1999 Exam #2 – Chem 36 Exam Questions w/Answers

1. The autoionization constant of water (K_w) is 1.139 x 10^{-15} at 0.00 ^oC and 9.614 x 10^{-14} at 60.00 ^oC.

$$2\ H_2O\ (l) \leftrightarrows H_3O^+(aq)\ +\ OH^-\ (aq)$$

   a. Calculate the enthalpy change (ΔH) for the autoionization of water.

      ΔH = 55.95 kJ/mol

   b. K_w = 1.0 x 10^{-14} at 25. ^oC. Calculate the standard molar free energy change (ΔG^o) for the autoionization of water at 25. ^oC.

      ΔG^o = 80. kJ/mol

   c. What is the pH of pure water at 0 ^oC and at 60 ^oC?

      At 0^{o}C: pH=7.47
      At 60^{o}C: pH=6.51

2. At T=1200 ^oC, the reaction

$$P_4\ (g) \leftrightarrows 2\ P_2(g)$$

has an equilibrium constant K = 0.612.

   a. Suppose the initial partial pressures of P_4 and P_2 are both 2.00 atm. Will the reaction proceed to the right or to the left as equilibrium is approached? (Note: you must show your work to receive full credit!)

      Reaction will proceed to the *left* (making more P_4)

   b. Calculate the partial pressure of P_2 at equilibrium.

      P_{P2} = 1.21 atm

   c. If the volume of the system is then increased, will the partial pressure of P_2 increase or decrease? Explain, briefly.

      P_{P2} will *increase* (shift to side with more moles of gas)

3. The strongest acid that can exist in a solvent is the conjugate acid formed from the autoionization of that solvent. So, for example, the strongest acid that can exist in water is the hydronium ion (H_3O^+).

   a. Write the acid dissociation equilibrium reaction for H_3O^+, the equilibrium constant (K_a) expression, and calculate the numerical value of K_a.

   H_3O^+ (aq) + H_20 (l) ⇆ H_3O^+ (aq) + H_20 (l)

   $K_a = \frac{[H_3O^+]}{[H_3O^+]} = 1$

   b. The approximate K_a values for HCl and HNO_3 are given on the table attached to this exam. In water, which of these acids is stronger? Explain.

   Both acids are *leveled* to the strength of H_3O^+

   c. What is the strongest acid that can exist in a solution of *liquid* ammonia?

   NH_4^+

   d. What fraction of Acetic Acid will be undissociated in a *liquid* ammonia solution? (DO NOT do a calculation for this!)

   Acetic Acid will be 100% dissociated in liquid ammonia

4. As you all recall from lab, Aspirin is a weak acid (acetylsalicylic acid). When a 0.150 M solution of this acid is prepared, it has a pH of 4.69.

   a. Calculate the K_a for acetylsalicylic acid.

   $K_a = 2.8 \times 10^{-9}$

   b. Calculate K_b for the acetylsalicylate ion.

   $K_b = 3.6 \times 10^{-6}$

   c. Calculate the pH of a 0.150 M solution of sodium acetylsalicylate.

   pH = 10.87

5. Predict the direction favored in each of the following acid-base reactions. That is, for each reaction, indicate the direction (forward or reverse) that the reaction will tend towards. You may wish to make use of the K_a and K_b values tabulated for you on the formula page handed out with this exam.

   a. $NH_4^+ + OH^- \leftrightarrows H_2O + NH_3$

      Forward

   b. $HSO_4^- + NO_3^- \leftrightarrows HNO_3 + SO_4^{2-}$

      Reverse

   c. $H_2CO_3 + CO_3^{2-} \leftrightarrows HCO_3^- + HCO_3^-$

      Forward

6. Circle the member of each of the following pairs that is the stronger acid and briefly explain your choice (based on molecular structure/bonding considerations).

   a. HF or HCl

      HCl **(Fluorine is so much smaller than Cl, that H-F bond strength is greater than H-Cl bond strength)**

   b. $HClO_2$ or $HClO_4$

      $HClO_4$ **(more electron-withdrawing oxygens to weaken H-Cl bond)**

   c. $ClCH_2CH_2COOH$ or $CH_3CHClCOOH$

      $CH_3CHClCOOH$ **(electron-withdrawing Cl is closer to H-O bond)**

   d. H_3PO_4 or $H_2PO_4^-$

      H_3PO_4 **(harder for a negatively charged species to give up a positively charged species)**

Extra Credit!!!

At 40 ^{o}C and 1.00 atm pressure, a gaseous monoprotic acid has a density of 1.05 g/L. After 1.85 g of this gas is dissolved in water and diluted to 450.0 mL, the pH is measured to be 5.01. Determine the K_a of this acid and use the provided table of K_a-values to identify it.

The mystery acid is: HCN (hydrocyanic acid)