the original ammonia has decomposed. What was the original partial pressure of ammonia before any decomposition occurred?

$$2NH_3 \rightleftharpoons N_2 + 3H_2$$

x	0	0
$-2y$	$+y$	$+3y$
$0.50x$	y	$3y$

$X - 2y = 0.50x$
$2y = 0.50x$
$y = 0.25x$

$k_p = 1.89 \times 10^{-6} = \dfrac{(y)(3y)^3}{(0.50x)^2}$

$1.89 \times 10^{-6} = \dfrac{(0.25x)(3(0.25x))^3}{(0.50x)^2}$

$1.89 \times 10^{-6} = \dfrac{0.105x^4}{0.25x^2}$

$1.89 \times 10^{-6} = \dfrac{0.105x^2}{0.25}$

$X = 0.00212$

$P\,NH_3\,initial =$
$x = 2.12 \times 10^{-3}$ atm