In Class Exercise for Chapter 16

1. Calculate the pH of solutions prepared by:

(a) dissolving 0.20 g of sodium hydroxide in water to give 100.0 mL solution

$$\left(0.20\ g \times \frac{1\ mol\ NaOH}{39.998\ g} \times \frac{1\ mol\ OH^-}{1\ mol\ NaOH}\right) \Big/ 0.1000\ L = 0.050\ M$$

$$pH = 14 + \log\left[OH^-\right] = 12.70$$

(b) dissolving 1.26 g of pure nitric acid in water to give 0.500 L solution

$$\left(1.26\ g \times \frac{1\ mol\ HNO_3}{63.018\ g} \times \frac{1\ mol\ H^+}{1\ mol\ HNO_3}\right) \Big/ 0.5000\ L = 0.040\ M$$

$$pH = -\log\left[H^+\right] = 1.40$$

(c) diluting 40.0 mL of 0.075 M $Ba(OH)_2$ to a volume of 300.0 mL

$$\left(40.0\ mL \times \frac{1\ L}{1000\ mL} \times \frac{0.075\ mol\ Ba(OH)_2}{1\ L} \times \frac{2\ mol\ OH^-}{1\ mol\ Ba(OH)_2}\right) \Big/ 0.3000\ L = 0.020\ M$$

$$pH = 14 + \log\left[OH^-\right] = 12.30$$

(d) mixing equal volume of 0.20 M HCl and 0.50 M HNO_3

$$\left(1\ L \times \frac{0.20\ mol\ HCl}{1\ L} \times \frac{1\ mol\ H^+}{1\ mol\ HCl} + 1\ L \times \frac{0.50\ mol\ HNO_3}{1\ L} \times \frac{1\ mol\ H^+}{1\ mol\ HNO_3}\right) \Big/ 2L = 0.35M$$

$$pH = -\log\left[H^+\right] = 0.46$$

2. Lactic acid ($C_3H_6O_3$), which occurs in sour milk and foods such as sauerkraut, is a weak monoprotic acid. The pH of 0.10 M solution of lactic acid is 2.43. What is the value of K_a for this acid?

$$HA \rightleftharpoons H^+ + A^-$$

	HA	H^+	A^-
Initial	0.10	0	0
Change	-x	+x	+x
Eq	0.10 - x	+x	+x

$$pH = 2.43 \rightarrow \left[H^+\right] = 10^{-2.43} = 0.00372\,M \quad H^+ = x$$

$$K_a = \frac{x^2}{0.10 - x} = \frac{(0.00372)^2}{0.10 - 0.00372} = 1.44 \times 10^{-4}$$

3. Aniline ($C_6H_5NH_2$) is an organic base used in the manufacture of dyes. Calculate the pH and concentrations of all species present in a 0.15 M solution of aniline ($K_b = 4.3 \times 10^{-10}$).

$$C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$$

	$C_6H_5NH_2$	$C_6H_5NH_3^+$	OH^-
Initial	0.15	0	0
Change	-x	+x	+x

Eq	0.15 - x	+x	+x

$$K_b = \frac{x^2}{0.15 - x} = 4.3\times10^{-10} \text{ assume x} \ll 0.15 \rightarrow 4.3\times10^{-10} \sim \frac{x^2}{0.15}$$

$$x = 8.03\times10^{-6} M \text{ ck assumption: } \frac{8.03\times10^{-6}}{0.15}\times100\% = 0.005\% < 5\%$$

assumption is therefore valid

$$\left[C_6H_5NH_2\right] \sim 0.15M;\ \left[C_6H_5NH_3^+\right] = \left[OH^-\right] = 8.03\times10^{-6} M$$

$$pH = 14 + \log\left[OH^-\right] = 8.90$$

4. Calculate the pH of 0.020 M solution of $NaNO_3$ (K_a is super huge). What about the pH of a 0.020 M $NaNO_2$ solution (4.5×10^{-4})?

$$NaNO_3 \rightarrow \underbrace{Na^+}_{conj\ acid\ NaOH} + \underbrace{NO_3^-}_{conj\ base\ HNO_3} \qquad pH = 7.0$$

$$NaNO_2 \rightarrow Na^+ + NO_2^- \text{ in water we get } NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$$

	NO_2^-	HNO_2	OH^-
Initial	0.020	0	0
Change	-x	+x	+x
Eq	0.020 - x	+x	+x

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{4.5\times10^{-4}} = 2.22\times10^{-11} = \frac{x^2}{0.020 - x} \sim \frac{x^2}{0.020}$$

$$x = 6.66\times10^{-7} M \quad \text{ck assumption: } \frac{6.66\times10^{-7}}{0.2}\times100\% = 0.003\% < 5\%$$

$$pH = 14 + \log\left[OH^-\right] = 7.82$$

5. Follow the directions given below and for each case explain your reasoning.

(a) arrange each group of compounds in order of decreasing acid strength

(i) H_2O, H_2S, H_2Se

As we go down a column we increase polarizability and reduce EN

$H_2Se > H_2S > H_2O$

(ii) $HClO_3$, $HClO$, $HClO_2$

Acidity increases with # of O-atoms: $HClO_3 > HClO_2 > HClO$

(iii) PH_3, H_2S, HCl

Across a row from left to right we increase EN – make sure we have an acid: $HCl > H_2S > PH_3$

(b) identify the weakest acid for each set below.

(i) $\boxed{H_2SO_3}$, $HClO_3$, $HClO_4$ the strongest acid is $HClO_4$ since it has both the most EN central atom as well as the largest number of O-atoms; since Cl is more EN than S, $HClO_3$ is a stronger acid than H_2SO_3

(ii) $\boxed{NH_3}$, H_2O, H_2S EN decreases going across a row from right to left

(iii) $B(OH)_3$, $Al(OH)_3$, $\boxed{Ga(OH)_3}$ for an oxoacid, acid strength decreases with decreasing EN of the central atom – since Ga is the least EN

Ga(OH)$_3$ is the weakest acid

(c) Identify the stronger base in each of the following pairs.

(i) $\boxed{ClO_2^-}$ vs. ClO_3^-

(ii) HSO_4^- vs. $\boxed{HSeO_4^-}$

(iii) HS^- vs. $\boxed{OH^-}$

(iv) $\boxed{HS^-}$ vs. Br^-

6. If the percent dissociation of a 0.1 M solution of HNO_3 is actually 99.6%, what is the K_a for this acid?

$$\%\ dissociation = \frac{[H^+]}{[HNO_3]} \times 100\% \rightarrow 0.996 = \frac{x^2}{0.1} \rightarrow x = 0.0996M$$

$$K_a = \frac{x^2}{0.1 - x} = \frac{0.0996^2}{0.1 - 0.0996} = 24.8$$