Name:
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CEM 152 SS09
Exam 3A – Mar 24, 2009

Answer each question in the space provided. Clearly mark your final answer. Show all work for full credit.

1. (12 pts) A 100.0 mL solution of 0.15 M HCl is titrated with 0.25 M NaOH. What is the pH of the solution after 10.0 mL of the strong base has been added?

mol HCl = 0.15M × 0.1 L = 0.0150 mol

mol NaOH = 0.25M × 0.010L = 0.0025 mol

mol xs HCl = 0.0150 mol − 0.0025 mol = 0.0125 mol (+4)

$[HCl] = [H^+] = \frac{0.0125\ mol}{0.110\ L} = 0.1136\ M$ (+4)

$pH = -\log(0.1136) = \boxed{0.94}$ (+4)

2. (10 pts) In lecture, the equilibrium reaction $N_2O_4 \leftrightarrow 2NO_2$ was demonstrated. The equilibrium concentrations of reactant and product at room temperature produced a light brown color in the reaction chamber. Would you expect the equilibrium concentrations to change if a catalyst were added to the reaction chamber? Briefly justify your answer.

No. (+5) Addition of catalyst reduces activation barrier for both forward and reverse reactions. K will be unaffected, as will equilibrium concentrations. (+5)

+3 each

3. (12 pts) Clearly indicate whether each of the following statements is true or false regarding the equilibrium condition for the reaction:

$PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

F a. The $[Cl_2]$ will not appear in the equilibrium expression, since Cl_2 is normally a gas at STP.

T b. If the equilibrium shifts left when the temperature is increase, the reaction as written is exothermic.

T c. Addition of Cl_2 will cause the equilibrium to shift left.

F d. The equilibrium constant K_p will have units of atm.

4. (12 pts) Determine the percent ionization of a 0.250 M solution of hypochlorous acid (HClO, $K_a = 3.0 \times 10^{-8}$). Clearly state any assumptions you make in your calculation.

	$HClO \rightleftharpoons$	H^+	$+ ClO^-$
start	0.250	0	0
change	$-x$	$+x$	$+x$
equil	$0.250 - x$	x	x

$K_a = 3.0 \times 10^{-8} = \frac{[H^+][ClO^-]}{[HClO]}$

$3.0 \times 10^{-8} = \frac{x^2}{0.250 - x}$ (+4)

assume x small relative to 0.250

$3.0 \times 10^{-8} = \frac{x^2}{0.250}$

$x^2 = 7.5 \times 10^{-9}$

$x = 8.66 \times 10^{-5}$ (+4)

$\%\ \text{diss.} = \frac{x}{[HClO]} \times 100$

$= \frac{8.66 \times 10^{-5}}{0.250} \times 100 =$

$= 0.035\%$ (+4)

5. (10 pts) For the equilibrium reaction:

$2SO_3(g) \leftrightarrow 2SO_2(g) + O_2(g)$

$K_c = 0.0043$ at 25° C. Determine K_p for this reaction under the same conditions.

$K_p = K_c(RT)^{\Delta n}$ (+2) $\quad \Delta n = 3 - 2 = 1$ (+2)

$K_p = 0.0043\left[(0.08206\ \frac{L\,atm}{mol\,K})(298\,K)\right]^1$ (+2) (+2)

$= 0.0043(0.08206)(298) = 0.105$ (+2)

+3 each

6. (12 pts) Consider the following statements regarding the kinetic aspects of the equilibrium process. Clearly state whether each statement is true or false.

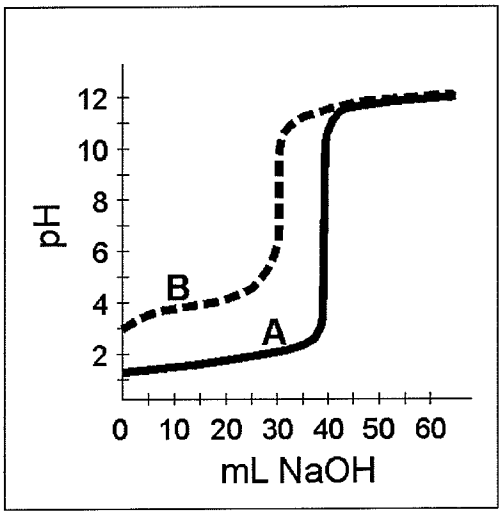
F a. The forward and backward reaction rates are zero at equilibrium.

T b. The equilibrium constant is the ratio of the forward and backward reaction rate constants.

F c. A reaction with Q > K will favor the forward reaction until equilibrium is established.

F d. Equilibrium reactions are spontaneous processes.

7. (10 pts) The accompanying graph shows the titration curves for two monoprotic acids.



   a. Which curve is that of a strong acid?

   A (+5)

   b. How does [A] and [B] compare based on the graph, assuming equal volumes of A and B are titrated by the strong base.

   $[A] > [B]$ (+5)

8. (12 pts) What is the pH of a buffer solution prepared from 0.16 M hypoiodious acid (HIO, $K_a = 2.3 \times 10^{-11}$) and 0.06 M sodium hypoiodate (NaIO).

$HIO \leftrightarrow H^+ + IO^-$

	HIO	H^+	IO^-
start	0.16M	0	0.06M (+4)
change	$-x$	$+x$	$+x$
equil	$0.16-x$	x	$0.06+x$

$K_a = \frac{[H^+][IO^-]}{[HIO]} = 2.3\times10^{-11} = \frac{(x)(0.06+x)}{(0.16-x)}$ (+4)

assume x small relative to 0.16 and 0.06

$2.3\times10^{-11} = \frac{x\,(0.06)}{(0.16)}$ (+4)

$x = 6.13\times10^{-11} = [H^+]$

$pH = -\log(6.13\times10^{-11})$

$= \boxed{10.21}$ (+4)

9. (10 pts) The energy profile for a hypothetical reaction is given below.

Predict whether the equilibrium constant for the process is greater than 1 or less than 1, and briefly justify your answer.

$K = \frac{K_f}{K_r} < 1$ (+5)

Since $E_F > E_r$ (+5)