Solutions

CHEM 104
PLI 35
Wednesday, July 20, 2016 Chapter 17

Something to keep in mind: When **equal** amounts of acid and base are mixed (at the equivalence point) the resulting solution will behave as follows:

Strengths of Acid and Base	Resulting Solution pH
Strong Acid + Strong Base	7 (Neutral)
Strong Acid + Weak Base	< 7 (Acidic)
Weak Acid + Strong Base	> 7 (Basic)
Weak Acid + Weak Base	< 7 if acid's K_a > base's K_b = 7 if acid's K_a = base's K_b > 7 if acid's K_a < base's K_b

1. Practice with the common ion effect: In the lab you make a solution that is 0.0048 M HNO_2 and 0.00056 M $LiNO_2$. What is the pH of your solution?

$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+$

$K_a = \frac{[NO_2^-][H_3O^+]}{[HNO_2]}$

	HNO_2	NO_2^-	H_3O^+
I	4.8×10^{-3} M	5.6×10^{-4} M	0
C	$-x$	$+x$	$+x$
E	$4.8\times10^{-3}-x$	$5.6\times10^{-4}+x$	x

$4.5\times10^{-4} = \frac{(5.6\times10^{-4}+x)(x)}{4.8\times10^{-3}-x}$ ← can't ignore

$x^2 + 1.01\times10^{-3}x - 2.16\times10^{-6} = 0$

$x = \frac{-1.01\times10^{-3} \pm \sqrt{(1.01\times10^{-3})^2 - 4(1)(-2.16\times10^{-6})}}{2}$ → $x = 1.05\times10^{-3}$

$pH = -\log x = \boxed{2.98}$

2. Which of the following can form a buffer?
   a. HCl and CH_3COOH → both acids!
   b. H_2CO_3 and $NaHCO_3$
   c. NaOH and NaCl → both strong
   d. $NaCH_3COCOO$ and $CH_3COCOOH$
   e. HClO and KClO

Four options
weak acid + conjugate base
weak base + conjugate acid
strong acid + weak base
strong base + weak acid

3. Ascorbic acid, $H_2C_6H_6O_6$ (s), is a diprotic acid with K_1 of 7.9×10^{-5} and K_2 of 1.6×10^{-12}. In a 0.005 M aqueous solution of ascorbic acid, which of the following species is present in the lowest concentration?
   a. H_2O (l) → this one should be obvious!
   b. H_3O^+ (aq)
   c. $H_2C_6H_6O_6$ (aq)
   d. $HC_6H_6O_6^-$ (aq)
   e. $C_6H_6O_6^{2-}$ (aq)

$K_1 = H_2O(l) + H_2C_6H_6O_6(aq) \rightleftharpoons HC_6H_6O_6^-(aq) + H_3O^+(aq)$

$K_2 = H_2O(l) + HC_6H_6O_6^-(aq) \rightleftharpoons C_6H_6O_6^{2-}(aq) + H_3O^+(aq)$

Using H.H. equation: $pH = pK_a + \log\frac{[A^-]}{[HA]} = -\log(4.79\times10^{-10}) + \log\frac{0.0619}{0.100} = \boxed{9.11}$

4. Determine the pH of an HCN/KCN buffer containing 0.100 mol HCN and 0.070 mol KCN before and after the addition of 50.0 mL of 0.100M HCl to 1.00 L of buffer.
K_a for HCN is 4.79×10^{-10}

Before $pH = pK_a + \log\frac{[A^-]}{[HA]} = -\log(4.79\times10^{-10}) + \log\left(\frac{0.070}{0.100}\right) = \boxed{9.16}$

After

	$HCN + H_2O \rightleftharpoons$	$CN^- + H_3O^+$	
I	0.0952 M	0.0667 M	0.00476 M
C	$+x$	$-x$	$-x$
E	$0.0952 + x$ $= 0.0952 + 0.00476$ $= 0.100$ M	$0.0667 - x$ $= 0.0667 + 0.00476$ $= 0.0619$ M	$0.00476 - x$ $= 0$

$K_a = \frac{[CN^-][H_3O^+]}{[HCN]} = \frac{(0.0667-x)(0.00476-x)}{0.0952+x}$ ← can ignore

$x^2 - 0.0714x + 0.000317 = 0$

$x = 0.00476$ M ← This makes sense, because we know all the strong acid will react with the CN^-.

5. A 25.0 mL sample of 0.175 M methylamine (CH_3NH_2, a weak base, $K_b = 4.4 \times 10^{-4}$) is titrated with 0.150 M HBr. What is the pH at one-half of the equivalence point?

At ½ equivalence point, $\frac{[A^-]}{[HA]} = 1$ so $pH = pK_a$ ← of conjugate acid!

Because $pH = pK_a + \log\frac{[A^-]}{[HA]}$ and $\log(1) = 0$

$K_w = K_a \cdot K_b$ (conj. acid/base pair)

$pK_w = pK_a + pK_b$

$pK_a = pK_w - pK_b$

$pH = pK_a = pK_w - pK_b$
$= 14 - (-\log 4.4\times10^{-4})$
$= \boxed{10.64}$

6. Please circle the best acid to combine with its sodium salt to make a solution buffered at pH 4.25. For the best choice, please calculate the ratio of the conjugate base to the acid required to attain the desired pH.

Chlorous acid, $HClO_2$	Formic acid, $HCHO_2$	Hypochlorous acid, HClO
$pK_a = 1.95$	$pK_a = 3.74$	$pK_a = 7.54$

pKa is closest to the desired pH

$pH = pK_a + \log\frac{[A^-]}{[HA]} \rightarrow \frac{[A^-]}{[HA]} = 10^{(pH-pK_a)} = 10^{(4.25-3.74)} = 10^{0.51} = \frac{3.24}{1}$

7. What change will be caused by addition of a small amount of HCl to a solution containing fluoride ions and hydrogen fluoride?
   a. The concentration of hydronium ions will increase significantly.
   b. The concentration of fluoride ions will increase as will the concentration of hydronium ions.
   c. The concentration of hydrogen fluoride will decrease and the concentration of fluoride ions will increase.
   d. The concentration of fluoride ions will decrease and the concentration of hydrogen fluoride will increase.
   e. The fluoride ions will precipitate out of solution as their acid salt.